

# THE 13<sup>TH</sup> INTERNATIONAL CONFERENCE ON QiR (QUALITY in RESEARCH)

<http://qir.eng.ui.ac.id>

**QiR**  
Yogyakarta  
25-28 June 2013



IN CONJUNCTION WITH :

**ICCS 2013**  
(THE 2<sup>ND</sup> INTERNATIONAL CONFERENCE ON CIVIC SPACE)

ORGANIZED BY :



Faculty of Engineering  
Universitas Indonesia

CO HOSTED BY:



IST AKPRIND



Universitas  
Gadjah Mada

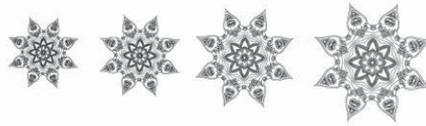
---

## PROCEEDING

---

ISSN 1411-1284





## WELCOME FROM THE RECTOR OF UNIVERSITAS INDONESIA

It is both a pleasure and honor for me to welcome you all to the 13<sup>th</sup> International Conference on QiR (Quality in Research) 2013. In this globalization era, mankind's competitive explorations to find new and better ways to enhance their life has often resulted in sacrificing the environment for their convenience. To preserve the environment for our future generations, steps must be made to ascertain that development and innovation of mankind must be more sustainable, balancing both mankind's effort in enhancing their quality of life and fulfilling their needs, with its harmony with nature.



Today, scientists and experts, in particular, people in engineering, architecture and design are looking to develop new environmentally friendly technologies, or eco-technologies. Innovation in eco-based multidisciplinary knowledge and skills becomes the important key, and this central issue should be encouraged for the motivation of current and future development. Eco-technology can help protect, conserve and even restore our precious shared environment. To develop this technology, we need to combine engineering, scientific or technological approaches, with ecology, economics and the social sciences and humanities. The eco-innovation field is now wide open and offers exciting new territories to explore and develop. Creative thinking by our top technical and scientific researchers is giving us a more and more treasures of new workable ideas.

However, innovations require more than just brilliant ideas. Innovations require resources, skills, technology, knowledge, tools, techniques and so much more. But most of all, innovations require people. People are the driving force behind every need of change, changes that are aimed to improve mankind's quality of life, to enhance their living conditions or to simply make life easier and more comfortable. This conference is about learning of the fundamental aspects which can transform the world and society, thinking ahead to possible challenges facing the globe, discovering innovations related to opportunities for industry, and most importantly, this conference is about bringing together interdisciplinary people to accelerate activities in many areas simultaneously. This is what makes the conference exceptional this year in terms of potential impact from this networking.

I extend my sincere thanks to the Faculty of Engineering Universitas Indonesia, supporting parties and institutions for their participation and contributions in QiR 2013. I would also thank the people of Yogyakarta for their gracious support and hospitality. Additionally, I extend a hearty thank you to the members of the organizing committees for dedicating their valuable time so that each one of us enjoys an exceptional conference program over the next several days. May we have a successful, stimulating, fruitful and rewarding conference.

Prof. Dr. Ir. Muhammad Anis M.Met.  
Rector  
Universitas Indonesia



## **WELCOME FROM THE DEAN OF FACULTY OF ENGINEERING UNIVERSITAS INDONESIA**

Welcome to the 13<sup>th</sup> International Conference on QiR (Quality in Research) 2013. The Faculty of Engineering Universitas Indonesia is thrilled that, together with our co-hosts IST-Akprind and Gadjah Mada University, we are able to present an international conference of this magnitude. This two-day conference speaks to the importance of fostering relationships among national and international front liners, thinkers, academics, executives, government and business officials, practitioners and leaders across the globe in an effort to share knowledge and best practices as part of a worldwide network.



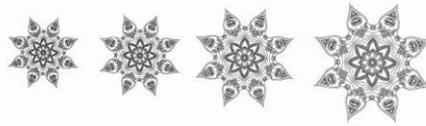
The quest for knowledge has been from the beginning of time but knowledge only becomes valuable when it is disseminated and applied to benefit humankind. It is hoped that QiR 2013 will be a platform to gather and disseminate the latest knowledge in engineering, architectural design and community services. Academicians, scientist, researchers and practitioners of these fields will be able to share and discuss new findings and applications of their expertise. It is envisaged that the intellectual discourse will result in future collaborations between universities, research institutions and industry both locally and internationally. In particular it is expected that focus will be given to issues on innovations for the enhancement of human life and the environment.

In accordance to this year's theme, this conference will cover a wide range of sustainable design and technology issues, especially state of the art information and knowledge of new innovations, ideas, creative methods or applications which can be implemented to enhance the human life and also our environment. The itinerary of the conference over the two days has been carefully planned to ensure a lively exchange of ideas and the development of innovative strategies and there will be many opportunities for everyone in attendance to share their expertise with, and learn from, peers from around the world.

We urge you to spend the next two days in interesting discussions and exchanging ideas among yourselves. We foresee more and more challenges in our future. Challenges in how to improve our life, how can we enhance our society, how can we make our lives and the lives of our society better? These challenges should be answered together by developing collaborations for future research in various engineering and design areas. It is our hope and aim that this conference would be able to provide an international media for exchange of the knowledge, experience and research as well as the review of progress and discussion on the state of the art and future trend of prospective collaboration and networking in broad field of eco-based technology development.

My deepest appreciation to our sponsors, supported parties and various contributors for their never ending supports of this conference. I would also like to convey my humblest thankfulness to all of our distinguished speakers for making the time to share their knowledge with us. To our fellow researchers and/or practitioners from Indonesia and overseas, welcome and enjoy your stay in this amazing historical city, Yogyakarta. I would also like to invite all participants in expressing our appreciation to all members of the QiR 2013 organizing committee for their hard work in making this conference another success.

Prof. Dr. Ir. Bambang Sugiarto, M.Eng.  
Dean Faculty of Engineering  
Universitas Indonesia



## WELCOME FROM THE QIR 2013 ORGANIZING COMMITTEE

Welcome to the 13<sup>th</sup> International Conference on QIR (Quality in Research) 2013. It is a great pleasure for Faculty of Engineering Universitas Indonesia to be co-hosting this biennial event with IST-Akprind and Gadjah Mada University, in the spirit of strengthening of cooperation and mutual growth to be world class institution. For the first time, the QIR 2013 is held in one of the most historical city in Indonesia – Yogyakarta. It is with our utmost pleasure to hold this year’s QIR 2013 in conjunction with the 2nd International Conference on Civic Space (ICCS 2013) and introducing the International Symposium on Community Development 2013 as a forum to share experience on engaging community for a better life and environment.



The aim of this International Conference with our selected theme, “Exploring Innovation for Enhancement of Human Life and Environment”, is to provide an international forum for exchanging knowledge and research expertise as well as creating a prospective collaboration and networking on various fields of science, engineering and design. We hope this conference can be a kick-off for the strengthened action and partnerships on creating a platform for us; national and international thinkers, academics, government officials, business executives and practitioners, to present and discuss the pivotal role of engineers in innovative products which will reduce environmental impacts, applications in sustainable planning, manufacturing, architecture, and many more to grow and ensure the rising prosperity of our society going into the future. Under this theme, the conference focuses on the innovative contributions in science, engineering and design as well as their market perspectives to the existing and future enhancement of human life and environment quality.

Over the period of 15 years, this biennial conference has become an important place of encounter between scholars and practitioners from different countries, cultures and backgrounds discussing contemporary engineering and design issues dealt in their hometown, country or even region. Serving as a platform for an engineering and design dialogue, this conference will have 16 invited speakers and has gathered more than 500 papers from more than 20 countries all over the world:

- 92 papers on International Symposium on Civil and Environmental Engineering
- 51 papers on International Symposium on Mechanical and Maritime Engineering
- 97 papers on International Symposium on Electrical and Computer Engineering
- 111 papers on International Symposium on Materials and Metallurgy Engineering
- 31 papers on International Symposium on Architecture, Interior and Urban Planning
- 57 papers on International Symposium on Chemical and Bioprocess Engineering
- 71 papers on International Symposium on Industrial Engineering
- 25 papers on International Symposium on Community Development

My deepest gratitude to all of our speakers, participants and contributors who have given this conference their generous support. I would also like to thank all members of the Organizing Committee and our distinguished International Board of Reviewers for all of their support and advice. Our thanks to all of our sponsors, supporters, exhibitors, and professional associations for their great support and encouragement through committed funding and any other form of help and support. We also owe our success to the full support of the Rector of Universitas Indonesia and the Dean of Faculty of Engineering. Thank you to IEEE Indonesia Section that has supported QIR 2013 to be approved as IEEE Conference. Last but not least, a special thanks to our co-hosts, IST-Akprind and Gadjah Mada University for all of their immense supports in making this conference a success.

Allow me to wish all of you a meaningful and rewarding conference. We wish you a pleasant and memorable stay in Yogyakarta. Thank you and we hope to see you again at the QIR 2015.

Prof. Dr. Ir. Bondan T. Sofyan, M.Si.  
Chairman of QIR 2013 Organizing Committee

## Table of Contents

### Symposium A

AbstractPlenary2_Study of the Safety Aspects of the Large Scale Use of LNG as a Fuel .....	1
A1.1-Furushima_Study on Mesoscopical Inhomogeneous Material Modeling for Surface Roughening Behavior of Polycrystalline Metal Sheets and Foils.....	2
A1.2-Sumarsono_Development of Gene Gun as Intradermal Vaccine Administration Device for Laboratory and Clinical Applications .....	3
A1.3-Sinaga_Simplified Model Of The Heave and Pitch Motions of an Fling Due to Slohing Effect and Comparison with Some Experimental Results.....	10
A1.4-Whulanza_Characterization of Low Cost UV-Lithography Result for Educational Purpose.....	17
A1.5-Baskoro_Analysis of Microchannels Manufacturing of Acrylic using Low Power CO2 Laser .....	20
A1.6-Widodo_Remaining Useful Life Prognostic of Rolling Element Bearings on Industrial Machinery Using Adaptive Neuro Fuzzy Inference System .....	21
A1.7-Triono_Effect of Phenolic Resin and Alignment to the Quality of Prototype Composite Railway Brake Blocks.....	26
A1.8-Muhajir_The Characteristics of the Sport Car Body Aerodynamics .....	27
A2.1-Experimental Study of Total Hull Resistance of Asymmetrical Pentamaran Model with Separation and Staggered Hull Variation of Side Hull I.....	32
A2.2-Nasruddin_The Study on Environmental Quality Interior, Ventilation and Indoor Air Quality Simulation .....	41
A2.3-Nasruddin_Characteristics of Heat Transfer on Heat Sink using Cross-Flow Synthetic Jet with Frequency Variation of Sinusoidal and Square Wave .....	45
A2.4-Prayudi_Simulation Model Transient Heat Transfers in Hot Box Billet Steel.....	51
A2.6-Putra_Application of Al <sub>2</sub> O <sub>3</sub> Nanofluids on Sintered Copper-powder Vapor Chamber for Electronic Cooling.....	59
A2.7-Harinaldi_Effect of Orifice Shape to Convective Heat Transfer of Impinging Synthetic Jet .....	67
A3.1-Baskoro_Effects of Welding Parameters in Micro Friction Stir Lap Welding of Aluminum A1100....	73
A3.2-Sunaryo_Thickness and Fiber Content Optimization in VARTM Method for High Speed Craft.....	79
A4.1-Manabe_Tube Forming Technology for Lightweight Components Manufacturing.....	83
A4.3-Kiswanto_Development and Testing of 5 kn Micro Forming Machine for Micro Part Manufacturing .....	84
A4.5-Malta_A Modified Rotor Model to Approach the Dynamic Responses of Anisotropic Rotor with Different Shaft Orientation.....	91
A4.6-Supriadi_Real-time Monitoring System for Dieless Bellows Forming using Machine Vision .....	97
A5.1-Tjahjanti_Numerical Modeling of Ship Composite-Based on Aluminum Casting as Alternative Materials for Ship Building.....	104

A5.2-Santosa\_Techno-Economic Review Of Hybrid / Electric Catamaran Fishing Vessel..... 105

A5.3-Priadi\_Determining Risk Accidents based on Shiphandling Difficulty Model for Ferry: A validation approach ..... 110

A5.4-Luhulima\_Selecting Mono- and Multi-Hull Passenger Vessels for Moluccas Waters: Resistance/Powering and Seakeeping Evaluation ..... 117

A5.5-Leksono\_Vane-Turbine as an Energy Conversion in the Propeller Slipstream of Single Screw Ship ..... 125

A5.6-Sunaryo\_The Role Of Multi -Yard Ship Construction Method in Integrated Shipbuilding Cluster .. 127

A6.1-Siswantara\_Combustion Analysis of Proto X-2 Bioenergy Micro Gas Turbine with Diesel – Bioethanol Blends ..... 132

A6.2-Sarjito\_Effect of Dwndraught Mass Flow Rate Generated and The Uniformity of The Velocity and Temperature Profiles Downstream of The Multi-Array Nozzles ..... 139

A6.3-Pujowidodo\_Improving Cooling Performance by Modification of Spray Nozzle on 10 kW Absorption Chiller Model ..... 145

A6.4-Dhiputra\_Experimental Study of Liquid-Vapor Mass Flow Rate Ratio of LPG Through Swirling Nozzle with Variation of Swirling's Chamber Volume ..... 151

A6.6-Lukiyanto\_Low Speed Electric Machine Used for Electric Generating from Savonius Windmill .... 162

A6.7-Wahyudi\_Optimization Design of Tandem Blade Rotor of Savonius Hydrokinetics Turbine Model 163

A6.8-Sugiarto\_Combustion of Diesel-Biodiesel Blend Using OpenFoam: Calculation of Pressure and Temperature in Combustion Chamber..... 171

A6.9-Sukamta\_FlowPatternMap of Steam-Condensate Flow in a Horizontal Double Pipe ..... 177

A6.10-Yabase\_Solar A bsorption Air-Conditioning system..... 182

A6.12-Oh\_CComparison between CFD Simulation and Experimental Heat Transfer Coefficient of Natural Refrigerants in Minichannel..... 190

A7.2-Dhiputra\_Experimental Study of Premix Air/LPG Flame Flashback's Depth Of Penetration in Tube Tubes of Bunsen Burner As A Function of The Tube's Diameters..... 197

## Symposium Bxxiv

AbstractPlenary5\_Kasai\_Low-Carbon Pretreatment Process of Iron Ores for Green Ironmaking ..... 202

B1.1-Obara\_Viscous Deformation of Zn-Al-C-O Complexes with Excited Electron States of Zn Atoms... 203

B1.2-Fasquelle\_Lead-Free Oxide Thin Films for Gas Detection ..... 205

B1.3-Andika\_Crystallographic Properties of Aluminum-doped Barium Zirconium Titanate Thin Films by Sol Gel Process..... 206

B1.4-Wahyuono\_Quasi-solid State DSSC Performance Enhancement by Bilayer Mesoporous TiO2 Structure Modification..... 207

B1.5-Tok\_Atomic Layer Deposition of Inverse Opals for Solar Cell Applications ..... 208

B1.6-Yuliarto\_Modifications of Multi-walled Carbon Nanotubes on Zinc Oxide Nanostructures for Carbon Monoxide (CO) Gas Sensitive Layer..... 209

B1.7-Repi-An investigation of structure and Complex Impedance Behavior of Composite (1-x)Ba <sub>0.5</sub> Sr <sub>0.5</sub> Fe <sub>11.7</sub> Mn <sub>0.15</sub> Ti <sub>0.15</sub> / xLa <sub>0.7</sub> Ba <sub>0.3</sub> MnO <sub>3</sub> .....	210
B1.8-Hiraishi_100W Sustainable Society Prospected from Electrical Power Consumptions between Indonesia and Japan .....	211
B2.1-Triyono_SKD 61 Material Surface Treatment With Electric Discharge Machining Using Cu, CuCr & Graphite Electrodes and Dielectric Fluid Jatropha Curcas .....	216
B2.2-Ariati_Application of Shot Peening and Shot Blasting to Increase Hardness and Depth of Nitride Hardened Layer to the Modified H13 Steel as Die Casting Die Materials.....	217
B2.3-Soepangkat_Optimization of Multiple Performance Characteristics in the Wire EDM Process of AISI D2 Tool Steel using Taguchi and Fuzzy Logic .....	218
B2.4-Syahid_Characterization of Al-7Si-Mg-Cu Turbine .....	219
B2.5-Hafid_Research on the Manufacturing of Steam Turbine Blade by Using Investment Casting Technology .....	220
B2.6-Darmawan_Comparison of Commercially Pure Titanium Surface Hardness Improvement by Plasma Nitrocarburizing and Ion Implantation .....	221
B2.7-Suwarno_Preparation of Uranium Nitride from Uranium Metal through by Hydriding and Nitriding Process.....	222
B2.8-Sianipar-Materials Selection in Appropriate Technology: Four Focuses in Design Thinking.....	223
B3.1-Yuwono_Optimizing the Nanostructural Characteristics of Chemical Bath Deposition derived ZnO Nanorods by Post-Hydrothermal Treatments .....	224
B3.2-Sholehah_High Coverage ZnO Nanorods on ITO Substrates via Modified Chemical Bath Deposition (CBD) Method at Low Temperature.....	225
B3.3-Suryadi_Influence of Intermetallic Inclusion to Brittle Fracture of Electric Motor Shaft AISI 1045 under Torsion Loading.....	226
B3.4-Yulianto_Performance of Natural Carotenoids from Musa aromatica and Citrus medica var Lemon as Photosensitizers for Dye-Sensitized Solar Cells with TiO <sub>2</sub> Nanoparticle .....	227
B3.5-Suastiyanti_Magnetic Behaviors of BaTiO <sub>3</sub> -BaFe <sub>12</sub> O <sub>19</sub> Nanocomposite Prepared by Sol-Gel Process Based on Differences in Volume Fraction .....	228
B3.6-Rosa_Fabrication of Polymer Solar Cells on Flexible Substrate.....	229
B3.8-Sulamet-Ariobimo_The Effect of Vertical Step Block Casting to Microstructure and Mechanical Properties in Producing Thin Wall Ductile Iron .....	230
B3.9-Sigit_Characteristics of Heat Treated Al <sub>7</sub> Si-Mg-Zn - SiC 5 wt.% Squeeze Casted Composite with Variation of Mg Content for Tactical Vehicle Application .....	231
B3.10-Sutanto_Controlled Process in Producing 490 MPa Class High Strength Low Alloys Steel for Shipbuilding Applications.....	232
B4.1-Soedarsono-The Influence of Coal Ratio in Reduction Process of Producing Iron Nugget.....	239
B4.2-Lalasari_Sulfuric Acid Leaching of Bangka Indonesia Ilmenite Ore and Ilmenite Decomposed by NaOH .....	240
B4.3-Sariman_Anatase TiO <sub>2</sub> Enrichment from Bangka Ilmenite (FeTiO <sub>3</sub> ) and Its Photocatalytic Test on Degradation of Congo Red.....	241
B4.4-Pintowantoro_Reduction of Nickel Ion Release on a TiO <sub>2</sub> Coated onto an Orthodontic Wire .....	242

B4.5- Chaldun_Synthesis and Characterization of Bacterial Cellulose-based Carbon Nanotube by Catalytic Graphitization .....	243
B4.6- Yuliwati_Submerged Ultrafiltration for Minimizing Energy Process of Refinery Wastewater Treatment.....	244
B5.1-Kim_Influence of Processing Method of ECAP on High-Strain-Rate Deformation Behavior of Ultra Fine Grained Al Alloy.....	245
B5.2-Risanti_Resolving Individual Solute Levels of AA6061 Through Multiple Sub-Ambient Temperatures Thermoelectric Power Measurements .....	246
B5.3-Anggono_Springback Prediction Compensation and Optimization for Front Side Member in Sheet Metal Forming using FEM Simulation .....	247
B5.4-Kadir_Effect of Rolling Direction to The Strength of A Thin-Walled Steel SHS Beam under Concentrated-Compressive Load and Bending Moment .....	248
B5.6-Darsin_Mechanical Properties and Micro Structure of Aluminum Alloys [Al-Mg-Si] as Results of Variation Time in Friction Welding.....	249
B5.7-Kusuma_Two-Dimensional Ferroelectric Polymer Films and Its Application for Resistive Switching Memories .....	255
B5.8-Baskoro_The Development of 550 MPa Class High Strength Low Alloy Steel for Atmospheric Corrosion Resistant Applications.....	256
B6.1-Fatchurrohman_The Development of 550 MPa Class High Strength Low Alloy Steel for Atmospheric Corrosion Resistant Applications.....	264
B6.2-Tjahjanti_Physics and Chemistry Test on Aluminum-Based Composite Materials an Alternative Material for The Manufacture of Drum Brake .....	265
B6.3-Ramdan_Oxidation Characteristics of Various Nickel Composite Coated on Ferritic Stainless Steel.....	266
B6.4-Suryadi- Effect of Equal Channel Angular Pressing and Post Heating on Microstructure and Hardness of Cu-Zn 70/30.....	267
B6.5-Candra_Simulation of Metal Flow to Investigate the Application of Antilock Brake Mechanic System in Deep Drawing Process of Cup .....	268
B6.6-Widyastuti-Hydrogen Absorpsivity-Desorbsivity of Mg doped by Ni, Cu, Al produced by Mechanical Alloying .....	269
B6.7-Winarto_Mechanical Properties and Microstructure of Welded DissimilarMetals using Buttering and Non-Buttering Layer.....	270
B6.9-Afandi_Formation and Characterization of Al-5%Cu-4%Mg/Sip MMC by Thixoforming Process ...	271
B6.10-Rahmalina_Deformation Behaviour of Silicon Carbide Reinforced Al-7Si Composite after Balistic Impacts.....	272
B6.11-Junus_The Influence Of Various Percentage Of Al <sub>2</sub> O <sub>3</sub> By Using Vortex Method To Tensile Strength And The Distribution Of Al <sub>2</sub> O <sub>3</sub> p Composite.....	273
B6.12-Suprpto_Role of Coordination Sphere Geometry to Properties Control of Powder Metallurgy Process.....	274
B7.1-Sudarsono-Optimization Design of Airfoil Propellers of Modified NACA 4415 Using Computational Fluids Dynamics.....	275

B7.2-Sudjadi_Study About Surface Hardening On Local Disc Brakes With Direct Current Plasma Nitrocarburizing Apparatus .....	276
B7.3-Widyastuti-Symposium A Study on PbSn Composites Produced by Powder Metallurgy as Core Bullet Projectile .....	277
B7.4-Dewanto_The Oxygen Control System Design (GAS SKID) and Oxygen Fuel Equipment (OFB) On Combustion: Metal, Glass, Glass and Ceramics in the Framework of Industrial Fuel Use Efficiency and Reduce Global Warming.....	278
B7.5-Lestari_The Phenomena of Dinamic Cyclic Trend to Cement-Fly ash Smart Concrete Compressive Strength and Resistivity in Various Composition of Polymer Carbon Fiber .....	285
B8.1-Mitsudo_Grain Growth in Millimeter Wave Sintered Alumina Ceramics.....	286
B8.2-Chalid_A Study on the Structural Analysis of Novel Polyurethanes Based on N,N'-1,2-Ethanediybis-(4-Hydroxy-Pentanamide) and 4-Hydroxy-N-(2-Hydroxyethyl)-Pentanamide .....	287
B8.3-Bertalya_Classification of Ceramic Tiles By Identifying Defect on Ceramic Tile Surface Using Local Texture Feature.....	288
B8.4-Aripin_Structural Characterization of Mullite-Based Ceramic Material from Al <sub>2</sub> O <sub>3</sub> and Silica Xerogel Converted from Sago Waste Ash .....	289
B8.5-Farid_Correlation of Normal Incidence Sound Absorption Coefficient (NAC) and Random Incidence Sound Absorption Coefficient (RAC) of Polyester/ Ramie Fibre Composite Materials.....	290
B8.6-Zulfia_Electroless Plating of Al <sub>2</sub> O <sub>3</sub> Particles Reinforced Composites.....	291
B8.7-Sutikno_Crystal Structures and Thermal Properties of Composite Brake Friction Materials Fabricated of Glass and Metal Wastes with Reinforcement of Bambo Nano Fibers.....	292
B8.8-Priyono_Synthesis of Highly-Ordered TiO <sub>2</sub> through CO <sub>2</sub> Supercritical Extraction for Dye-Sensitized Solar Cell Application.....	293
B9.1-Nurlia_Improvement of Stress Corrosion Resistance in Aluminum Alloy 7075 through Retrogression and Re-aging Modification .....	294
B9.2-Rustandi_Behavior of CO <sub>2</sub> Corrosion of API 5L X52 Steel in [a1] NaCl Solution Under Turbulent Flow Condition .....	295
B9.3-Badaruddin_Hot Corrosion of Aluminized 1020 Steel with NaCl Deposit .....	296
B9.4-Pradityana_Tafel Polarization Evaluation of Myrmecodia Pendans Extract as Eco-Friendly Corrosion Inhibitor for Material API 5L Grade B in 3,5% NaCl Solution .....	297
B9.5-Setiawan_High Temperature Oxidation Behavior of Co-based Coating at 800 oC as Alternative Coating Material for SOFC Interconnect .....	298
B9.6-Munir_Influence of Hot Dip Galvanizing Layer to Cleavage Failure of AISI 4140 Bolt for Padeye Fixing in Marine Environment .....	299
B9.8-Ismail_Corrosion Inhibitor Performance with presence of FeCO <sub>3</sub> film in CO <sub>2</sub> Corrosion Environment under Fluid Flow Effect.....	300
B10.1-Mohammed_Effect of CaO Dopant on The Dielectric Properties of NiO .....	301
B10.2-Dong_Plasmonic Photocatalyst Ag/AgCl Nanohybrids on Titanate Thin Film for Photocatalytic Application .....	302
B10.3-Yuliarto_Synthesis of SnO <sub>2</sub> Nano Structure Thin Film and Its Prospective as Gas Sensors .....	304

B10.4-Widodo_Physical Characteristic and Magnetic Properties of Barium Hexaferrite BaFe <sub>12</sub> O <sub>19</sub> Derived from Mechanical Alloying .....	305
B10.5-Dinari_SrTiO <sub>3</sub> Thin Films Deposition Using Pulsed Laser Deposition Technique .....	306
B10.6-Agustina_Photocatalytic Degradation of C.I. Reactive Red 2 by Using TiO <sub>2</sub> -Coated PET Plastic under Solar Irradiation .....	307
B11.1-Ko_Development of Plasma Electrolytic Oxidation Coating for Structural, Electrochemical, and Biological Applications .....	308
B11.2-Prihandoko_Electrochemical Behavior of Li <sub>4</sub> Ti <sub>5</sub> O <sub>12</sub> under in situ Process of Sintering and Surface Coating with Cassava Powder .....	309
B11.3-Adi_Microstructure and Phase Analysis of La <sub>0.8</sub> Ba <sub>0.2</sub> Ti <sub>x</sub> Mn <sub>(1-x)</sub> O <sub>3</sub> system for Microwave Absorber Material (x = 0 – 0.7) .....	310
B11.4-Pranoto_Synthesis and Characterization of Nanocrystalline TiO <sub>2</sub> by Non-Aqueous Sol Gel in Acidic Condition for Dye-sensitized Solar Cells .....	311
B11.5-Pratitajati_Microstructural Characterisation and Microwave Absorption Characteristics of La <sub>(1-x)</sub> Ba <sub>x</sub> Fe <sub>0.25</sub> Mn <sub>0.5</sub> Ti <sub>0.25</sub> O <sub>3</sub> (x = 0, 0.25, 0.75, 1) .....	312
B12.1-Pramono_Preliminary Observation on Macro Texture of Nb <sub>3</sub> Sn Low Temperature Superconductor (LTS) .....	313
B12.2-Novizal_Crystallite Size Characterization of Mechanically Alloyed of (Ba,Sr) Hexaferrite and (Ba,Sr) Titanate Composite System .....	314
B12.3-Hardiyanto_Quantum Approximation for Josephson's Tuneling in Th <sub>x</sub> DUO <sub>2</sub> Nano Material for 535 Tesla at Muon Cyclotron.....	315
B12.4-Suastiyanti_Nanosize Effects on Magnetic Properties and Peak Shifting of X-Ray Diffraction Pattern of BaFe <sub>12</sub> O <sub>19</sub> Produced by Sol Gel Method .....	316
B12.5-Harjanto_Properties of Fe-Mn-C Alloy as Degradable Biomaterials Candidate for Coronary Stent .....	317
B12.7-Susila_Structure and Mechanical Properties of Al-Cu/SiC Composite Prepared by Hot Press Method .....	318
B12.8-Komalasari_Synthesis and Characterization of TiO <sub>2</sub> Nanoparticle Using Starch as a Template by Sol-Gel Method for the Application of UV Protection.....	322
B12.9-Sofyan_Synthesis of Mesoporous Silica from Tetraethylorthosilicate by Using Sodium Ricinoleic as a Template and 3Aminopropyltrimethoxysilane as Co-Structure Directing Agent with Volume Variation of Hydrochloric Acid 0.1 M .....	323
B12.10-Mulyani_Synthesis And Characterization of Silica-Lavender Microencapsulation by Sol Gel – Emulsion Method for Anti Mosquito Textile .....	324
B12.11-Nuryadi_Sensitive Layer Tickness Dependence on Microcantilever Sensor Sensitivity .....	325
B12.12-Setiyorini_Improvement Biocompatibility of NiTi Orthodontic Wire from Various Coatings .....	326

## Symposium C

AbstractPlenary3_Microbial cell factories for the production of bio-fuels and bio-based chemicals from cellulosic materials.....	327
--	-----

C1.2_YohdaM_Structure and Functional Mechanism of Small Heat Shock Proteins .....	328
C1.3_AchmadiS_Measurement of Chemical Markers in Dragon's Blood .....	330
C1.4_AznuryM_Acidogenic Fermentation of Palm Oil Mill effluent (POME) on Volatile Fatty Acids production as Precursor.....	336
C1.5_HendrokoR_Bio-refinery Study in Crude Jatropha Oil Process : Co-digestion Sludge of Crude Jatropha Oil and Capsule Husk Jatropha curcas Linn as Biogas Feedstocks .....	343
C1.6_SuhartoI_Bioconversion of Waste Pineapple Juice Into Ethanol and Acetic Acid .....	344
C1.7_SetyahadiS_Cellulase from Bacillus sp. BPPT CC RK 2 for Saccharifying Process using Pulp and Paper Industry Sludge .....	351
C2.2_GustianiI_Synthesis of Poly (1-vinyl-1,2,4-triazole) and Preparation of Proton Conducting Membrane for High Temperature Operation.....	357
C2.3_ZakirM_Adsorption of Lead (II) and Copper (II) Ions on Rice Husk Activated Carbon Under Sonication .....	358
C2.4_AndreasA_Synthesis and adsorption characteristics of activated carbons originated from banana peel waste for dye removals .....	365
C2.5_IkonoR_Synthesis of pH-Dependant ZnO Nanoparticle by Sol-Gel Method.....	372
C2.8_Nofrizal_Improvement of Zinc Oxide Nanoparticle Dispersion Stability With Polyelectrolyte Stabilization Mechanism.....	377
C3.1_WulanPPDK_Kinetics of Carbon Nanotubes Growth on Ni-Cu-Al Catalyst by Catalytic Decomposition of Methane.....	384
C3.2_KaramahEF_Disinfection of Bacteria Escherichia Coli Using Hydrodynamic Cavitation.....	392
C3.3_SupramonoD_Performance of a Biomass-Gas Stove using Fuel of Rubber Wood Pellets.....	393
C3.5_AdinurainiPG_Enhancement of Biogas Production from Capsule Husk Jatropha curcas Linn Substrates Using Urea and Crude Jatropha Oil as Additive.....	399
C3.7_WidhyastutiNS_Evaluation of Concentration and Initial pH of Synthetic Nutrient Solution in N2O Biofiltration by Nitrobacter winogradskyi Inoculated on Lampung Natural Zeolite and Activated Carbon.....	405
C3.8_Dianursanti_Preliminary Study of Biodiesel Synthesis from Microalgae Lipid of Chlorella vulgaris Based Walne Medium through Esterification-Transesterification and Transesterification Reaction .....	411
C3.9_PramantyoMH_Simulation of Natural Gas Pipeline for Leak Detection.....	416
C3.10_Wahida_Distillation Column Control using Multiple Model Predictive Control Based on Representative Model Predictive Control Method.....	423
C3.11_TristantiniD_Monitoring Consumption of Premium and Diesel Subsidized Fuel for Transportation Sector on Island of Bintan Using Control Card and Barcode Sticker .....	429
C3.12_SudibandriyoM_Activated Carbon Produced from Bamboo Using Activating Agent H3PO4 And KOH .....	437
C4.1_YonemotoT_High Quality Biodiesel Production from Acid Oils Using Ion-exchange Resin as Catalysts and Adsorbent .....	438
C4.4_The Effect of Biofilm and Biomass in Electricity Generation by MicrobialFuel Cell System.....	440
C4.5_GozanM_Simulation of Bagasse Saccharification and Fermentation to Bioethanol .....	447

C5.1_SytaniE_Waste Processing Equipment for Small Industries Based on Ozone and Ultraviolet-C...	448
C5.5_AgustinaTE_Photocatalytic degradation of C.I. Reactive Red 2 by using TiO <sub>2</sub> -coated PET plastic under solar irradiation.....	455
C5.6_SaksonoN_Effect of Mixing on pH and Conductivity of NaHCO <sub>3</sub> and CaCl <sub>2</sub> Solutions and CaCO <sub>3</sub> Formation.....	462
C6.1_PerkasaAY_Formation of KCl in Prolonged Heating of Coconut Shell.....	468
C6.2_MuryantoS_Influence of Flow Rates and Cu <sup>2+</sup> on Kinetics of Gypsum Scale Formation In Pipes	472
C6.3_WinantiWS_Decomposition of Carbon Dioxide in the Three-Pass Flow DBD Non-Thermal Plasma Reactor.....	474
C6.5_Setiyono_The Hydrogen Gas Effect to the Efficiency Fuel by the 135 cc Motorcycle Engine.....	475
C6.8_KrisnandiYK_Anatase TiO <sub>2</sub> enrichment from Bangka Ilmenite (FeTiO <sub>3</sub> ) and its photocatalytic test on degradation of Congo Red .....	482
C6.9_NugrohoDW_The Na <sup>+</sup> Cationic Effect Towards Iron Sand's Ilmenite Crystals Destruction .....	489
C7.1_Yuliusman_Adsorption of Carbon Monoxide (CO) Gas And Clearing of Fire Smoke Using Activated Carbon From Coconut Shell Impregnated TiO <sub>2</sub> .....	496
C7.2_KartohardjonoS_Dissolved Oxygen Removal through Polyvynylchloride Hollow Fiber Membrane Contactor via Vacuum Degassing Process .....	504
C7.3_Yuliusman_Natural Zeolite Modification by TiO <sub>2</sub> for NO <sub>2</sub> Gas Adsorption from Vehicles Emission .....	505
C7.4_SahlanM-Octaarginin-Apoptin Induces Apoptosis in the Human Cervix Cancer HeLa Cell Line...	511
C7.5_KusriniE_Removal of Heavy Metals from Aqueous Solution by Hydroxyapatite/Chitosan Composite... ..	512
C7.6_MuharamY_Simulation of Gas Leakage in a City Gas Utilization System in Household Sector ....	513
C7.7_PurwantoWW_Synthesis of aligned carbon nanotubes By methane catalytic decomposition reaction On spherical substrate .....	514
C7.8_MuliaK_Practical isolation of bullatacin from Annona muricata leaves extract using an open column chromatography technique .....	521
C7.10_Setiadi_A Catalytic Conversion of Ethanol to High Quality Hydrocarbon Fuel Using the Catalyst Mixture Al <sub>2</sub> O <sub>3</sub> -HZSM-5.....	522
C7.11_HermansyahH_Preparation of the Edible Biocomposite Film Gelatin / Bacterial Cellulose Microcrystal (BCMC): Variation of Matrix Concentration, Filler, and Sonication Time .....	529
C7.13_Sukirno_Process Making of a Calsium Sulfonate Complex Biogrease and Its Antiwear Performance .....	530

## Symposium D

AbstractPlenary4_Intelligent transport systems – technological, economic, system performance and market views.....	531
D1.1_YangCL_Quality in Color Laser Printing and Data Mining.....	532

D1.2\_HidayatnoA\_Analysis on Consumer Adoption Process in Marketing Strategy Implementation using A System Dynamics Model (Study Case of Fast-MovingConsumerGoodsProduct) ..... 533

D1.3\_RasyantiAH\_The Model Development of Revenue Management in Fashion Retailer Using Game Theory..... 539

D1.4\_Martatil\_The Public Policy Model in Coal Mine Management..... 545

D1.5\_HidayatnoA\_Understanding the Dynamics of 6P Branding Strategy with Brand Equity for a Mature Customer-Goods Brand using a System Dynamics Model..... 549

D1.6\_PangriptadewiG\_The Simulation of Booking Limit Models for Entertainment Event Ticketing Using Revenue Management Approach ..... 557

D1.7\_AyuKG\_Customer Perception Towards Green Bag and Its Distribution System in A Retailer A Case Study in P.T. Carrefour Indonesia ..... 565

D2.1\_GabrielDS\_Value Chain Upgrading Scheme of Thermoplastic Recycling Manufacturing Systems: A Product Quality Perspective ..... 573

D2.2\_IriantoD\_Implementing Design for Six Sigma in Green Manufacturing; a Case at a Food Industry ..... 580

D2.3\_NurcahyoR\_Manufacturing Cycle Time Reduction For Product Flavors Food And Tobacco At PT IFF Indonesia Using Six Sigma ..... 587

D2.4\_Yadrifil\_Design of Lean Manufacturing with VALSAT Method in Production Line IMV Type of Drum Brake – Case Study of PT AKEBONO BRAKE ASTRA INDONESIA ..... 595

D2.5\_IndrawatiS\_Lean Manufacturing Improvement Program For Sustainability of Small and Medium Enterprise A Metal Processing Industry Case Application ..... 603

D2.6\_ZagloelTYM\_Production System Design Using Value Stream Mapping and Object Oriented Simulation in Dairy Toddler Industry ..... 610

D2.7\_AmranTG\_Analysis and Measurement of Intangible Factors for Automotive Part Manufacture by TEAM Model ..... 618

D2.8\_UtamaC\_Usability Software: Application to Exponentially Weighted Moving Average Control Chart. .... 622

D3.1\_Farizal\_Economic Analysis of Middle Class Residential With Solar Cell: Case Study of Cyber Orchid Town Houses in Depok..... 627

D3.2\_GabrielDS\_Intervening Variables to Motor Cycle User Satisfaction: Positive and Negative Impacts of Vehicle Operation Discipline and Knowledge..... 633

D3.3\_PuspasariMA\_Product Development of Cylinder Head Component using Quality Function Deployment and Value Analysis Approach..... 639

D3.4\_AnjaniS\_An Ergonomic Review on the Traditional Stool and Batik Stand used by Batik Crafters 645

D3.5\_NurtjahyoB\_Indonesian Body Surface Area Database and Estimation Formula Based on Interpolation Method..... 646

D3.6\_Farizal\_Investment Feasibility Analysis of CNG Fueling Station in Central Jakarta under Acceleration Scenario..... 654

D4.1\_AnisahNN\_Analysis Cellular Phone Design based on User-Centered Design for College Student 661

D4.2\_Herianto\_Application of Two-Dimensional Image in Digital Anthropometric Measurement System Design ..... 669

D4.3\_AryaniSM\_Design Alternatives for Elementary School Desk and Chair As an Effort in Optimize Learning Process; Anthropometrical and Aesthetical Approaches ..... 676

D4.4\_ChristianiaA\_Usability Testing of UPH Library Website based on WEBUSE Indicator ..... 681

D4.6\_SoebandrijaKEN\_Neuro Strategy, Industrial and Systems Engineering: Malcolm Baldrige Criteria toward Performance Excellence, Innovation and Sustainability Perspectives ..... 688

D5.1\_SudijajengL\_Defining Comprehensive Ergonomics in Engineering Design and Construction Processes ..... 694

D5.2\_MoeisAO\_Ergonomics Analysis Of Medium-Range Twin-Engined Transport Plane Emergency Door ..... 700

D5.3\_CaiD\_The Legibility Threshold of Chinese Characters in Three Type Styles ..... 705

D5.4\_ChiCF\_The Effect of Icon Formats on Vehicle Icon Recognition ..... 706

D5.5\_SuziantiA\_The Assessment of Acoustic and Lighting Condition in Auditoriums As Lecture Halls. 714

D5.6\_WijayaD\_Organisation Risk Management Maturity and Performance: Initial Evidence ..... 722

D6.2\_IndrianyE\_Project Profit Margin Determination on Information Technology Contractors ..... 728

D6.3\_AriniHM\_Project Risk Management Implementation in Indonesia: Initial Study ..... 735

D6.5\_HermawatiP\_Feasibility Study on the Selection of Alternative Access Road to Gunaksa Harbor. 244

D6.6\_WahyudiRD\_Service Dimension for Information System in Higher Education Field ..... 750

D6.7\_SophaBM\_Industrial Symbiosis: Past Researches, Current Findings, and Future Direction ..... 757

D6.8\_SubrotoB\_Intention Behavior of Villagers in Adopting Telecommunication Technology: A Case Study of Using Cellular Phone in Indonesia ..... 764

D6.9\_FirdausOM\_Knowledge Sharing Attempt of Doctors in Teaching Hospital using Partial Least Squares (PLS) Analysis ..... 771

D6.10\_PamungkasS\_Modeling a Feasible and Sustainable Business of Traditional Batik Home Industry ..... 777

D7.1\_MuslimE\_Analysis of the Effectiveness of Kompas Newspaper Advertising Based on Size and Color Factors Using Eye Tracking Method ..... 785

D7.3\_SoebandrijaKEN\_Innovation and Malcolm Baldrige: Effect of Strategic Planning, Customer Focus and Operations Focus toward Result of Performance Excellence and Sustainability ..... 791

D7.4\_AmranTG\_Partnership Strategy to Build Technopreneurship as a Mean to Achieve the Entrepreneurial University ..... 799

D7.5\_HidayatnoA\_Conceptual Model for Evaluation the Impact of Transit-Oriented Development Initiatives to the Income Growth of MRT Operating Company ..... 804

D7.6\_HakimIM\_An Inventory Model on Damaged Product with Calculating Crashing Cost and Variable Lead Time ..... 810

D8.3\_NurhasanahN\_Fuzzy Lead Time Application to Material Requirement Planning Piano UP B1 PE816

D8.4\_SaraswatiD\_Integrated Inventory Model under Lot-Streaming Delivery Policy using Vendor-Managed Inventory ..... 816

D8.5\_SaputroOA\_MODEL DEVELOPMENT OF PROJECT COMPLEXITY ..... 822

D8.6\_NataliaC\_Multipliers And Structural Path Analysis For Logistics Sectors In Social Accounting Matrix Framework Of Indonesia ..... 829

D9.1_WidodoEM_Improving Product Quality Of Dining Table Through Painting Process By Using Taguchi Method .....	835
D9.2_Harwati_Data Mining Techniques for Redesign Traditional Market .....	843
D9.3_HadiyatMA_Integrating Steepest Ascent for Taguchi Experiment: A Simulation Study .....	849
D9.4_Yuliana_Quality Management Assessment of Food and Beverages Companies in Indonesia .....	856
D9.5_SurjandariL_Factors Affecting The Selection of Toll Payment System: A Nested Logit Approach .	865
D9.6_Balal_A Comparative Study of Housing Quality in Nigerian Public Housing Developments.....	871

## Symposium E

E1.1-Ito_Simple Dual-Mode Wearable Antenna for Body-Centric Wireless Communications.....	879
E1.2-Tabe_Single-dopant Atom Devices for Future of Nanoelectronics .....	880
E1.3-Kawata_Nanophotonics for Live Cell Observation with High Resolution .....	882
E1.4-Nuryadi_Piezoresistive Microcantilever-Based Gas Sensor using Dynamic Mode Measurement.	886
E1.5-Inokawa_Evolution of Photodetectors by Silicon-On-Insulator Material .....	890
E1.6-Udhiarto_Observation of nanosize effect in lateral nanoscale p-n and p-i-n junctions.....	895
E2.1-Rohmah_Lung Tuberculosis Identification Based on Statistical Feature of Thoracic X-ray.....	900
E2.2-Putranto_Substrate Bias Effects on Noise and Minority Carrier Lifetime in SOI MOSFET Single-Photon Detector.....	908
E2.3-Prilianti_Microplate Luminescence Automated Digital Analyzer for Medicinal Plants Evaluation on Quorum Sensing Inhibition .....	912
E2.4-Ikeda_KFM Evaluation of Seebeck Coefficient in Thin SOI Layers.....	916
E2.5-Purwiyanti_Observation of Negative Differential Conductance in Nanoscale p-n Junctions.....	920
E2.6-Mimura_Development of Multi-gated Field Emitters .....	924
E2.7-Mochiduki_Multi-aperture High-speed CMOS Imager .....	927
E2.8-Salleh_Variation of Seebeck Coefficient in Ultrathin Si Layer by Tuning Its Fermi Energy .....	931
E2.9-Harini_The Application of Spectrophotometry Method for Measuring Iron Content of Groundwater after Merapi Mountain Eruption .....	935
E3.1-Anggraini_Parallel Computing of WaveCluster Algorithm for Face Recognition Application .....	940
E3.3-Ralianto_Design Simulator Detection Fuel Tank on Condition Genset Use SMS Through Microcontroller ATMega 8535.....	944
E3.4-Santoso_Prognosis of Bearing Damage Performance to Industrial System Using Nonlinear AutoRegressive with eXogenous (NARX).....	948
E3.6-Samaullah_Power Element Management System via Radio Microwave at PT Smartfren Telecom Palembang.....	952
E3.7-Aditomo_Bandwidth Enhancement of Ultra-Wideband Microstrip Bandpass Filter Using Defected Ground Structure.....	957
E4.1-Hiryanto_Incorporating Dynamic Constraint Matching into Vertex-based Graph Coloring Approach for University Course Timetabling Problem.....	960

E4.2-Sumarno_Handwritten Word Segmentation Using Kaiser Window .....	965
E4.3-Reynaldo_Green House Monitoring and Controlling Using Android Mobile Application .....	971
E4.4-Haryanti_Task Execution Reliability of Resource Allocation with Tasks Replication in Mobile Ad Hoc Grid .....	978
E4.5-Mardi_Multi Objective Optimization Based Intelligent Agent for NPC Behavior Decision.....	982
E4.6-Prima_Secondary Camera Placement in Machinema Using Behavior Trees .....	986
E5.1-Ratna_Analysis and Comparison of MD5 and SHA-1 Algorithm Implementation in Simple-O Authentication based Security System .....	991
E5.3-Fatwanto_Software Requirements Specification Analysis Using Natural Language Processing Technique.....	997
E5.4-Liem_P2P Locality Awareness Architecture In Ethernet Passive Optical Networks .....	1003
E6.1-Jamal_On Robotic/Tactical Behavioral Layer of an Agent in a Continuous Topography Agent Base Model for Traffic Simulation .....	1008
E6.2-Sumaryo_Improved Discrete Event Simulation Model of Traffic Light Control on A Single Intersection .....	1013
E6.3-Devega_Rolling Element Bearing Fault Diagnosis Using Radial Basis Function Neural Network (RBFNN).....	1018
E6.4-Yuniantoro_The pqr-coordinate in the Mapping Matrices Model of Kim-Akagi on Power Transformation based on Euler Angle Rotation Method.....	1022
E6.5-Santoso_Review of Microgrid Technology.....	1028
E6.6-Irawan_Modeling the Magnet Electric Power Planning as the Alternative Energy .....	1034
E6.7-Murakami_Formation of Fluorine Doped Tin Oxide Nanorods as the Front Electrode in Dye Sensitized Solar Cells .....	1039
E6.8-Indrajit_Development of Whole Body Motion Imitation in Humanoid Robot .....	1040
E6.9-Herlina_Comparative Analysis the Usage of Prepaid and Postpaid KWH Metre .....	1043
E7.1-Sirait_An Implanted Dipole Antenna for RFID-Based Patient Monitoring System .....	1047
E7.2-Syafitri_The Modified Alternator 115/208 Volt, 400 Hz, 15 KVA on Fokker-27 Aircraft, At SKADRON 2nd .....	1050
E8.1-Yunus_Radiation Pattern Characterization of Single Patch Spiral Resonator (SR) Structure Using Linear Array Approach .....	1055
E8.2-Munir_Multiple Slots Technique for Bandwidth Enhancement of Microstrip Rectangular Patch Antenna .....	1059
E8.4-Palantej_Lungs Patch Structures: Numerical Computation, Testing and Application .....	1064
E9.1-Smith_ A Comparision of the Merits of Nuclear and Geothermal Energy in Indonesia .....	1069
E9.2-Prastawa_New Approach on Renewable Energy Solar Power Prediction in Indonesia based on Artificial Neural Network Technique: Southern Region of Sulawesi Island Study Case.....	1075
E9.3-Sudiarto_Voltage and Current Distortion Correlation Characteristics of Compact Fluorescent Lamp in Frequency Range of 2-150 kHz.....	1079
E9.4-Sari_Wind Powered Turbine for Urban Environment as an Adaptation to Climate Change.....	1083
E9.5-Zein_Cost Allocation of Transmission Usage Based on Current Magnitude.....	1087

E9.6-Zubaidah\_Magneto-Static Flux Manipulator Prepared for Future Geomagnetic Power Plant..... 1092

E9.7-Multi\_Design of Slotted Core Axial Flux Wound Rotor Synchronous Generator ..... 1097

E9.8-Sutanto\_The Effect of Number of Blades on the Performance of H-Darrieus type Wind Turbine 1104

E9.9-Soetedjo\_Development of Data Acquisition System for Hybrid Power Plant..... 1109

E9.10-Asfani\_Simulation Analysis on High Impedance Temporary Short Circuit in Induction Motor Winding ..... 1114

E10.1-Kagawa\_Optimization of Light Pulse Response of CMOS Image-Based Receiver for Spatial Communications..... 1120

E10.2-Hadinegoro\_Ultra Wideband Microstrip Antenna Using T-Shaped Stub Fed by Coplanar Waveguide ..... 1121

E10.3-Zubaidah\_Comprehensive Geomagnetic Signal Processings for Successful Earthquake Prediction ..... 1125

E10.4-Mekeng\_Pi Slot Array Two Elements Multi Wide-band Microstrip Antenna Fed by Tuning Stub ..... 1133

E11.1-Ramdan\_Fluid Structure Interaction Simulation in IC Encapsulation Process ..... 1137

E11.2-Sapteka\_Effect of Gauss Doping Profile on Electric Potential of p-n Diode ..... 1143

E11.3-Ardi\_ColorDetection on CarComponent Knock Down using MicrocontrollerPIC 16F877A and a Photodiode as a Sensor ..... 1149

E11.4-Sugihartono\_Effects of Growth Temperature on Crystal Structure, Electrical, and Photoluminescence of ZnO Thin Films..... 1156

E11.7-Aoki\_Direction Detection of Radioisotopes by Enrgy Spectra of Compton Scattering in flat CdTe Radiation Recorder..... 1159

E12.1 Optimalization Of Multi atunning Stub Proximity Couple E-Slot Microsrip Patch Array Antena For Enhance Multi-Wideband ..... 1160

E12.2-Nakanishi\_Investigation about Pr-effective concentration and influence of Al-addition on the luminescence properties of SrTiO3:Pr3+,Al phosphors ..... 1165

E12.3-Suryanegara\_5G Key Technologies: Identifying Innovation Opportunity ..... 1166

E12.4-Suhartomo\_Vulnerability and Economic Considerations in Designing Network Topology ..... 1170

E12.6-Purnomo\_Circularly Polarized Array Pentagonal Microstrip Antenna for Mobile Satellite Applications..... 1175

E12.7-Nurwijayanti\_Design Of Monitoring Status Dvor in Desk at the Airport Tower Halim Perdanakusuma using Sms (Short Message Service) ..... 1179

E12.9-Natali\_Call Processing Simulation in GSM Network ..... 1189

## Symposium F

F1.1\_Rizalihadi\_The Generation of Syntetic Sequences of Monthly Rainfall Using Stochastic-Autoregressive Model..... 1195

F1.2\_Listyani\_Genesis of Saline/Brackish Groundwater in Parangtritis and Surrounding Area, Yogyakarta Province..... 1203

F1.3 Influence of Pseudomonas aeruginosa presence in The Biodegradability Study of Solvent-based and Water-based Dispersant in Oil Spill Handling.....	1208
F1.4_Komala_Biodegradation of Azo Dye Remazol Black 5 by Mono Culture Bacteria with Tempe Industrial Wastewater as Co-substrate.....	1209
F1.6_Arifin_Urban Water Management Challenges: Case Study PDAM ‘Tirtawening’ Bandung.....	1210
F2.1_Kholil_Sedimentation and Water Pollution Control Systems Engineering To Prevent Upwelling in Cirata Reservoir West Java, Indonesia.....	1217
F2.2_Sunarsih_Modeling of Domestic Wastewater Treatment Facultative Stabilization Ponds.....	1226
F2.3_Cornelia_CHARACTERISTICS OF ENVIRONMENTAL FRIENDLY LABELED PLASTIC SHOPPING BAGS IN INDONESIA.....	1234
F2.4>Weerakkody_Reducing CO2 Emissions from Buildings and New Developments by The Strict Enforcement of Regulations Imposed by Local Authorities.....	1235
F2.6_Kristanto_COMPOST AS LANDFILL COVER MATERIAL AND ITS IMPACT ON LANDFILL STABILITY.....	1241
F4.2_Suprpto_Land Use/Land Cover Clasification in Urban Areas with Supervised Maximum Likelihood Classifier Method.....	1247
F4.3_Arifin_Field Study on Undrained Shear Strength of Soft Soil around Micropiles.....	1258
F4.5_Ramanto_Study of the Mechanical Behavior of Paving Blocks made of Concrete Sludge Waste (CSW) and Coconut Fiber.....	1264
F5.1_Prakoso_Estimation of Land Development Induced Subsidence in Northern Jakarta Areas.....	1270
F5.2_Kusumawardani_Buildup of Cyclic Pore-Water Pressure of Yogyakarta’s sand Using Cyclic Shear Strain Testing.....	1285
F5.3_Muntohar_Development A Simple Model for Preliminary Evaluation on Extreme Rainfall Induces Shallow Slope Failure.....	1291
F5.4_Widodo_Geogrid as Asphalt Pavement Reinforcement.....	1297
F5.5_Puri_Pile Spacing and Length Effects Due To the Additional Modulus of Sub Grade Reaction of the Nailed-Slab System on the Soft Clay.....	1302
F5.6_Agung_INFLUENCE OF SAND ADDITION ON EXPANSIVE CLAY TO CBR AND SWELLING POTENTIAL VALUES.....	1311
F6.1_Putramento_THE EFFECT OF EXTERNAL DISTURBANCE TO CAR DRIVER AND MOTORCYCLE RIDER BEHAVIOUR.....	1315
F6.2_Widjajanti_Traffic Control of Road Closure on Saturated Two Way Two Lane Roads.....	1322
F6.4_Soemabrata_Modeling Risk Guarantee on Highway Infrastructure Development Using Real Option Approach.....	1329
F6.6_Susantono_Development of Indonesian Airport Infrastructure “Is the PPPs Solution?”.....	1337
F7.1_Setyowati_The Orientation Angles Rating of the Simple Model Construction In Residential Region Closed to the Airport.....	1342
F7.2_Isvara_A Neural Network Approach for Conceptual Cost Estimation of Building Construction Projects.....	1350
F7.4_Hardiwardoyo_Contribution of Short Coco Fiber on Skid Resistance Pavement Performance...	1357

F7.6_Arijoeni_Study of Compressive Strength of Mortar Containing Rice Husk Ash (RHA) and Concrete Sludge Waste (CSW) with composition 1 Cement : 2 Fine Aggregate.....	1358
F8.1_Rahmawati_The Role of Knowledge Management in Collaborative Design to Support Construction Process.....	1365
F8.2_Iskandar_The Analysis of Construction Type for Effective and Efficient Bridge Upper Structure with Value Engineering Method (Case Study in Singomoyo Bridge Development Project in Malang Regency).....	1371
F8.3_Willar_Organisational Culture: The Case of Indonesian Construction Industry .....	1379
F8.4_Mochtar_Intelligence Functions in Construction .....	1385
F8.5_Trigunarysyah_Sharia-Compliant Financing in Indonesia Infrastructure Projects .....	1394
F9.1_Dina_DETERMINATING SIGNIFICANT FACTORS INFLUENCING.....	1399
F9.2_Gambiro_DETERMINATING SIGNIFICANT FACTORS INFLUENCING CEMENT COMPRESSIVE STRENGTH AT PADANG CEMENT COMPANY.....	1406
F9.3_Ahmad_Corrosion of Concrete Using Portland Composite Cement and Rice Husk Ash under Simulated Acid Rain Environment.....	1414
F9.6_The Study on Compressive Strength of Normal Concrete Containing Rice Husk Ash (RHA) and Concrete Sludge Waste (CSW) Designed for Moderate Strength.....	1416
F10.1_Novita_Adoption of Smartphones of Mobile Professionals in Indonesia and Its Implications on Travel Pattern using the concepts of Mobile Interaction-based Coordination: Preliminary Study .....	1426
F10.2_Sugiharto_The Development of Monorail Design Based on Local Industrial Component as an Alternative Implementation Concept of MRT for the Growth of Indonesian Sustainable Transportation System.....	1434
F10.3_Juanita_TRAFFIC IMPACT OF HOUSING DEVELOPMENT TELUK – PURWOKERTO .....	1441
F10.5_Setyawan_The Mock Application of Greenroad Rating System for Design and Construction at Cemoro Sewu Road .....	1445
F11.1_Latifa_The Performance of Dynamic Stability and Roughness of Hot mixed Asphaltic Concrete with Superpave Aggregate Gradation.....	1450
F11.2_Agrensa_Deformation Behaviour Of Soft Soils Railway Subgrade Reinforced By Wooden Pile	1457
F11.3_Setyowati_Building Materials Composition Influence to Sound Transmission Loss (STL) Reduction .....	1464
F11.4_thambiratnam_Safety Enhancement of Water-filled Composite Road Barriers.....	1465
F11.5_Lee_Managed Motorways Research in Queensland, Australia .....	1466
F11.6_Agah_Modified Buton Granular Asphalt with SBS as binder of hot-mix asphalt .....	1467
F12.1_Handajani_The Urban Transportation System and Fuel Consumption of Metropolitan and Large Cities In Java .....	1473
F12.2_Setyawan_The Influence of Grout Containing Fly Ash on The Tensile Strength of Grouted Macadam .....	1481
F12.4_Sambowo_EVALUATION OF PRECAST SYSTEM STRUCTURE FOR A HISTORICAL BUILDING REHABILITATION .....	1487
F12.5_Nurlaelah_Analysis of Construction Management Accomplishment on Building Project of Manufacture Industry in PT. Damai Indah Kaca Tipis - Indonesia .....	1495

## Symposium G

AbstractPlenary1_Yatmo_Architecture for People: Educating, Empowering, and Sustaining.....	1504
G1.1_DyahSPP_Building not Growing Case of study : nDalem Pangeranan Kasunanan Palace at kampong Baluwarti Surakarta .....	1505
G1.3_EddyH_The Application of Sustainable Development System at Dr.Kariadi-Hospital in Semarang.....	1514
G2.2_DianeVW_Towards a Grand Scenario: Innovations in Green Architecture .....	1517
G2.3_Suparwoko_Green Open Space Approach to the Building Mass Arrangement in Yogyakarta: Case Study of the Revitalization of the Tugu Rail Station .....	1518
G3.1_AntonyS_Partnership between Private Sector and Low-income Community in Self-Help Housing as a Model for Urban Settlement .....	1526
G3.3_TriatnoYH_Contestation of Public Space: Areas Surrounding the Public Transport Terminal Kampung Melayu, Jakarta .....	1531
G3.4_DitaT_Urban Invasion and Contestation of Space: Houses to Shop-houses to Street Vendors alongMadura Island’s Primary Collective Road .....	1539
G3.5_YukeA_The Triadic Column and Pivot Hinge: To Realize the ‘Beautiful House’ to ‘Wong Cilik’ As the Architecture Innovation to Low Cost Housing.....	1545
G4.1_KlaraPI_Lesehan Culture at Yogyakarta Tourist’s Night Space.....	1550
G4.2_ImmaWA_BRO: AN APPROPRIATE DESIGN TO UNIFY PEOPLE, PLACES, AND TRAFFIC IN THE CITY CENTRE PLAZA OF MALANG CITY .....	1558
G4.3_AntoniusKM_The Role of Indigenous Community in the Production of Street Space Use Justice .....	1565
G4.4_MahmoudYMG_Toward Resilience Urbanization: The Shared Roads as a Mean for Enlarging the Public Spaces .....	1569
G4.6_FebyHK_‘Urban Legend’ of Wakaf Cemeteries at Jalan Pangeran Antasari and Kemang.....	1579
G4.7_NurFR_Women’s Space of Activities in Slum Areas: Territories and Negotiation .....	1588
G4.8_AntonyS_DevelopingSquatterKampungs, a PoliticalResolution CaseStudyKampungLio, Depok, Indonesia .....	1594
G4.9_TitienWM_Transformation from Conventional To Modern Urban Open Space In Semarang City1600	
G4.10_MikthaFA_Void: A Mechanism of Delaying Space.....	1606

## Symposium H

H1.1_NiGAGEM_Accelerating Village Development through Institutional Arrangement.....	1613
H1.2_BaniaM_Coping in Widows Who Have Children with Moderate Mental Retardation.....	1620
H1.3_BudiB_Corporate Waqf – An Islamic Model CSR for Community Development.....	1627
H1.4_AlamsyahL_The Influence of Service Quality on The Satisfaction of Regular Patients in The In-Patient Wards in Putri Hijau Hospital Kesehatan Daerah Militer I/Bukit barisan Medan .....	1632

H1.5\_EllyaZ\_Participatory Approach to Support Community Development of Rural Craftspeople..... 1638

H1.8\_GedeS\_Strengthening Social Capital on Agricultural Development Lesson from Subak of Guama, Marga Subdistrict, Tabanan, Bali Province-Indonesia ..... 1646

H1.9\_EIKMN\_Vertical Housing for Low-Income People in Urban Areas Case Study: The Vertical Simple Housing (Rusunami / Rumah Susun Sederhana Milik) Project of Kalibata Area ..... 1654

H2.1\_IgnJM\_Measurement of Education Quality with KANO Model : A Case Study on Elementary School ..... 1658

H2.2\_IrmayantiR\_The Relationship between Type 2 Diabetes Mellitus with Diabetic Retinopathy Assessed by HbA1c asA Parameter of Blood Sugar Control..... 1669

H2.3\_RusdiY\_The Effectivity of Single Dose Albendazole to Trichuris Trichiura Worm Infection for One,Two and Three Days Therapy ..... 1674

H2.4\_Aulanni'am\_Mobile Pet Health Care Servicesfor Preventing Zoonoses Spreading..... 1682

H2.7\_DjokoMH\_Training of Standard Operating Procedures on Semi Material Recovery Facilities/UPS to increasing its efficiency for officers of Depok Cleanliness Department/DKP-Depok ..... 1688

H3.1\_ChairunN\_Future Welfare of Neglected Children: Empowerment or Community Development. 1693

## Symposium I

I2.1\_DianaA\_The Pre-specific City: ATheoreticalNarrativein the Post-Generic Age ..... 1697

I2.2\_RatnaEMS\_Unconventional and Original Anecdoche: Textual Space Construction in The Dictionary of Obscure Sorrows, a Tumblr Blog ..... 1703

I2.3\_SusinyP\_The Changing of Play Culture and Electronic Game: It's Meaning on Children Emotional Ties and the Loss of Children's Sense of Place in Outdoor Space..... 1711

I2.4\_DianeW\_From Bricks to Bytes: Digitizing Green Cities ..... 1719

I2.6\_YudiA\_Video Games Modification in Indonesia As Players Creative Contribution In Producer-Consumer Model of Popular Culture ..... 1727

## Plenary 2

# Study of the Safety Aspects of the Large Scale Use of LNG as a Fuel

**L. Vandebroek<sup>a</sup>, J. Berghmans<sup>b</sup>**

<sup>a</sup> *M-Tech, Hasselt, Belgium*  
*l.vandebroek@m-tech.be*

<sup>b</sup> *Katholieke Universiteit Leuven, Leuven, Belgium*  
*jan.berghmans@mech.kuleuven.be*

The use of liquefied natural gas (LNG) as a transport fuel presently is drawing considerable attention, mainly in the marine sector. The reason for this is the benign nature of LNG with respect to the environment as compared to the conventional fuels. LNG does present safety problems however. The results of a risk analysis for the storage and transfer of LNG are presented. The role of risk mitigation measures is analyzed. It is found that the pressure of the LNG at the moment of release has a large influence on the accident effect distances. Releases of LNG at atmospheric pressure lead to accident scenarios very similar to those occurring during the release of conventional liquid fuels. Accidents with pressurized LNG may lead to scenarios with more serious consequences.

### Keywords

*LNG, safety, risk*

## Study on Mesoscopical Inhomogeneous Material Modeling for Surface Roughening Behavior of Polycrystalline Metal Sheets and Foils

Tsuyoshi Furushima<sup>a</sup>, Ken-ichi Manabe<sup>a</sup>, Sergei Alexandrov

<sup>a</sup> Department of Mechanical Engineering,  
Tokyo Metropolitan University  
1-1 Minami-ohsawa, Hachioji, Tokyo, 192-0397 Japan  
E-mail :furushima-tasuyoshi@tmu.ac.jp

<sup>b</sup> Institute for Problems in Mechanics,  
Russian Academy of Sciences  
101-1 Prospect Vernadskogo, 119526 Moscow, Russia

### ABSTRACT

Recently, the demand for the miniaturization of components has come from technical applications such as electronic devices, medical equipments, sensor technologies and optoelectronics. The development of a novel micro metal forming technologies with high productivity, by which a large number of small metallic parts can be produced, has been attracted. For quantitative prediction of free surface roughening behavior, an FE model considering mesoscopic material inhomogeneity is developed. New concept of determination method of mesoscopical material inhomogeneity parameter is suggested by two simple experimental tests; microstructure observation and uni-axial tensile test, and the iteration of inhomogeneous FE analysis. The material inhomogeneity parameter expressed by standard deviation of variation in flow stress for crystal grain is determined from suggested determination method. The free surface roughening behavior obtained from the inhomogeneous FE analyses is compared with continuous observation by confocal laser microscope under equi-biaxial and plane strain tensile states for A5052-, SPCC and C1220P-O. Evolution of convex and concave patterns and surface profile can be simulated by the FE analyses considering material inhomogeneity determined by proposed determination method. Actual surface roughness values during equi-biaxial and plane strain tensile deformation can be predicted quantitatively by proposed inhomogeneous FE analyses. Therefore the validity of the inhomogeneous FE analyses and new concept of determination method of mesoscopical material inhomogeneity can be verified.

### Keywords

*Surface roughening, inhomogeneity, material modeling*

# Development of Gene Gun as Intradermal Vaccine Administration Device for Laboratory and Clinical Applications

Danardono AS<sup>a</sup>, M Satrio Utomo<sup>a</sup>, Sonia Tzarina GS<sup>a</sup>, Fera Ibrahim<sup>b</sup>, Budiman Bela<sup>b</sup>, Silvia Triwidyaningtyas<sup>b</sup>

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : danardon@eng.ui.ac.id, m.satrio@ui.ac.id

<sup>b</sup>Institute of Human Virology and Cancer Biology (IHVCB), University of Indonesia, Salemba

## ABSTRACT

Vaccine administration via skin tissue gives people globally a promising, novel way to fight diseases and improve health quality. There are many ways to do it; one of them is called particle bombardment. In this technique, nano-sized gold particles are coated with the vaccine formula then shot by a device called gene gun straight into the skin tissue. To make gene gun capable of delivering vaccine into human, further research and development are needed. Thus, we conduct series of research to design, make, and develop desk gene gun for laboratory uses and portable gene gun for clinical applications. We set up an assembly consist of pneumatic lines, valves, a fluid container to be the mechanism of the gene gun, and a nozzle to configure the fluid flow. The development focuses on the designing of each component, especially for non-common components and assembling all of the components to obtain the most effective and efficient design which will gives optimum results. To sum up, prototypes of desk gene gun and portable gene gun have been made, but many developments in many aspects are still needed to fulfill the need of gene gun as intradermal vaccine administration device in laboratory and clinical applications.

### Keywords

*Biolistic, design, gene gun, intradermal, vaccine*

## INTRODUCTION

Vaccination is one of human endeavor to face many contagious and deadly diseases. First vaccination was done by Edward Jenner in 1796 to address chickenpox disease. Vaccination itself means a preventive efforts done by inserting germs or viruses that have been attenuated to the human body. This was done in order to stimulate the antibody cells so it would able to form immunity system against the diseases. Increasing intensity in terms of amounts and types of deadly and infectious diseases in any parts of the world has triggered scientists to develop more effective and efficient ways of delivering vaccine into human body. One of the method is done by putting vaccine into the skin tissue which is known as intradermal method. Vaccine delivery by intradermal method gives people globally a novel and promising way to fight diseases and improve health quality.

Far before intradermal method has been stated, vaccine is inserted into the human body via the blood vessel(vascular) by the help of a syringe. Until now, this method is still the most widely used method to administer vaccine into the human body. However, intravascular technique has potential risks and other things to be cautioned at. The operation of this technique requires skilled and professional medical personnel. A little mistake can cause a dangerous risk for both the patient and the medical personnel. The pain that emerged at the time of process of syringe injection also cause discomfortness and unpleasant feeling for the patient, especially if the patient is a child. This can lead to a psychological trauma that could hinder the healing process. The problem of syringe sterility and disposability are also be the side effect of the use of intravascular techniques. The nature of the hazardous waste of the syringe in terms of both physical and biology that are sharp, not sterile, and could potentially contain diseases can not be simply ignored.

As a solution for points stated above, scientists develop many other ways beside intravascular method to administer vaccine into human body, which are: oral (by mouth), intramuscular (by muscle tissue), transdermal (through skin), and the latest one, intradermal. From all of the mentioned methods, intradermal is one that still needs many developments and research to make it able to be used for human properly. Although some devices have been made an developed as intradermal vaccine administration device, none of them have passed the clinical trial to be used for human. As part of the effort to improve the health quality and help people to fight diseases, we decide to design and develop two models of gene gun which will be used as a laboratory instrument and clinical applications.

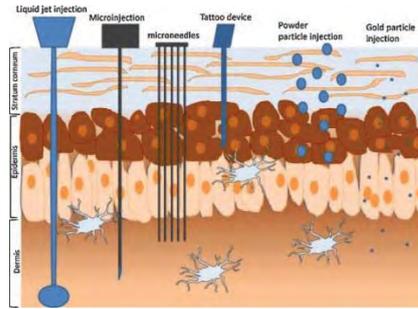


Figure 1. Variation of techniques used as intradermal method

## MATERIALS AND METHODS

The design and development of gene gun are done by following the steps of product design and development principles. Some core principles of new product development (NPD), design function deployment (DPD), and other product design and development methods are combined to obtain the most appropriate way to develop gene gun. The key elements of the design and development strategy then are defined as those which may be used to collate essential information for such areas as follows:

- The establishment of user needs.
- Analysis of the functional requirements of the product.
- Evaluation of existing products.
- Exploration of other avenues for solutions to identified design problems. (Cross, 1994)

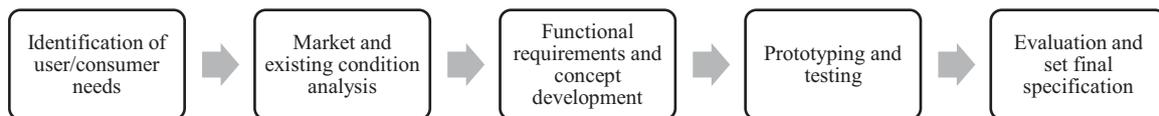


Figure 2. Process design and development steps

In case of gene gun, there are three groups that we consider as our user or customer, which are medical researchers, medical practitioners, and patients. Each of them have their own role and urgencies toward the application of gene gun for intradermal method of vaccine administration. Based on this situation, we decide to design and develop two types of gene gun. One is what we called by desk gene gun. It is designed to fulfill the need of gene gun of medical researchers so they can conduct research and develop other matter that required to make gene gun capable of delivering vaccine into human skin. The main points of this desk gene gun is the ability to read and control some varying parameters with respect of medical laboratory instrument standards, ease of use, and any other factors that should be considered so they can use it as a laboratory instrument. The other is called portable gene gun. It is designed for clinical purposes meaning that the customers are medical practitioners like doctor or nurse and also the patients itself. The main points of designing portable gene gun is the safety and comfortness of the patient and also the medics. Moreover, the compactness, simplicity, and other additional points like aesthetics and environmental issues should be considered to in the designing of portable gene gun with respect of course, to the main function of desk gene gun to deliver vaccine by intradermal method in a more effective and efficient way.

After defining each of customer/user needs, we are trying to formulate the functional requirements of the product and start the design and development of mechanisms and required components to make the gene gun. Gene gun itself was developed for the first time at 1989 by John Sanford, Klein, and Wolfe in Cornell University as a mechanism of introducing new genetic material into plant cells. The original gene gun transfection procedure involved placing the sample in a sealed chamber, which was then placed under vacuum before firing DNA-coated microparticles into the target. Today, gene guns have come in many kinds of forms and mechanisms that are more sophisticated. They have been used successfully to deliver a wide range of tissues and organisms, including whole animals and plants, bacteria, mammalian cells and even organelles. This technique has been particularly successful for biological samples that have previously been difficult or impossible to transfect, such as non-dividing cells or primary neurons. Transfection using a gene gun (often referred to as biolistics) is a simple procedure requiring minimal training; it basically consists of two steps: (i) coating microprojectiles with DNA and (ii) firing the coated microprojectiles into the sample. (O'Brien, 2007)

The fundamental principle of gene gun is to accelerate microparticles using external force that may come from an ignited explosion, electric impulse, or compressed fluid so the microparticles have enough velocity to penetrate skin tissue and reach the antibody cells. We decide to use compressed fluid as the driving force for our gene gun design. As a consequence of using compressed fluid as the driving force, uses of pneumatic components to control the flow are required. Common components like 3/2 NC valve, quick exhaust valve, pressure regulator, and flowmeter are used to control the flow with respect of its own function. Beside common components, we also use a specifically designed components including fluid container and nozzle.



Figure 3. First gene gun developed by John Sanford, Klein, and Wolfe in 1989.



Figure 4. Helios® Gene Gun, first commercialized gene gun

## RESULTS AND DISCUSSION

There are many aspects of both direct and indirect results from the development of gene gun that could be delivered here. Despite of it, to keep the focus straight to the design development of gene gun, we just present the design development activity with prototypes of desk and portable gene gun as the results. In total, we have made one prototype of desk gene gun and three prototypes of portable gene gun.

The current desk gene gun consist of a subassembly of stand as the supporting structure and the main components of gene gun itself that mounted at the top of the structure. We decide to use aluminum as the material of the structure with consideration of its strength, mass, environment condition, ease of production, and aesthetics. The stand subassembly itself consists of two aluminum plates, acts as the base and upper supportive plate, jointed with four hollow aluminum tubes which act as the structure pillar. At each side of the device, leaving one side open as an access to inside area of it, we put a clear acrylic as a wall to reduce the interaction between inside chamber and environment.

For the mechanism of the gene gun, we use pressure regulator and flowmeter to control the fluid flow, an electrical-controlled 3/2 NC solenoid valve, a quick exhaust valve, and a fluid container. All of them are mounted fix to the upper supportive plate except for the fluid container. To direct and configure the fluid flow, we design some nozzles with its own distinctive design and put it right after quick exhaust valve inside the chamber. The target will be placed right under the nozzle with the desired distance.

We have tested the desk gene gun and it worked just like it should. There isn't any leaks at the fluid lines, the fluid can be precisely controlled, and the pressure loss inside the assembly still can be tolerated as well. This makes sure that the architecture of the subassembly is good and appropriate enough. The operation was also easy although it requires supply of both electrical power and compressed fluid lines. Several things that should be consider at are the effect or force from the pressurized fluid. The force when the valve was opened and the fluid flows out of the nozzle cannot be considered low. A well and precise design of support with damper or mounting bracket should be made in order to absorb the vibration. The structure was also a bit unstable because of the lightweight structure and the propotion. The height was just too high and it was just supported by four hollow aluminum tubes. This makes that each time a shot was done, the device receive a moment force and it was like swaying over. The problem can be solved by lowering the height of the device or changing the materials of the structure so it will be more stable.

Based on the evaluation and to improve the performance of the device, we decide to make a computer-aided control system to the device. By using solenoid valve and solenoid pressure regulator, we can control the fluid electrically. The usage of pressure transducer can also be applied to change the pressure gage role so the amount of pressure can also be displayed in the computer. In addition, we are also planning to make a motor-controlled platform inside the chamber using screw system so in the future, users don't have to put the target in specific distance manually. They just have to put the distance into the computer and the system will do it automatically. This addition is also capable to make the inside chamber to be sealed better so it will reduce any interruption from the environment. Hence, it will increase the reliability of the shooting results in the future.



Figure 5. Prototype of desk gene gun

There are three prototypes of portable gene gun that we have made, each of them with their own designs and combinations of components. The core components of gene gun will be the same for each prototypes which are consist of 3/2 valve and quick exhaust valve along with a fluid container and the nozzle. Instead of using electrical controlled 3/2 solenoid valve, we use a mechanical-actuated 3/2 valve. We also use smaller size of valve for the portable gene gun. If the desk gene gun use a 3/8' valve, portable gene gun use 1/4' or 1/8' valve.

We are still using the standard or common components in the market to make it easy to be replaced and assembled. We combines wide range of products to find the most optimum design. We decide to use a mechanical-actuated valve in order to increase the simplicity of the mechanism. If we use a solenoid valve, then it needs an electric power source which could be mean a battery will be needed. This will increase the dimension and weight of the assembly. Thus, in consequence of using mechanical-actuated valve, we have to design the most appropriate handling position and add some linkage so the device can be used easily and without so much effort.

In the gene gun assembly, there are two components that was designed distinctively, which are fluid container and nozzle. Just like its name, the fluid container is used to store some amounts of compressed fluid that will be used to accelerate the microparticles. The most important thing to be considered of the design of the fluid container is the capacity which will determine the dimension. Based on the principle of continuity equation and law for compressible fluid, to obtain the same fluid flow capacity, smaller fluid container capacity would mean higher driving pressure is required, and vice versa. Here, the fluid driving pressure will play a very important role. A pneumatic system with higher operating pressure will be also considered more dangerous than the one with lower operating pressure. A well and precise decision should be taken to obtain the most compact design of fluid container with proportional driving pressure. Until now, we are still trying to find the most appropriate combination of fluid container combination to driving pressure. The requirement of compact and mobile design of portable gene gun will be the challenge of this fluid container design problem.



Figure 6. Prototypes of portable gene gun

Beside the pneumatic mechanisms, another component that has a very important role to successfully make gene gun able to deliver vaccine into human body is the nozzle. Nozzle is used to form and direct the fluid flow so it will give the most optimum result. Not only that, in gene gun, nozzle is also used as the location to put the tube containing microparticles which coated with the vaccine. This will be the constraint yet the key point of the nozzle designing. Based on the user needs and literature, it is known that the nozzle used for gene gun should be categorized as supersonic nozzle.

Supersonic nozzle has its own distinctive rules of design. In general, the form of supersonic nozzle can be considered as a convergent-divergent nozzle (C-D nozzle). The most special thing in this type of nozzle is the existence of throat section. Supersonic nozzle can be divided to three sections: converging sections, throat section, and diverging section. In converging section, subsonic flow developed until it reaches near supersonic flow. Inside the throat area, the fluid flow will develop into fully supersonic flow. In the diverging area, the fluid flow will keep developing, increasing its velocity until it meets the stagnant fluid condition of environment. With these two key points, we design nozzles for gene gun that capable to hold the tube and acted as a supersonic nozzle.



Figure 7. Nozzles of gene gun

The manufacturing process to make gene gun nozzle should be distinctively considered too. Conventional manufacturing method using conventional tools and machine are hardly able to be used to make a precise and accurate gene gun nozzle. Considering limitations of manufacturability, we decide to simplify gene gun nozzle to a converging nozzle, as the preliminary study for next research and development. As an addition, based on some developments done by the other about gene gun nozzle, we also decide to put baffle holes angle variations and shooting distance to our development. The main purpose of baffle holes angle is to deflect the fluid flow so it will not hit the target, leaving only the microparticles that hit the target. This was done to minimize the side effect of the high velocity fluid flow which will cause an impact force that may destroy the target tissue. In terms of vaccination into human skin, this impact force would mean harm and cause pain to the patient. We use three variations of baffle holes angle which are:  $30^\circ$ ,  $90^\circ$ ,  $150^\circ$ . Each of the nozzles will be tested at three different shooting distances, which are: 0 mm, 10 mm, 20 mm.



Figure 8. Impact force to variations of shooting distances

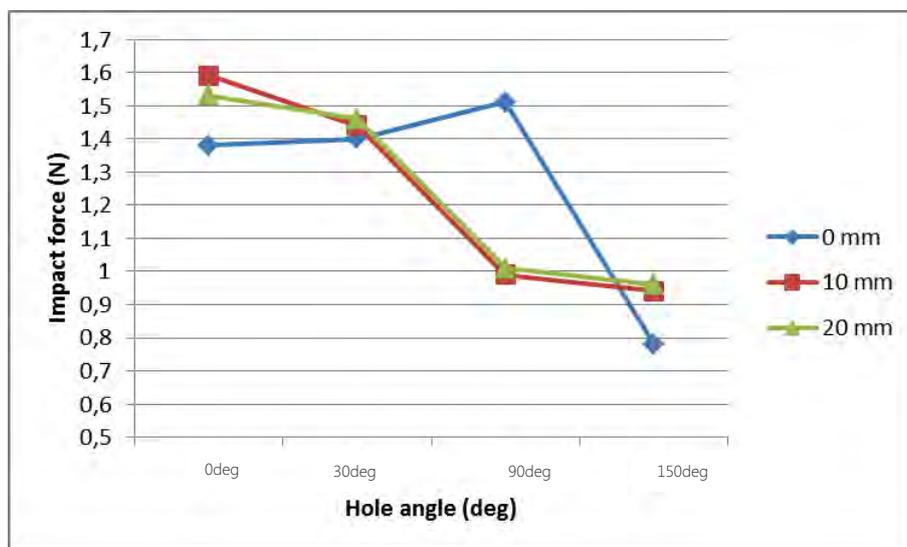


Figure 9. Impact force to variations of holes angles

The test to determine the effect of baffle holes angle and shooting distance variations to impact force has been done. From the results, it is known that the lowest impact force was created by nozzle with 150° of baffle holes angle shot in shooting distance of 0 mm. This result will be put as one of the considerations of gene gun nozzle designing. For the material, we decide to use aluminum. Later, to fulfill the standard of medical equipment, development of nozzle made by medical-approved material will be done. The testing of the gene gun has also been done to the agarose to determine the effect of driving pressure to the depth of penetration and spread diameter. Research to find the most effective combination of driving pressure and shooting distance are still in progress.

## CONCLUSION

The initial prototype of desk gene gun and portable gene gun have been made as a mark of our involvement of the development of intradermal vaccine administration device. Further development like adding computer-aided system, more precise controls and readings, appropriate material selection, and design of the architecture will be done to enhance the reliability of desk gene gun as medical laboratory equipment. For the portable gene gun, many developments are still needed, especially for non-common parts to find the most optimum design in terms of dimension, weight, looks, and ease of operation with heed to the main function of the gene gun.

## **ACKNOWLEDGMENT**

This research is a part of and funded by Incentive Research Funding of Ministry of Research and Technology 2011-2012. Many gratitudes and thank you are delivered to the team of Department of Mechanical Engineering - University Indonesia, Department of Microbiology- University of Indonesia, Institute of Human Virology and Cancer Biology (IHVCB) – University of Indonesia, and others who have involved direct and indirectly for all of their helps and supports in this research activity.

## **REFERENCES**

- [1] Barry, B.W. Novel mechanisms and devices to enable succesful transdermal drug delivery. 2001
- [2] Cottam, M. Development of a design strategy for an established semi-technical product: A case study of a safety harness for tree workers. 2001.
- [3] Cross, N. Engineering Design Methods. 1994.
- [4] Kis, Elsa E and Gerhard Winter. Devices for intradermal vaccination. 2011.
- [5] Lambert, Paul H and P.L. Laurent. Intradermal vaccine delivery: Will new delivery systems transform vaccine administration?2008.
- [6] Levine, MM. Can Needle-free Administration of Vaccines become the Norm in Global Immunization? 2003.
- [7] Medical Research Council. Gene guns: How one researcher improved his shot. 2007.
- [8] Mitragotri, S. Immunization without Needles. 2005.
- [9] O'Brien, John A and Sarah C.R. Lummis. Diolistics: incorporating fluorescent dyes into biological samples using a gene gun. 2007.
- [10] O'Brien, John A et al. Modifications to the hand-held Gene Gun: improvements for in vitro Biolistic transfection of organotypic neuronal tissue. 2001.
- [11] Sikorskaite, Sidona et al. HandyGun: An improved custom-designed, non-vacuum gene gun suitable for virus inoculation. 2010.
- [12] Sivaloganathan, S.et al. A hybrid systematic and conventional approach for the design and development of product: a case study. 2000.
- [13] Ulrich, Karl. Product Design and Development. 2005.
- [14] United States Patent Application Publication. US 2004/0033589. John Anthony O'Brien. Biolistic Device. 2004.
- [15] WHO. Safety of Injections: Global Facts and Figures. 2004.

# Simplified Model Of The Heave and Pitch Motions of an Flng Due to Sloshing Effect and Comparison with Some Experimental Results

LTP.Sinaga (1), IKAP Utama (2), A.Sulisetyono (3)

(1) PhD Student, Department of Naval Architecture & Shipbuilding Engineering ITS, Surabaya, Indonesia  
Email: luhuttps@yahoo.com.sg

(2),(3) Professor and Lecturer, Department of Naval & Architecture are Shipbuilding Engineering ITS, Surabaya, Indonesia  
Emil: kutam@na.its.ac.id.

## ABSTRACT

The coupled heave and pitch motions of a simplified sloshing effect at the FLNG on still water surface and subjected to induced by sloshing have been investigated. The FLNG was considered to be rigid body supported by non permanent pole with distributed spring damper. Based on the general equation of the ship motion in waves, and various wave amplitude, period governing equation induced by sloshing were derived. For the case of various fluid level on the cargo tank and various wave period, wave amplitude “ exact solution “ was obtained. For the purpose of comparison and more general studies, a numerical approach was also introduced. The influences on the dynamic responses of FLNG of some factors such as sloshing effect, heaving, various fluid level on cargo tank initial velocity and acceleration, were studied. To check the reliability of the numerical result a simple model was conducted and validated with some experimental result. The reason for discrepancies between experiments and theory are discussed. For simplicity, the damping effect and sloshing effect to the FLNG induced waves are replaced by damping ratio in this study.

## Keywords

*simplified, sloshing, coupled heave and pitch, damping, and waves*

## 1. INTRODUCTION

There are two primary concerns related to sloshing flows in ship hydrodynamics: the prediction of sloshing-induced impact loads on ship structures, and the dynamics of ship motion coupled with sloshing-induced excitation. The former is an important task in the design of internal cargo structure. In particular, this is an essential element in the design of membrane-type liquefied natural gas (FLNG) carriers or FLNG platforms. The latter has been of interest for the prediction of dynamic behavior of ship motion. Meanwhile the design load of the main hull structure is governed by the external wave load and inertial load due to ship motion, the sloshing impact load due to liquid motion inside the tank governs the design load for the FLNG containment system and surrounding bulkheads.

Many studies on the ship sloshing problem were carried out in 1970's and early 1980's for the design of FLNG carriers. Recently, the demand of sloshing analysis is rising again for the design of larger FLNG carriers and LNG floating-production-storage-offloading (FPSO) vessels. Many numerical studies on sloshing flows have been reported during last two decades. Some representative works have been introduced by ([1], [2]), [3], [4], [5], and [6]. Despite numerous studies, not many methods are applicable for actual engineering use such as the simulation of violent flows and the prediction of impact loads. However, recent experimental and numerical study shows that even at the milder sea states, the sloshing load at the filling level near the 30% of tank height can be as high as the sloshing load at the high filling level at the North Atlantic ([7]);([8]).

This study aims to observed on the physical phenomena involved in violent sloshing flows, and the development of proper numerical models for practical use. To this end, both the experimental observation and numerical computations are carried out ([10], [11]).

## 2. MODEL SET-UP AND ITS PARTICULAR

The FLNG model was produced according to a scale 1:70 .The model consists of hull body (barge shape structure) completed with cargo tank, normal bilge tank. The FLNG model was made from wood and steel frame which is required strengthen the hull body. The model should be statically and dynamically balanced to adjust the position centre of gravity and radii gyration. The Cargo tank are made of acrylic transparent glass 1 cm wall thickness. In the following lines plan and table of principal dimension of FLNG with scale factor:

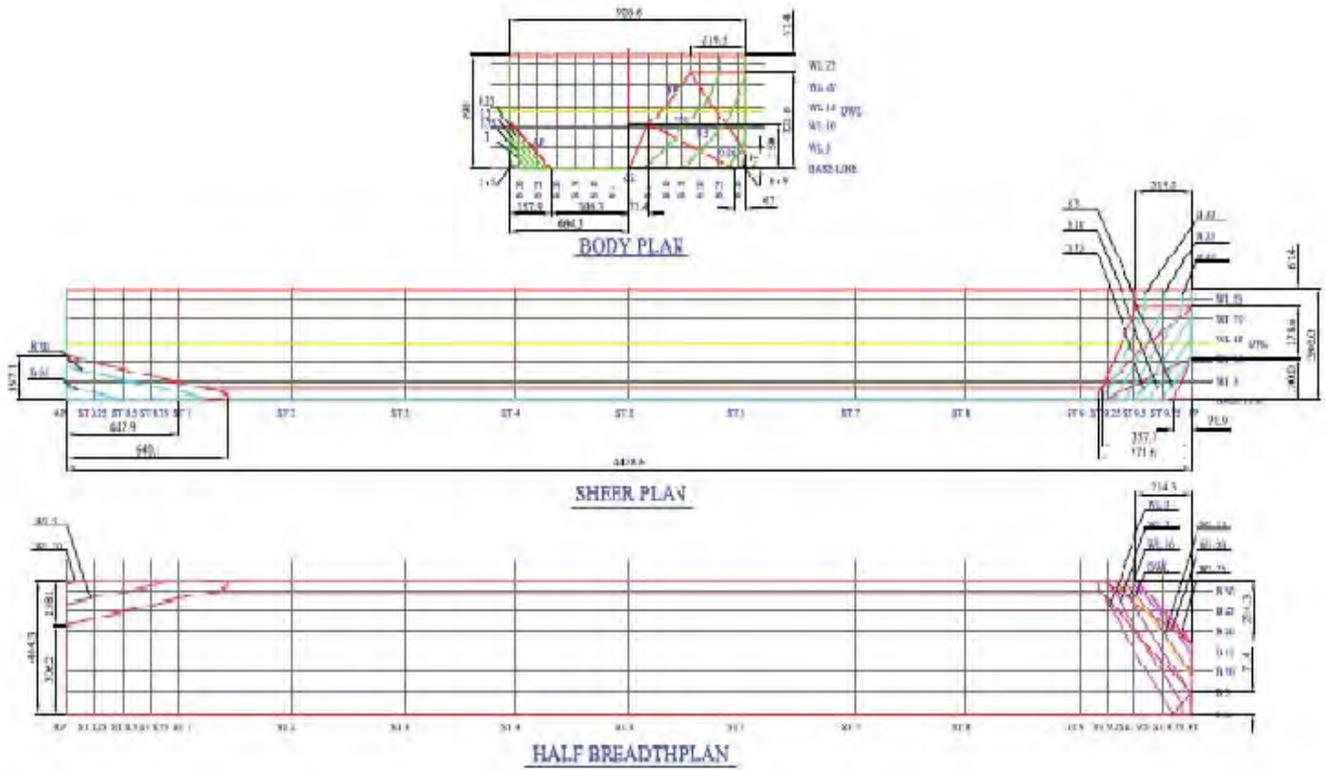


Figure 1: Lines Plan of FLNG

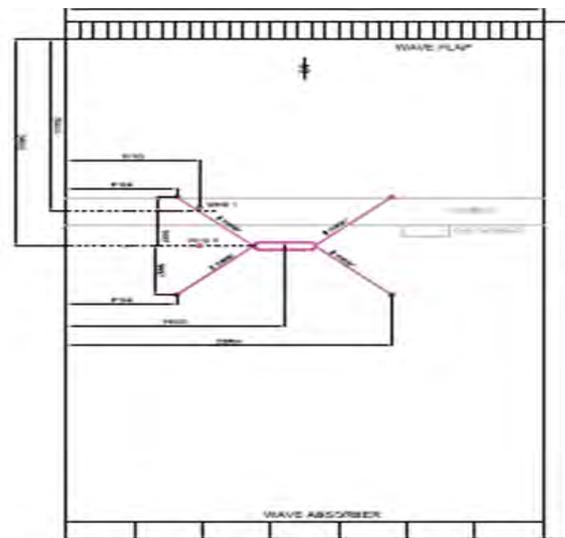


Figure 2: Set Up Position Of Model FLNG In Model Basin

Table 1: Principal Particular

Description	Symbol	Full scale		Model scale	
Length Overall	LOA	=	350.000 m	500.00	cm
Length between perpendiculars	LPP	=	310.000 m	442.86	cm
Breadth mid ship section	B	=	65.000 m	92.86	cm
Depth	D	=	27.300 m	39.00	cm
Draft	T	=	13.800 m	19.71	cm
Displacement	Disp	=	271260000.000 kg	771.56	kg
Long. Center of Gravity from AP	LCG	=	150.583 m	215.12	cm
Center of Gravity from keel	KG	=	21.800 m	31.14	cm
Long. Center of Buoyancy from AP	LCB	=	150.585 m	215.12	cm
Vertical Center of Buoyancy	KB	=	6.999 m	10.00	cm
BM trans	BMt	=	25.745 m	36.78	cm
BM long	BML	=	571.173 m	815.96	cm
Roll Radius of Gyration	K <sub>xx</sub>	=	24.050 m	34.36	cm
Pitch Radius of Gyration	K <sub>yy</sub>	=	74.400 m	106.29	cm
Keel to Metacentic	KMt	=	32.745 m	46.78	cm
Transverse GM	GMt	=	10.945 m	15.64	cm
Calculated Roll Natural Period	T <sub>roll</sub>	=	17.300 sec	2.07	sec

Table 2: Tests With Regular Wave

No	Billing Level	Bilge-Keel Type	Heading (deg)	Amplitude (m)	Period (s)	# of oscillation
1	30%	Normal	90	2.0	14.5	15
2	30%	Normal	90	2.0	16.3	15
3	30%	Normal	90	2.0	17.3	15
4	30%	Normal	90	2.0	18.3	15
5	30%	Normal	90	2.0	19.0	15
8	30%	LRSD	90	2.0	14.5	15
9	30%	LRSD	90	2.0	16.3	15
10	30%	LRSD	90	2.0	17.3	15
11	30%	LRSD	90	2.0	18.3	15
12	30%	LRSD	90	2.0	19.0	15
15	30%	LRSD	180	2.0	11.3	15
16	30%	LRSD	180	2.0	12.3	15
17	30%	LRSD	180	2.0	13.3	15
18	30%	LRSD	180	2.0	14.5	15

The model test were carried out in regular and random waves. The random waves were adjusted to represent Pierson-Moskowitz wave spectrum. The waves in basin were generated by means of a wave generator.

### 3. PROCEDURE CALIBRATION

All from the recorded decay curves of the various motion decay or free extinction tests natural periods have been derived to used for evaluated. The damping coefficients were derived from the decrease of motion amplitude for two successive oscillations as follows: (See Figure 3)

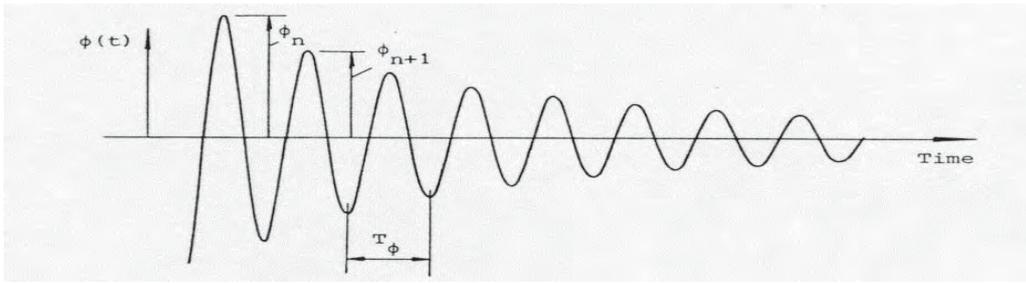


Figure 3: Decay Test

$\phi(t)$  = time trace of motion  $\phi$   
 $\phi_n$  = motion amplitude of n-th oscillation  
 $T_\phi$  = natural period of motion  $\phi$ .

The logarithmic decrement  $\Delta$  can be determined:

$$\Delta = \ln(\phi_{n1}/\phi_{n2})$$

The dimensionless damping coefficient or damping ratio to critical damping is expressed by:

$$k = b/b_{critical}$$

Which can be calculated from the logarithmic decrement by:

$$k = \Delta / (4\pi^2 + \Delta^2)^{1/2}$$

### Linear (Equivalent) Damping

When the system behaviors is almost linear (equivalent) damping can be derived as follows:

The linear motion  $x(t)$  during a free extinction test can be described by, assuming a linear system:

$$(m + 1) \cdot \frac{d^2x}{dt^2} + B_x \cdot \frac{dx}{dt} + C_x \cdot x = 0 \quad \dots\dots(1)$$

$$(I + I_A) \cdot \frac{d^2\phi}{dt^2} + B_\phi \cdot \frac{d\phi}{dt} + C_\phi \cdot \phi = 0 \quad \dots\dots(2)$$

Where:

- |                                    |     |  |
|------------------------------------|-----|--|
| $m$ = vessel mass                  | and | $I$ = vessel inertia for rotation      |
| $A$ = added mass                   | and | $I_A$ = added inertia for rotation     |
| $B_x$ = linear damping coefficient | and | $B_\phi$ = angular damping coefficient |
| $C_x$ = linear spring coefficient  | and | $C_\phi$ = angular spring coefficient  |

The spring coefficients are a combination of the hydrostatic spring and the stiffness of the mooring system.

The non-damped natural period of this system can be calculated as:

$$T_\phi = 2\pi \sqrt{\frac{I + I_A}{C_\phi}}$$

$$T_x = 2\pi \sqrt{\frac{m + A}{C_x}}$$

For such a system the critical damping  $B_{crit}$  is defined as:

$$B_{x_{crit}} = 2\sqrt{(m + A) \cdot C_x}$$

$$B_{\phi_{crit}} = 2\sqrt{(I + I_A) \cdot C_\phi}$$

If the damping is equal to, or larger than, the critical damping, no overshoot of dynamic amplification occurs in the system. To determine the degree of damping in a system, the damping is sometimes expressed as a ratio  $B_\beta$  of the linear damping coefficient  $B$  and the critical damping  $B_{crit}$ :

$$B_\beta = \frac{B}{B_{crit}}$$

## 5. ANALYSIS AND DISCUSSION

### 5.1 Response Amplitude Operator

The prediction of responses structure of an FLNG is generally made in regular wave. In currently work various heading angle (90,180) degree and filling of the water 30 % for simplicity analysis. In this model test sort term response calculation of linier non linier are given natural Response Amplitude Operator (RAO) of FLNG. Based on linier theory it is assumed that for each wave period the relation between input wave amplitude and motion always the same. From the test were carried out at beam seas 180 degree the wave amplitude increase compare to head seas 90 degrees (See Figures 5 and 6). For heaving motion at beam seas 180 degrees and head seas 90 degrees, there is not many different (See Figures 7 and 8).

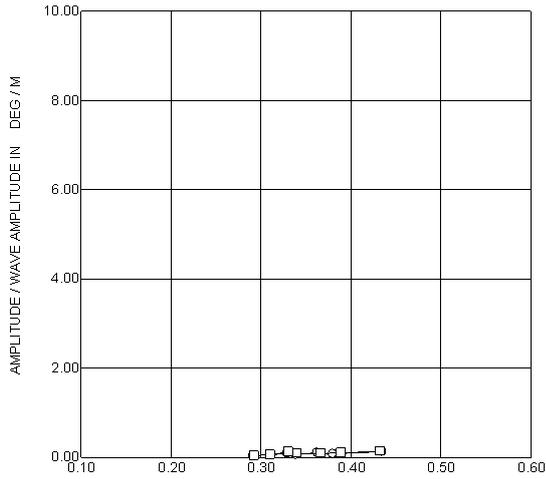


Figure 5: RAO Pitch (Angle 90 deg)

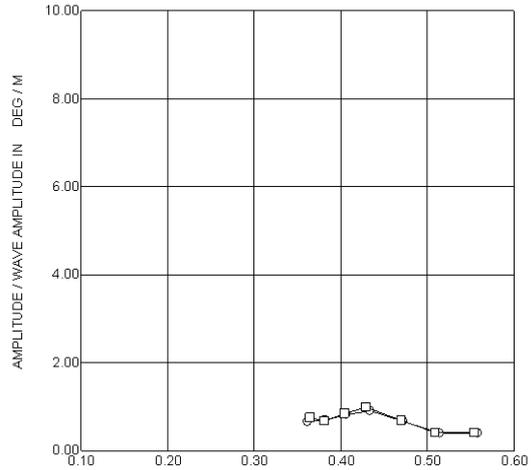


Figure 6: RAO PITCH (Angle 180 deg)

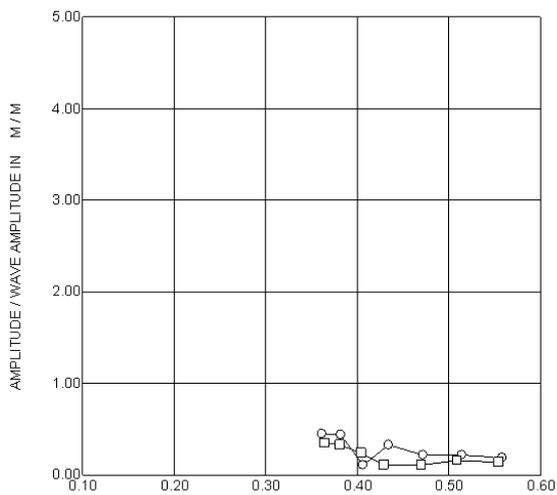


Figure 7: RAO Heave (Angle 90 deg)

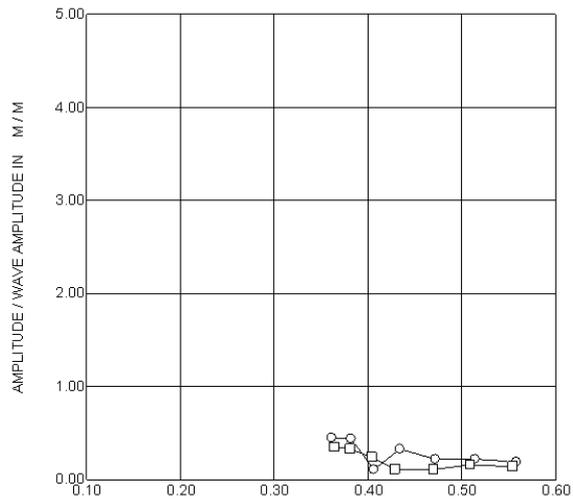


Figure 8: RAO Heave (Angle 180 deg)

## 5.2. Time Traces of Wave Spectrum and Impact pressure at Sloshing Tank

Figures 9 and 10 show an actual time history of wave spectra and impact pressure to support the analysis of natural frequency of the ship motion as particular for pithing and heaving motions. And also the correlation between wave spectra and the maximum impact pressure.

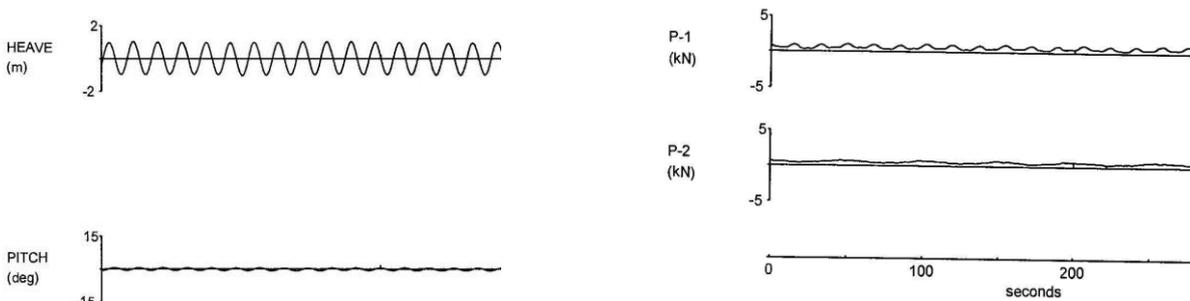


Figure 9 Wave Spectrum and Impact pressure with heading 180 deg

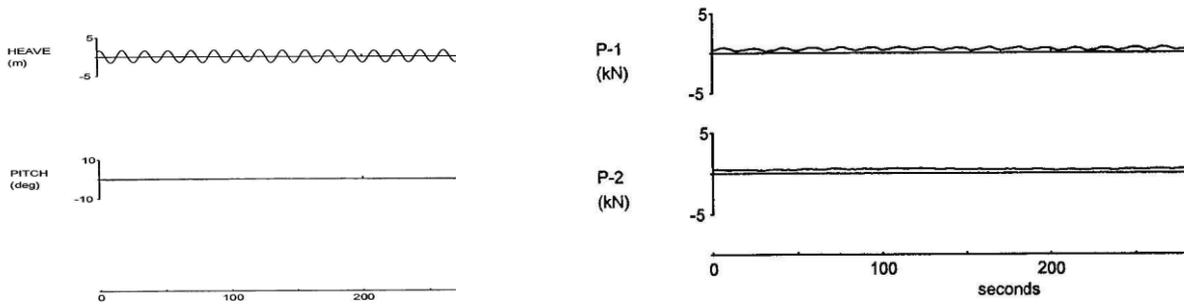


Figure 10: Wave Spectrum and Impact pressure with heading 90 deg

Table 3 Result of Decay Test

NO	ID	BILGE KEEL	DECAY	RAO Pitch,Heave	Tn (sec)	P	Q
1	D 03	Normal	Pitch	0,4deg,0.9m	12.094	5 Kg	5 Kg
2	D 06	LRSD	Pitch	0.03deg,0.7m	11.672	5 Kg	5 Kg
3	D 09	Normal	Pitch	0.11deg,1.6m	11.658	5 Kg	5 Kg
4	D 15	LRSD	Pitch	0.05deg,1.74m	11.753	5 Kg	5 Kg

Figures 11 and 12 show the step of run-up water dynamic in the storage tank. The storage tank was filled with water until 30% from maximum storage given splashness significantly increase.



Figure 11: Wave peak (t=6)

Figure 12: Run up wave (t=5)

## 6. CONCLUSIONS

In the present study, the physical and technical issues of sloshing flows in FLNG the ship are described. The physical phenomena in violent sloshing flows have been carefully observed in experiments, which was carried out at IHL Surabaya. Based on the present study, the following conclusions are drawn:

- There are several physical issues which should be considered in sloshing analysis. These issues include the effects of cushioning due to air pocket, local wave breaking, splashes. To understand their effects is critical to develop numerical models for sloshing analysis is need to study more detail.
- There are several technical issues in the numerical simulation of violent sloshing flows. Due to discrete spatial and time domain, proper numerical techniques are essential to make the solution more continuous, stable, and realistic.
- The nonlinearity of sloshing flow plays a critical role in the ship motion coupled with sloshing. The sloshing-induced force and moment are not linearly proportional to excitation amplitude. Therefore, the ship motion coupled with sloshing does not vary in a linear manner with respect to wave amplitude.
- The coupled problem is well predicted by the linear theory based on the impulsive response function. This method is accurate and robust, and particularly very efficient in computational time.
- The coupled Pitching and heaving problem is well predicted by the linear theory based on the impulsive response function must be continued with mathematical modeling to validated and solve the instrumentation error. Specially for pitching, heaving motion induced by sloshing dynamic.

## ACKNOWLEDGEMENTS

The authors wish to thank Indonesia Hydrodynamic Laboratory (IHL) staff for providing the experimental data of the current paper.

## REFERENCES

- [1] O.M. Faltinsen, A numerical non-linear method of sloshing in tanks with two-dimensional flow. *J Ship Research* 18 (1978) pp. 224-241
- [2] O.M. Faltinsen, O.F. Rognebakke, Sloshing, *Int. Conf. on Ship and Shipping Research*, NAV, Venice, Italy (2000)
- [3] T.J. Bridges, A numerical simulation of large amplitude sloshing, *Proc. of the 3<sup>rd</sup> Int. Numerical Ship Hydrodynamics*, Paris, France (1982)
- [4] N.E. Mikelis, Sloshing in partially filled liquid tanks and its effect on ship motions: Numerical simulations and experimental verification. RINA Spring meeting, London (1984)
- [5] G.X. Wu, Q.W. Ma, R. Eatock-Taylor, Numerical simulation of sloshing waves in a 3D tank based on a finite element method. *Applied Ocean Research* 20 (1998) pp. 337-355
- [6] Y. Kim, Numerical simulation of sloshing flows with impact load. *Applied Ocean Research* 23 (2001) pp. 53-62
- [7] Y. Kim, Y.S. Shin, K.H. Lee, Numerical study on slosh-induced impact pressures on three-dimensional prismatic tanks. *Applied Ocean Research* 26 (2004) pp. 213-226
- [8] J.J. Monaghan, Simulating Free Surface Flows with SPH. *Jour Computational Physics* 110 (1994) pp. 399-406
- [9] J. Dillingham, Motion studies of a vessel with water on deck. *Marine Technology* 18, (1981)
- [10] Y. Kim, A numerical study on sloshing flows coupled with ship motion-the anti-rolling tank problem. *Journal of Ship Research* 46 (2002) pp. 52-62
- [11] O.F. Rognebakke, O.M. Faltinsen, Coupling of sloshing and ship motions. *Jour Ship Research* 47 (2003), pp. 208-221.

# Characterization of Low Cost UV-Lithography Result for Educational Purpose

**Yudan Whulanza, Jos Istiyanto, Sugeng Supriadi**

*Faculty of Engineering*

*University of Indonesia, Depok 16424*

*Tel : (021) 7270011 ext 51. Fax : (021) 7270077*

*\*E-mail : yudan@eng.ui.ac.id*

## ABSTRACT

A common UV lithography technology uses a series of instruments which are spin-coater, hot plate and UV curing system. This had restrained the application of UV lithography technology in a laboratory with limited resource. The purpose of this work is focused on how to produce and characterize microstructures with our home-made instruments. The thickness of around 100 $\mu\text{m}$  was achieved by our system. Furthermore, an optimum condition for UV curing was also characterized in term of exposure dose ( $\text{J}/\text{cm}^2$ ).

### Keywords

*UV lithography, MEMS, photoresist, spin-coating sytem, UV Box.*

## 1. INTRODUCTION

Ultra violet (UV) lithography is the most common microfabrication technique to realize microstructures with high resolution for Micro Electronic Mechanical System (MEMS) applications. UV light is emitted by electric arcs and specialized lights such as mercury lamps and black lights. The UV light is illuminated through a predetermined mask and is then transmitted onto silicon wafer coated with photoresist. Hence, the mask intercepts UV light corresponded with the pattern and detained the light onto photoresist material. During the exposure stage, the photoresist polymer is crosslinked and permanently unremoved at subsequently developing stage. On the other hand, the unexposed area is washed away altogether with developing solution. Thus, the remaining photoresist form a structure corresponded with the mask [1].

The critical knowledge of this process is the characterization of the UV light intensity and the interaction with the polymer photoresist material. A common photoresist material such as SU-8 is reported to have resolution in the range of 15-270  $\mu\text{m}$  width with a thickness up to 275  $\mu\text{m}$  [2]. Furthermore, Hsieh successfully correlated the photoresist thickness and exposure dose. He reported that a dose of 16-20  $\text{J}/\text{cm}^2$  is required to expose the photoresist layer with thickness of 200  $\mu\text{m}$  [3]. Currently, the interest of researchers is realizing high precision result with lowest cost as possible. A conventional lithography process requires a set system of spin coater, uv exposure and mask aligner system. Here, we present a result of our home made spincoater and UV exposure system during laboratory course work of microfabrication.

## 2. EXPERIMENTAL PROCEDURES AND APPARATUS

Photo lithography process in this paper was conducted with following procedure:

### 2.1 Spin Coating

Liquid negative photoresist AL-217 from Aldrich Chemical was soaked onto wafer silicon. The wafer silicon was attached to the spin coating and was then rotated at 500 RPM in the 5 seconds (level 1) and 1000 RPM in the next 10 seconds (level 2). Low cost spincoater machine contains only motor with speed controller. The substrate attach to the spincoater disc by adhesive band. Utilization of adhesive band to substitute the function of vacuum suction that reduces cost significantly.

### 2.2 Pre Baking

Prebaking process is to evaporate photoresist solvent and to solidify resist on the wafer. Wafer coated with photoresist was placed on a hot plate for 15 minutes at 70  $^{\circ}\text{C}$ .

### 2.3 UV Exposure

In order to expose the photoresist, a wooden box with a dimension of 30x20x10  $\text{cm}^3$  is prepared. The purpose of UV exposure is to active crosslinking agent. In this work, five TUV Philips lamps with 11 W were installed inside the box. Moreover, simple mask with predetermined pattern was contacted directly on the top of photoresist film. Dose, D, or energy ( $\text{J}/\text{cm}^2$ ) was adjusted by tuning the exposure time (seconds) at the surface of film. In this work, exposure time was set at 5,10, and 15 minutes.

### 2.4 Development

Development is a process to remove uncrosslinked part on the wafer, while the linked photoresist will remain on the wafer. The developer agent used throughout was from also Aldrich Chemical. The exposed wafer was dipped into beaker glass filled with developer solution for 30-60 seconds.

### 2.5 Post Baking

Post baking is applied to cure the photo resist. After exposure, a post exposure baking was performed on a hot plate for 20 minutes at 70 °C. This step is defined to stabilize photoresist film.

The experimental result was conducted in the scanning electron microscope EVO MA10 Zeiss Germany was used to determine the thickness and line width of resulted pattern.

## 3. RESULTS AND DISCUSSION

### 3.1 Spin Coating Characterization

Spin coater was mainly composed of DC motor controlled with a DC voltage supply. By regulating the voltage supplier, angular speed of motor can be determined thus correlation of angular speed and thickness is known. Figure 1 depicts a cross section of sample and thickness measurement of photoresist film via SEM. Note that the measurement was made after prebaking the wafer. Hence, it can be assumed that the excess solvent is removed. Figure 1 also demonstrates that photoresist thickness is distributed quite evenly with some deviation. Moreover, a more complete result is tabulated in table 1.

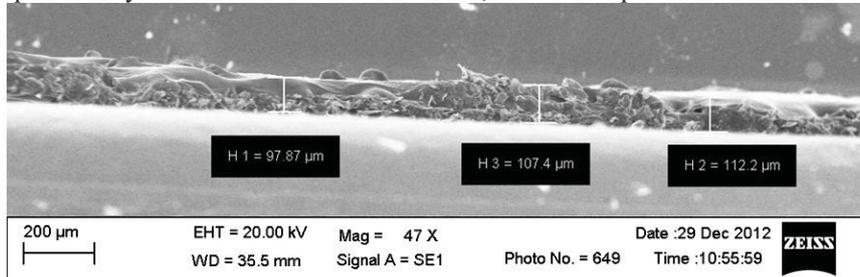


Figure 1: A sample of thickness measurement of photoresist film via SEM

Intuitively, table 1 show that slower angular speed gives thicker photoresist film. The result also demonstrates that at 500 RPM speed gives the highest standard error. It can be inferred that at this low angular speed, a uniform thickness is harder to achieve. On the other hand, thickness measurement at above 1000 RPM confirms that the standard error is lower than 7%.

Table 1: Result of thickness measurement

No	Speed at level 1 [RPM]	Speed at level 2 [RPM]	Voltage Output [V DC]	Thickness [ $\mu\text{m}$ ]
1	500	500	5.5	$140.80 \pm 26.88$
2	500	1000	5.8	$105.67 \pm 7.10$
3	500	1500	6.5	$64.45 \pm 2.39$

### 3.2 UV Exposure Characterization

The exposure experiments were performed with 5 parallel TUV lights that assembled inside a wooden box. The intensity of incident UV light was measured as about  $0.2 \text{ W/cm}^2$ . Subsequently, an exposure scenario was conducted to find optimum working condition. The measurement shows that the optimum exposure time is at 10 minutes. During developing time, a weak bonding between photoresist and substrate was observed at 5 minutes exposure time. Additionally, a significant temperature increasing of UV box was also indicated during UV exposure stage at 15 minutes exposure time.

Performance of the process was tested by varying structure dimension. The result shows that the propose photo lithography apparatus is able to produce photoresist structure up to  $100 \mu\text{m}$ . Simple quadratic pattern was tested in this study to observe the result of UV exposure. Figures 2 (a), (b), and (c) illustrate the predetermined mask that designed with various line widths from 100; 150 and  $200 \mu\text{m}$ . Later on, figures 2 (d), (e), and (f) depict the realized pattern after the post bake process under microscope observation. These results shows that the propose photolithography system is able to produce micro-structures.

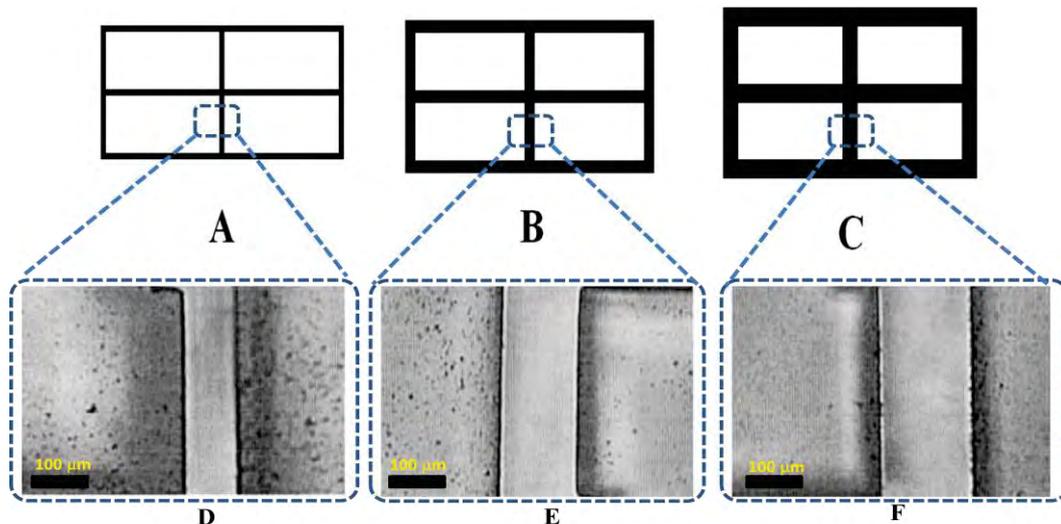


Figure 2.: Predetermined mask with various line width: (a) 100  $\mu\text{m}$  (b) 150  $\mu\text{m}$  and (c) 200  $\mu\text{m}$  Realized line width of photoresist after post baking stage (d) 100  $\mu\text{m}$  (e) 150  $\mu\text{m}$  and (f) 200  $\mu\text{m}$

The SEM photograph of developed photoresist structure is shown in figure 3. A gear structure with about 100  $\mu\text{m}$  thick is released but some cracks can be observed in the bottom of the structure. The cracks are formed in the residual of the exposed photoresist. Until now, the development conditions are still not optimized, therefore, some exposed photoresist are remained on the bottom of structure occasionally.

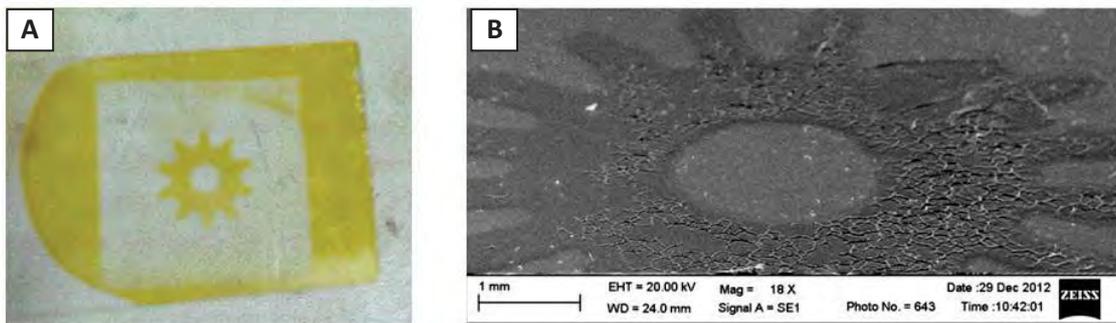


Figure 3: (a) Photograph and (b) SEM graph of product from lithography process for micro gear project

The contact masking method was indicated to damage the resist structure during mask removal stage. An improvement in masking method is obviously needed in further improvement. Additionally, a better light adjustment is also an area of improvement to have more focused and intensity of the UV luminance.

#### 4. CONCLUSION

Our educational lithography process that utilized a handmade spin coating and exposure systems shows a promising result. The system attains the thickness up to  $140.80 \pm 26.88$  and a line width in the range of 100  $\mu\text{m}$ . However, it is indicated a low aspect ratio during the project of realizing micro gear part. A further adjustment is proposed to improve this system which at this moment cost less than \$500.

#### ACKNOWLEDGMENT

Authors would like to thanks to IMHERE program at the Department of Mechanical Engineering Universitas Indonesia. The realizing of apparatus and materials was financed by research and teaching grant of IMHERE project in 2012.

#### REFERENCES

- [1] M.J. Madou, *Fundamentals of Microfabrication: the science of miniaturization*, CRC Press, 2002, pp. 322-325
- [2] J. Zhang, K. L. Tan, H. Q. Gong, "Characterization of the polymerization of SU-8 photoresist and its application in micro-electro-mechanical systems (MEMS)", *Polymer Testing*, vol. 20, pp. 693-701, 2001.
- [3] G. W. Hsieh, Y. S. Hsieh, C. R. Yang, Y. D. Lee, "Novel positive-tone thick photoresist for high aspect ratio microsystem technology", *Microsystem Technologies* vol. 8, pp. 326-329, 2002.

## **Analysis of Microchannels Manufacturing of Acrylic using Low Power CO<sub>2</sub> Laser**

**Ario Sunar Baskoro<sup>1</sup>, Agus Siswanta<sup>1</sup>, KGS. Ismail<sup>1</sup>**

*<sup>1</sup>Mechanical Engineering Department, Faculty of Engineering  
Universitas Indonesia, Depok, Indonesia (16424)  
Tel : (+62 21) 7270032 ext 203. Fax : (+62 21) 7270033  
E-mail : ario@eng.ui.ac.id*

### **ABSTRACT**

Several studies have demonstrated the ability of laser for microchannels fabrication. There are some important aspects that must be considered to use laser for machining process, such as machining method, type of laser and interaction between laser and workpiece. In this research, CO<sub>2</sub> laser machine was used as a tool to fabricate a microchannels on acrylic. Some parameters that can influence the outcome of the cuts were setup, which are focus distance on Z axis, laser power, cutting speed, and the repetition of cutting process (number of pass). Cutting results were width and depth of cut. Observation was made by using digital microscope as measuring tool, and measurement results was analyzed by using Anova method. The results of the analysis shows that the parameter of laser power has a dominant influence on depth of cut, and then parameter of cutting speed and number of pass. By determining width and depth of the cut based on given parameters, it will be easier to take a shape and size on microchannel fabrication.

### **Keywords**

*Acrylic, Anova, CO<sub>2</sub> Laser, number of pass, microchannels*

**This Paper is Published in Advanced Materials Research Journal**

# Remaining Useful Life Prognostic of Rolling Element Bearings on Industrial Machinery Using Adaptive Neuro Fuzzy Inference System

Dyah Puspito Dewi Widowati<sup>a</sup>, Toni Prahasto<sup>b</sup>, Achmad Widodo<sup>c</sup>

*Master of Information System Department  
Diponegoro University, Semarang 50241  
Tel : (024) 8449610. Fax : (024) 8449610*

*<sup>a</sup> dyah.queenaya@gmail.com, <sup>b</sup> toni\_prahasto@yahoo.com,*

*<sup>c</sup>Department of Mechanical Engineering  
Diponegoro University, Semarang 50241  
Tel : (024) 8449610. Fax : (024) 8449610  
awid@undip.ac.id*

## ABSTRACT

Remaining useful life prognostic of rolling element bearings on industrial machinery is important to be applied for determining the condition of its health during the operation. By knowing the remaining useful life, the ultimate failure is inevitable and the maintenance cost also can be optimized. Monitoring vibration conditions that generate time series data is a good method to indicate the beginning of defect that occurs in rolling element bearings. The vibration data are used to extract relevant features. This paper presents an intelligent capability to perform the remaining useful life prognostic which the input data are from the extraction of multiple features. Intelligent capabilities conducted by using adaptive neuro fuzzy inference system (ANFIS). The data input are derived from several features extracted from vibration data. ANFIS output would be worth accurate when showing values less than the root mean square error (RMSE). Result shows that the ANFIS output has the average error which is smaller than RMSE. Trial testing data may indicate that remaining useful life can be performed with good performance.

### Keywords

*Rolling Element Bearings, Remaining Useful Life, Prognostic, ANFIS, Features Extraction.*

## 1. INTRODUCTION

CBM (condition based maintenance) is a maintenance technique used to determine the current condition of the machine. CBM supports the scheduled maintenance reporting which performed mechanical condition continuously, so that the failure of the industrial machinery can be avoided. Another benefit using this CBM technique, is to reduce the maintenance cost. Prognostic is one method that supports CBM to know RUL (remaining useful life) of industrial machinery [1-6].

Prognostic of industrial machinery can be performed on multiple elements of the machine. One of the important element in the industrial rotating machinery is bearing. This paper will discuss about RUL prognostic of rolling element bearings. Rolling element bearings are major elements of bearing that serve to rivet shaft and give the possibility of rotating shafts on it. The existence of rolling element bearings damage that is not known as early as possible can result in total failure, because the machine cannot spin optimally.

Prognostic of rolling element bearings that will be discussed is time series analysis to predict the RUL based on time domain vibration data. RUL means the time remaining before the final failure occurred. Measurement of vibration is an excellent method to determine the condition of rolling element bearings due to vibration can indicate the beginning of a defect on a rotating machinery such as rolling element bearings. This paper focuses on an intelligent system that can do the prognostic for rolling element bearing failure with adaptive neuro fuzzy inference system (ANFIS) method. Vibration data is used for training and testing hybrid in ANFIS after data preprocessing with feature extraction vibration data.

In the next section of this paper will be discussed as follows: Section two will discuss the features extraction from time series vibration data. Section three will discuss how the ANFIS support RUL prognostic. Section four discusses the result and discussion. Furthermore, section 5 is conclusions and suggestions.

## 2. FEATURE EXTRACTION

Feature extraction is an important step to do prognostic. Features used can affect both good and poor prognostic outcome. Good features will produce accurate results [3]. In this paper, the following feature extraction will be used: mean, RMS, skewness, kurtosis and betakurtosis. Some of these features can be written as follows:

$$Mn = \frac{1}{N} \sum_{k=1}^N (x_k - \bar{x})^n \quad (1) [4]$$

$$RMS = \sqrt{\frac{1}{N} \sum_N x^2(t)} \quad (2)$$

$$S = \frac{M_3}{\sigma^3} \quad (3) [4]$$

$$K = \frac{M_4}{\sigma^4} \quad (4) [4]$$

$$BK = \frac{M_4}{(\sigma^2)^2} \quad (5) [5]$$

Eq.1 is mean, eq. 2 RMS, eq.3 skewness, kurtosis and eq.5 eq.4 betakurtosis. N is the number of data points.

## 3. ANFIS TIME SERIES PREDICTION

ANFIS is a combination of fuzzy logic and artificial neural network (ANN). Fuzzy logic has advantages in modeling the qualitative aspects of human knowledge and decision-making process by applying the rule base. ANN has advantages in recognizing patterns, learn and practice to solve a problem without the need for mathematical modeling and works based on historical data that is entered to it and be able to predict upcoming events based on the data. So that ANFIS has the ability both [2]. The basic structure of ANFIS is shown in Figure 1 and ANFIS modeling is shown in figure 2.

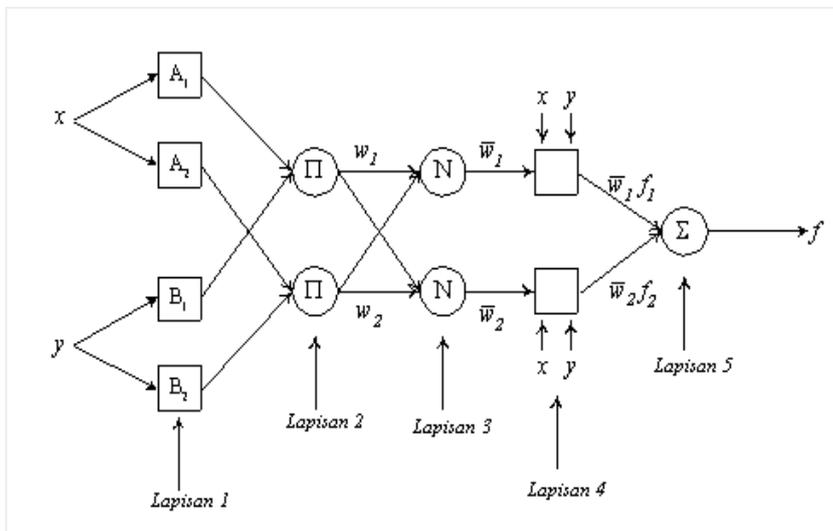


Figure 1: ANFIS structure

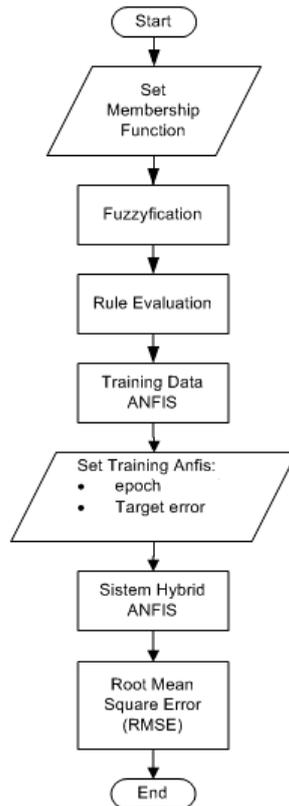


Figure 2. Flowchart ANFIS modeling

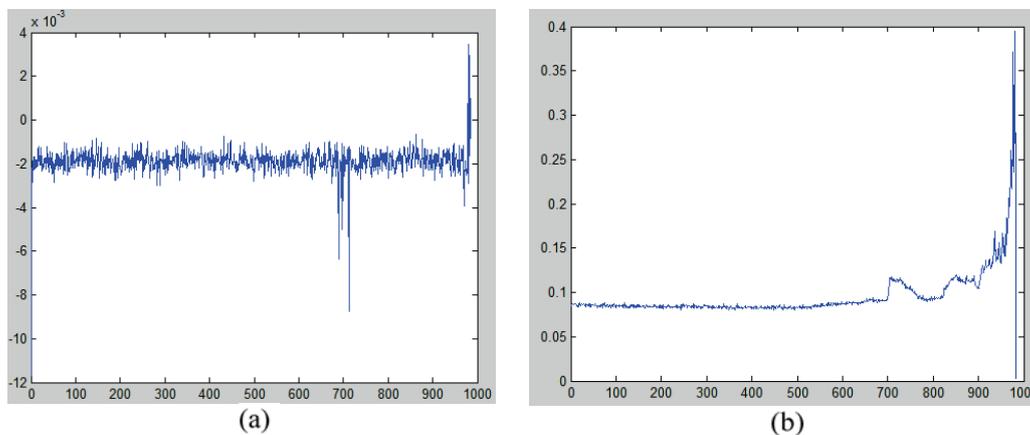
In time series prediction, it should be known the value from a certain time to time (t), to predict the value in the future (t + P). The standard method for this prediction is the mapping of the data sample points (D), sample of each unit in time ( $\Delta$ ),  $(x(t-(D-1)\Delta), \dots, x(t-\Delta), x(t))$ , to predict the future value  $x(t + P)$  [2].

To start the training data needed FIS structure that determine the structure and parameters of FIS beginning to learn. Genfis1 function handles this specification.

```
fismat = genfis1 (trnData);
```

#### 4. RESULT AND DISCUSSION

In this case, the prognostic by using ANFIS intelligent system is done by inserting 5 features extracted vibration data as input. Features used are the mean, rms, skewness, kurtosis and betakurtosis. Figure 3 shows the results of the data extraction vibrations into 5 features.



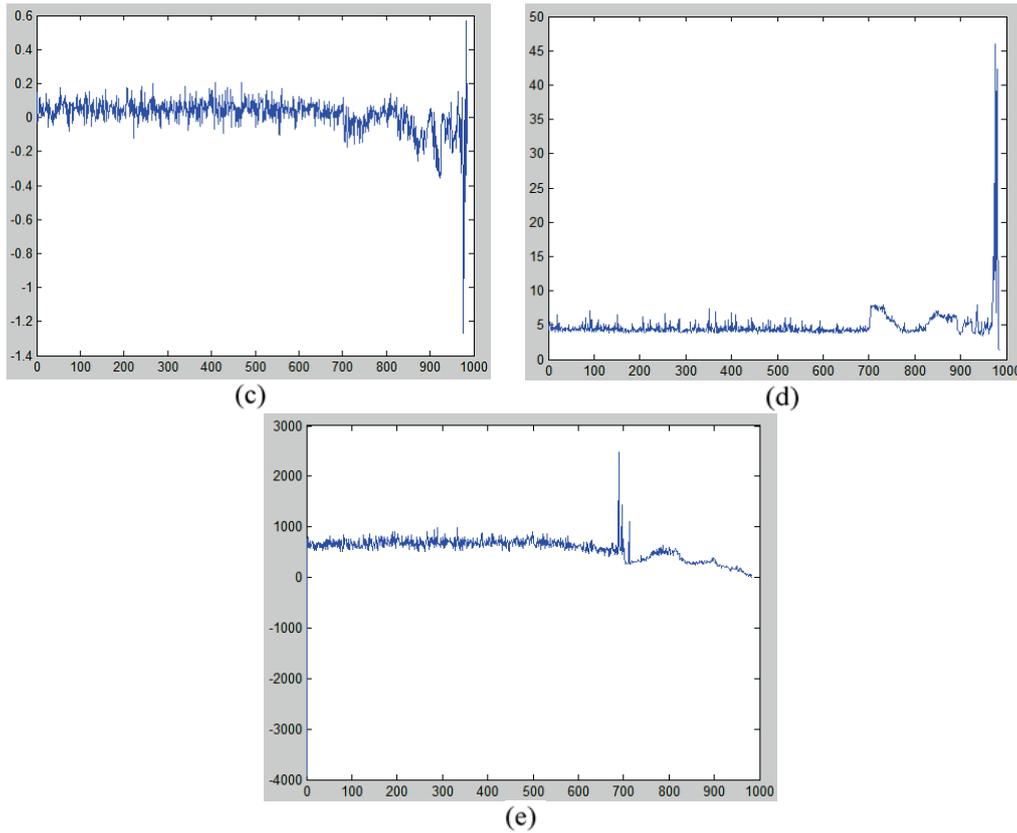
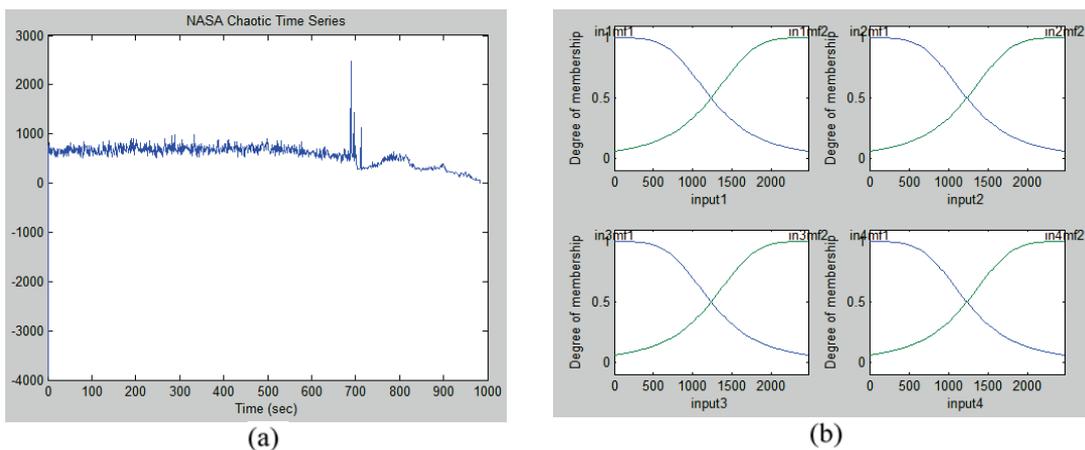


Figure 3. Plotting 5 features extracted from time series vibration data, (a) mean, (b) RMS, (c) skewness, (d) kurtosis, (e) betakurtosis

From the results of plotting to five features in Figure 3, the features of RMS, kurtosis, and betakurtosis has a good overview for doing prognostic. It can be seen that there is a sharp rise uphill to describe the failure.

The number of time series vibration data which used in this research as much as 20480. After the feature extraction, generating matrix of  $984 \times 5$ , which shall mean that each feature has a number of 984 data. From 5 features ANFIS is used as input by taking a number of 800 for training data and 150 for checking data. Figure 4 shows the results of plotting output ANFIS time series prediction.



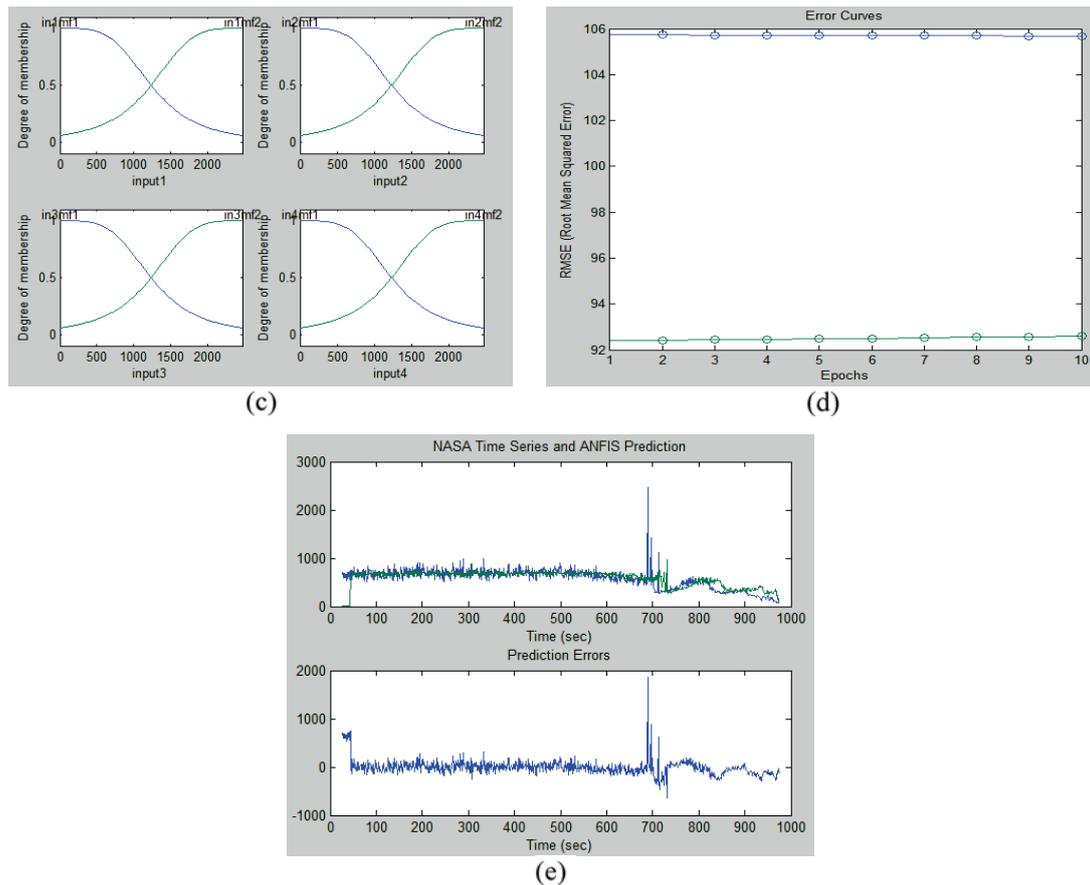


Figure 4. Plotting the results of ANFIS time series prediction, (a) input ANFIS of 5 features, (b) initial membership functions, (c) new membership functions, (d) error signals, (e) FIS output versus the training or checking of data  
 From the results of plotting in Figure 4 (e), ANFIS can show the prediction error curve described by a sharp increase in vibration at  $\pm 700$  seconds.

## 5. CONCLUSION

Prognostic remaining life of rolling bearings function on industrial machines is very important in supporting the CBM. By knowing the RUL, the total failure can be avoided.

ANFIS is a method that is suitable for prognostic. With 5 data input form features extraction (mean, rms, skewness, kurtosis, betakurtosis) of time series vibration data, ANFIS can clearly describe the condition when the failure occurred, so that the remaining life of the function can be determined. This method can run well and as expected as indicated by the value of the error is smaller than RMSE.

This research can be developed online and can also be developed using other feature extraction.

## REFERENCES

- [1] Chen, C. 2012. "Machine remaining useful life prediction: an integrated adaptive neuro-fuzzy and high-order particle filtering approach". *Mechanical systems and signal processing*, 597-607.
- [2] Jang, J, R. 1997. "Neuro Fuzzy and soft computing". Upper Saddle River: Prentice-Hall, INC.
- [3] Medjaher, K. 2012. "Feature Extraction and Evaluation for Health Assessment and Failure Prognostics". *Proceedings of first European Conference of the Prognostics and Health Management Society, PHM-E'12*, hal.00718330. Dresden: Germany.
- [4] Niu, X. 2005. "New statistical moments for the detection of defects in rolling element bearings". *Int J Adv Manuf Technol*, 1268-1274.
- [5] Wang, W, Q. 2001. "Assessment of Gear Damage Monitoring Techniques Using Vibration Measurements". *Mechanical systems and signal processing*, 905-922.
- [6] Widodo, A. 2011. "Model Prognosis untuk Bantalan Gelinding". *Prosiding seminar nasional sains dan teknologi*, hal. D.79. Semarang.

## Effect of Phenolic Resin and Alignment to the Quality of Prototype Composite Railway Brake Blocks

Agus Triono<sup>a</sup>, IGN Wiratmaja Puja<sup>b</sup>, Satryo S. Brodjonegoro<sup>c</sup>, Aditianto R<sup>d</sup>

<sup>a</sup>Mechanical Engineering, Universitas Jember, Indonesia  
E-mail : agustriono1@gmail.com

<sup>b,c,d</sup>Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Indonesia  
E-mail : wirat00@yahoo.com, satrio1@indo.net.id

### ABSTRACT

The use of composites for railway brake provides several benefits among others: five times lighter than cast iron, install easily, lifetime five times longer, lower wear rate, cost to lifetime ratio better than other. Studies about composite brake have been done before. Optimum composition have been found also. But when the composition is applied to the manufacture of the prototype, the results are unsatisfactory. Therefore it needs advanced research about composition and procedure of process. In this studies, effect of phenolic resin and alignment would be researched. Results of that studies shows that addition of phenolic resin improve the quality of the prototype. Crack would be occurred if position of the prototype was not alignment with the axis of dies.

### Keywords

*Phenolic, resin, alignment, prototype*

**This Paper is Published in Advanced Materials Research Journal**

# The Characteristics of the Sport Car Body Aerodynamics

**Khairul Muhajir**

*Department of Mechanical Engineering, Faculty of Industrial Technology, Institute of Science and Technology of AKPRIND  
 Yogyakarta,  
 Jl. Kalisahak 28 (Komplek Balapan), Yogyakarta, Indonesia.  
 Email : khairul.muhajir@ymail.com*

## ABSTRACT

This study aims to discover design and car body structure which stream line and aerodynamics and also have the low drag coefficient in order to give economic fuel consumption with minimum side force coefficient and low drag force coefficient to keep out the skidding.

The experimental methods used in this study with a subsonic wind tunnel by model dimensions as 30 cm x 30 cm x 48 cm with experimental specimen on the scale of 1/33 than the actual dimensions. The simulations of this study used ANSYS fluent 13.0 program to make the vector visualization analysis for the velocity vectors and the form of air flow with the pressure distribution and the streamlines.

The result of this experiment showed that on the normal angle or (0°) give the drag coefficient as 0,311259, the lift forced coefficient as 0,045312 and the number of side forced coefficient as 0.415493 that showed the car body has very aerodynamically. The form of flow pattern at the car body which designed has in streamlines conditions that it was showed on the low turbulence flow presentation. The number of drag coefficient and the number of lift coefficient from the result simulation was not so far different than the experimental study which of 0,318525 for the drag coefficient and the lift coefficient of 0,04206875.

### Keywords

*Characteristics, Sport Car Body, aerodynamics.*

## 1. INTRODUCTION

Vehicle body shape is closely related to the aerodynamic load. Range of aerodynamic loads are grouped into 3 drag force, lift force and side force. Drag force is the force that are inhibiting the direction the vehicle. Lift force is the force that are raising vehicles side force is the force pushing the vehicle laterally nature. Drag force, lift force and side force is affected by the shape of the contours of the vehicle body, vehicle dimensions and speed of the vehicle.

## 2. REFERENCES

Viscosity caused by the molecular friction between the fluid particles. According to Newton's law for flow in a parallel plate is

$$\tau = \mu \frac{du}{dy} \dots\dots\dots(1.)$$

Shear stress  $\tau$  is proportional to the magnitude of the velocity gradient .

$\mu$  is constant factor properties of the fluid is called the dynamic viscosity. In general, this constant factor is temperature dependent.

$$\nu = \frac{\mu}{\rho} \dots\dots\dots(2.)$$

Continuity Equation. The basic principle of this equation is the mass can not be created and can not be destroyed, in which the mass in a system constant can be expressed in the formula:

$$Q = A_1 \cdot v_1 = A_2 \cdot v_2 \dots\dots\dots(3.)$$

Momentum Equation. Newton's second law equation for a system used as a basis to seek a linear equation for a control volume.

$$F = \frac{d(mv)}{dt} \dots\dots\dots(4.)$$

Bernoulli Equation :

$$gz + \frac{v^2}{2} + \frac{P}{\rho} = \text{konstan} \dots\dots\dots(5.)$$

The amount of aerodynamic drag can be formulated:

$$F_D = C_D \cdot \frac{\rho}{2} \cdot A_F \cdot V^2 \dots\dots\dots(6.)$$

The magnitude of the lift force has a formula:

$$F_L = C_L \cdot \frac{\rho}{2} \cdot A_F \cdot V^2 \dots\dots\dots(7.)$$

Great addition to the aerodynamic force is can be formulated:

$$F_S = C_S \cdot \frac{\rho}{2} \cdot A_F \cdot V^2 \dots\dots\dots(8.)$$

### 3. RESEARCH METHODS

Specimens used in size (L x W x T) is 12.6 cm x 5.9 cm x 4 cm, or 1/33 times the actual size.



Fig. 1<sup>st</sup>. Sport Car Body Model.

Experimental method is done using a wind tunnel. Wind tunnel used to study the interaction between objects moving relative to the air against the body. The type of wind tunnel used is kind of low turbulence subsonic wind tunnel.



Fig. 2<sup>nd</sup> . Low turbulence subsonic wind tunnel.

#### 4. DISCUSSION AND THE RESEARCH RESULTS

Experimentally test results demonstrate the value of the coefficient of drag force on a scaled body as shown below.

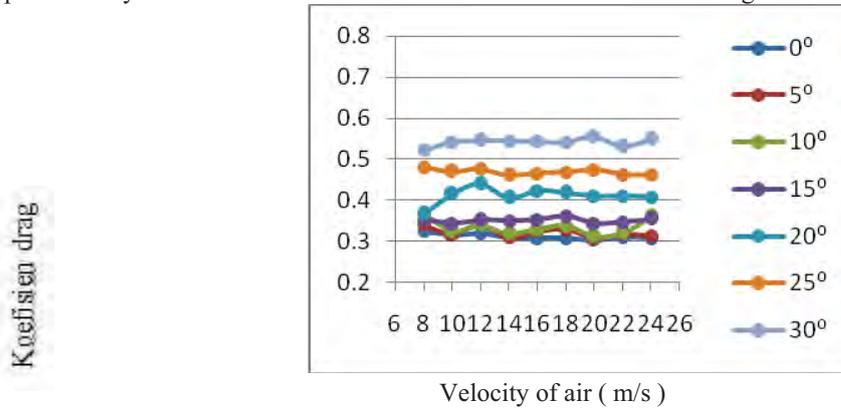


Fig. 3<sup>rd</sup>. Graph drag force coefficient correlation of test results versus of velocity of air.

Curve at an angle of attack  $0^\circ$ ,  $5^\circ$  and  $10^\circ$  drag coefficient indicates the difference is not too big a difference. In contrast to the curve with the angle of attack  $15^\circ$ ,  $20^\circ$ ,  $25^\circ$  and  $30^\circ$  showed a considerable difference in terms of the difference is due to the increase frontal area large enough so that the drag force caused magnification value. curve at angle of attack  $15^\circ$ ,  $25^\circ$  and  $30^\circ$  shows the drag coefficient is quite stable, this is caused airflow stable and so that the coefficient of drag is much influenced by the style of sliding surface, in contrast to the curve with the angle of attack  $0^\circ$ ,  $20^\circ$  and  $30^\circ$  coefficient of drag fluctuations.

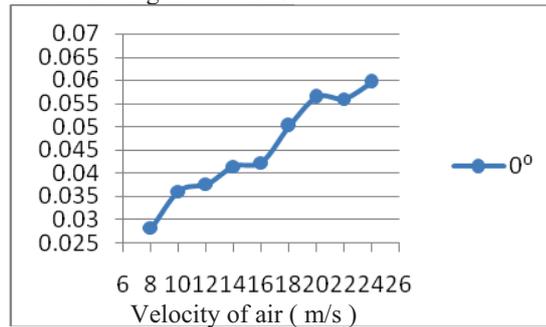


Fig. 4<sup>th</sup>. Graph lift force coefficient correlation of test results versus velocity of air

The graph above shows the curve of the ratio between lift coefficient with air velocity. of the image is visible lift coefficient increases quite sharply at a flow rate of 8 m / s to 20 m / s it is comparable to the value of the coefficient of drag.

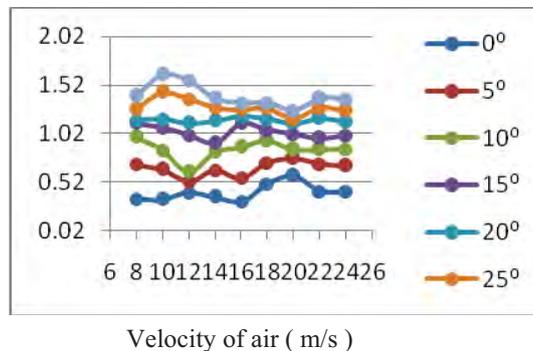


Fig. 5<sup>th</sup> Graph relations side force coefficient versus velocity of air test results.

Side force coefficient at 25o and 30o angle of attack decreased and this is because the speed of stream flow momentum increases. Coefficient of side force on the angle of attack 0°, 5°, 10°, 15° coefficients tend to be unstable. On the curve with the angle of attack 20o side force coefficient tends to be stable. Value Coefficient Drag Force and Lift Force Research with fluent was made to resemble the actual conditions on the highway where the ambient temperature is expected to range from 40° C, while the value of the coefficient of drag force and lift force shown in below. The research with fluent was made to resemble the actual conditions on the highway where the ambient temperature is expected to range from 40 ° C, while the value of the coefficient of drag force and lift forcenya shown in below. From the above table it can be seen that the average value of the coefficient of drag force simulation results in the range of 0.3185. The figure below shows the speed of the air flow on the surface of the body with the air flow velocity parameters at the inlet surface of 69.44 m / s.



Fig. 6<sup>th</sup> Velocity of air flow at the front body interface.

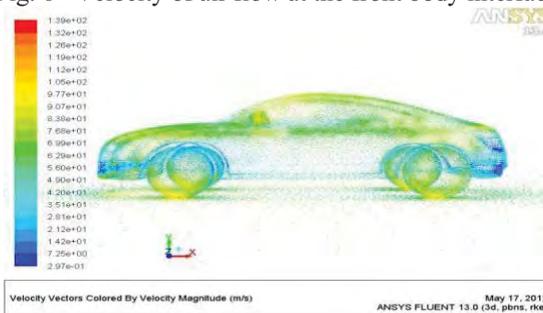


Fig. 7<sup>th</sup> Velocity of air flow at the side body interface.

The top image shows that the greatest pressure on the front surface, and the windshield and rear view mirror car. This affects the value of the coefficient of drag. While the lowest pressure occurs in the bottom of the front body, rear view mirror, roof and rear body upper body.

## 5. CONCLUSIONS

The results scale car body using wind tunnel and simulation using fluent ANSYS 13.0 can be concluded as follows:

1. Experimental results on a normal angle (0°) obtained drag coefficient of 0.311259, and 0.045312 for coefficient of lift force and side force coefficient value of 0.415493. which means the body of the car is very aerodynamic.
2. Coefficient of drag force and side force will increase with increasing angle of attack this is due to the increase in the frontal area of the angle of attack will increase.
3. Based on the analysis carried out by the program ANSYS fluent indicate a change in the value of the pressure at the surface of the body, caused by changes in fluid flow velocity.
4. Shape the flow pattern on the body that planned already streamlined, it can be seen in the percentage of very small flow turbulence.
5. Drag and Lift coefficient value simulation results do not very much with the results of experimental testing. ie 0.318525 to coefficient of drag and coefficient of lift at 0.04206875.

## ACKNOWLEDGMENT

This research was funded by The Institute of Science and Technology of AKPRIND of Yogyakarta Research Competition.

## REFERENCES

- [1] Alexandrou, Andreas., 2001, *Principles of fluid mechanics*, Prentice hall, Inc., New Jersey.
- [2] Anderson, John D., Jr., 1986, *Fundamental of Aerodynamic*, McGraw-Hill Book Co., New York.
- [3] Anonym. 2005. "Principles of helicopter Flight", at: <http://www.cavalrypilot.com/fm1-514/Ch1.htm>,
- [4] Anonym. 2008. "Open and closed wind tunnel", in: <http://www.grc.nasa.gov/WWW/k-12/airplane/tunoret.html>,
- [5] Fox, Robert W. And McDonald, Alan T., 2003, *Introduction to Fluid Mechanics*, 6th Edition, John Wiley & Sons, Inc., New York.
- [6] Gerhart, Philip M., Gross, Richard J., & Hochstein, John I., 1992, *Fundamentals of fluid mechanics*, 2nd ed, Addison- Wesley Publishing Company., New York.
- [7] Hucho, Wolf-Heinrich., 1998, *Aerodynamic of road vehicles*, 4th ed, SAE international, London.
- [8] Jazar, Reza N., 2008, *Vehicle Dynamic theori and application*, Springer, New York.
- [9] Munson, Bruce R., Young, Donald F. & Okiishi, Theodore H., 2003, *Fundamental of Fluid Mechanics*, 4<sup>th</sup> Edition, John Wiley & Sons, Inc., New York.
- [10] Streeter, Victor L, & Wyle E.B., 1992, *Fluid Mechanics*, 8<sup>th</sup> Edition, Mc. Graw-Hill Book Co. New York.

# Experimental Study of Total Hull Resistance of Asymmetrical Pentamaran Model with Separation and Staggered Hull Variation of Side Hull I

Yanuar<sup>1</sup>, Gunawan<sup>1</sup>, Kurniawan Teguh Waskito<sup>2</sup>

<sup>a</sup>Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel : (021) 7270011 ext 51. Fax : (021) 7270077  
E-mail : yanuar@eng.ui.ac.id, gunawan\_kapal@eng.ui.ac.id

<sup>b</sup>Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel : (021) 7270011 ext 51. Fax : (021) 7270077  
E-mail : kurniawan.teguh01@gmail.com

## ABSTRACT

Application of multi-hull ships as marine transportation began to grow rapidly at the present. Advantages of pentamaran due to lower draught with the same displacement of monohull. This study aimed to determine the effect of variations in separation and staggered of side hull I to the total resistances to get the configuration with the lowest resistance interference. Configuration varied by adjusting the separation and staggered of side hull I. Method of towing tank experiments are used with variations of Froude number from 0,10 to 0,70. Conclusion, the highest drag reduction of Fr less than 0,40 is II.a configuration (S/L = 3/16, R/L = 1/20) with a maximum percentage of 46,14%, the Fr around 0,50 is III.B configuration (S/L = 2/16, R/L = 3/20) with a maximum percentage of 43,94%, but, while the Fr higher than 0,55 back to II.a configuration. The influence of the configuration to the resistances depends on the value of Fr, the influence of hull separation indicates the closer hull with the other gives a high interference resistance, while the influence of staggered hull indicates the position of side hull I in optimal separation will give the lowest resistance in mid staggered positions.

## Keywords

*Pentamaran, resistance, side hull I, hull separation, staggered hull.*

## 1. INTRODUCTION

Pentamaran with five hulls is the development of multihull ships catamaran, trimaran and quadrimaran. Determination of the number of hull in multihull ships will give different characteristics. Pentamaran recently started to be developed in Europe as freight transport (High Speed Cargo Ship), passenger transport (High Speed Ferry), troops transport (Sea lift), patrol boats (Combatant), and other high speed craft.

Development of the research in multihull associated with one of the efforts to reduce ship resistances by modifying the ship hull form which is an example of passive control resistances, which passive control can provide relatively high reduction percentage of resistances. Characteristics of pentamaran ship that can have much smaller resistances at high speed compared to monohull vessel will give efficiency in fuel consumption, time and operational costs in the voyage.

Researches on total hull resistance in pentamaran ship model is still a significant challenge for researchers in determining the precise characteristics of the interactions that occurred in each hull, so it is still being developed better configuration to get the lowest resistance interference.

This study aimed to determine the effect of variations in the distance of side hull I longitudinally (staggered hull) and transversely (hull separation) to the total resistance asymmetrical pentamaran models for wave and viscous resistance interference that produces the lowest resistances.

## 2. MULTIHULL AND PENTAMARAN CONCEPT

The effect of hydrodynamic hull form type, side-hull configurations, position, displacement, transverse and longitudinal location can be varied to obtain the lowest resistances and better seakeeping characteristics. Displacement of side-hull influences on frictional resistance and stability, position can determine the effects of the interaction between side-hull and main hull, stability, and rolling parameters. There are three types design of multi-hull ship, symmetric, asymmetric inboard and asymmetric outboard as shown in figure 1. Symmetric side-hull much influences on the magnitude of the interference effect between main hull and side-hull. Asymmetric inboard configuration is likely to show the greatest variation in the magnitude of the interaction and produce interference effects are very high or very low on some speed and position of side-hull. Symmetric side-hull configuration also showed variation but not as extreme asymmetric inboard configuration. Eventually, for asymmetric

outboard configuration produces the smallest interference variations [Oller et al, 2003].

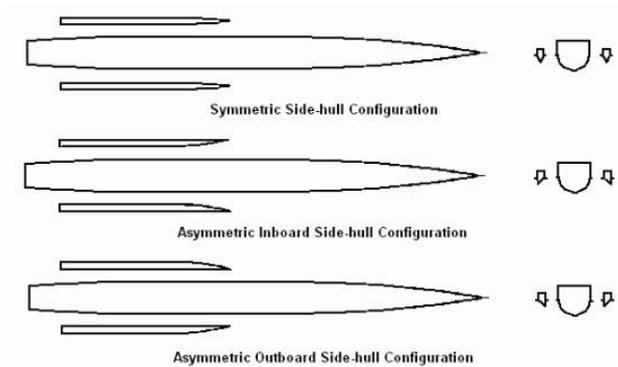


Figure 1: Hull form type of trimaran [Acker et al, 1997]

The type of body plan hull form is divided into :

- Round Bilge
- Hard chine

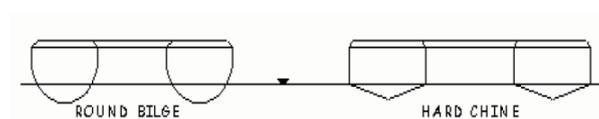


Figure 2: Hull form type of catamaran body plan

Type of hard chine hull form is simple and straightforward in construction work. This hull type has a larger static wetted surface area so that it improves frictional resistance at low speeds. While at high speed, the wetted surface area will lose due to the presence of dynamic lift. Round bilge hull types are suitable for more loads and low speed. This hull type has a relatively small movement, and not prone to the waves (slamming) so as to provide comfort to the extreme wave conditions. Usually this type of hull fitted with sprayer on the bow to reduce the effects of water spray.

Pentamaran is a type of multihull ships, slender hull (high ratio L/B) with one main hull and four side hulls [Gee, 2005]. Main hull is optimized to get the minimum resistances for deadweight and certain speeds. Side-hull configuration is designed and arranged to deliver the expected stability characteristics. The use of four side-hulls to replace the two side-hulls of the trimaran provides better stability at minimum drag and rolling resistance, Pentamaran provide the possibility of power constraints and most small and seakeeping characteristic is better.

Pentamaran design advantage is [Gee, 1999]:

- a) The need for low power
- b) Loss of speed due to waves is lower
- c) Very good of seakeeping characteristics

### 3. EXPERIMENTAL SET-UP

Referring to R.V. Triton trimaran [Research Vessel Triton, 2001] which uses asymmetric outboard configuration of side-hull, then on the model in this study used asymmetric outboard configuration pentamaran model for side hull I and side hull II, while the body plan hull form is designed for ships with more load, so, the selected types Bilge round. Displacement models of multihull for towing tank test are same as monohull displacement. Pentamaran ship models are designed as shown in Figure 3 - 6. Model specifications as shown in Table 1.

Table 1: Model hull specification

Main Measure	Main hull	Side hull I	Side hull II	Mono hull
L <sub>OA</sub>	2,00 m	1,00 m	0,75 m	2,00 m
B <sub>I</sub>	0,20 m	0,10 m	0,07 m	0,54 m
T	0,07 m	0,07 m	0,06 m	0,07
H	0,15 m	0,15 m	0,14 m	0,15
C <sub>B</sub>	0,57	0,59	0,58	0,58
C <sub>D</sub>	0,58	0,61	0,60	0,61
WSA	0,39 m <sup>2</sup>	0,18 m <sup>2</sup>	0,11 m <sup>2</sup>	0,83 m <sup>2</sup>
Δ	12,50 kg	3,25 kg	2,75 kg	24,5 kg

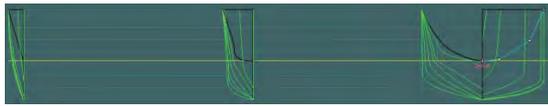


Figure 3: Round bilge type body plan of pentamaran model

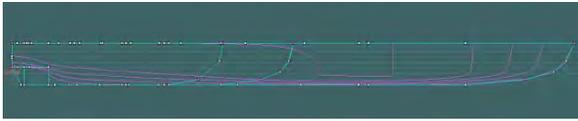


Figure 4: Sheer plan of pentamaran model

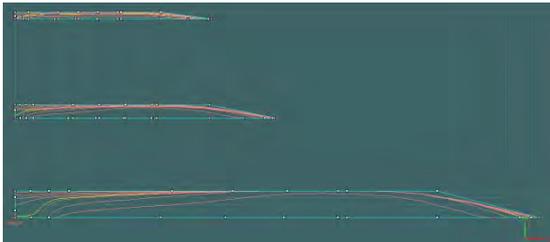


Figure 5: Half breadth plan of pentamaran model

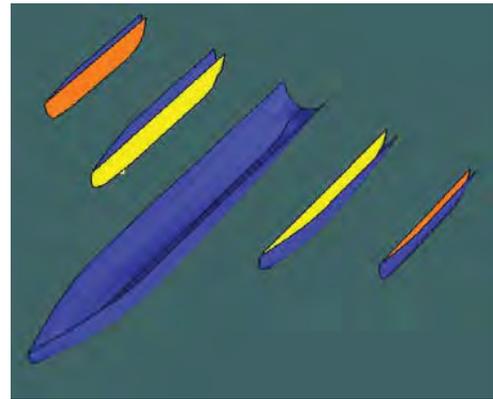


Figure 6: Isometric view of pentamaran model

Towing tank test is performed in the towing tank with a size of 20 m x 8 m x 2 m, Using an electric motor which equipped with voltage regulator to control the velocity, load cell transducer is mounted on the model and associated with the acquisition data to read the value of the model resistance, as shown in figures 7 and 8.

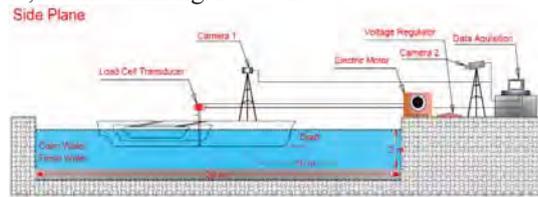


Figure 7: Side plane view of towing tank test set-up

Configuration of pentamaran model is arranged by transverse distance variation (hull separation, S/L) and longitudinal distance variation (staggered hull, R/L). S is transverse separation distance between side hull I to main hull, R is midship longitudinal separation distance between side hull I to main hull, and L is length over all of the model as shown in figure 9 and 10 below.

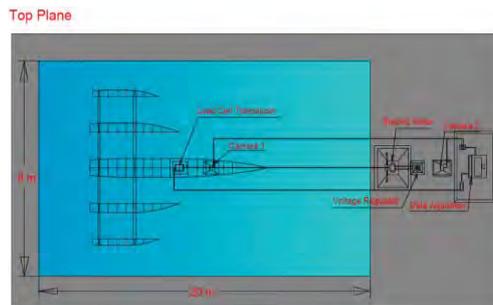


Figure 8: Top plane view of towing tank test set-up

#### 4. TEST ANALYSIS

International Towing Tank Conference (ITTC) classifies ship resistance in calm water into two components, these are viscous resistance which related with Reynolds number and residual resistance, those are wave resistance which related with Froude number, component of air resistance as residual resistance can be ignored because in the model testing, superstructure is not used, only the characteristic of the hull resistance is tested, so the coefficient of total resistances can be defined as :

$$R_T = R_V + R_W \tag{1}$$

$$C_T = C_V + C_W \tag{2}$$

$$C_T = (1 + \phi k) \sigma C_F + \tau C_W \tag{3}$$

$$C_T = (1 + \beta k)C_F + \tau C_w \quad (4)$$

Which  $R_T$  is total resistance,  $R_V$  is viscous resistance,  $R_w$  is wave resistance,  $C_T$  is the total resistance's coefficient,  $C_V$  is the viscous resistance's coefficient,  $C_W$  is the coefficient of residual wave resistance,  $C_F$  is the frictional resistance's coefficient,  $k$  is the hull shape factor,  $\phi$  is the factor of pressure change in the hull,  $\sigma$  is the increasing factor of velocity-stream around the hull,  $\tau$  is the interference factor of wave resistance. For practical purpose,  $\phi$  and  $\sigma$  can be combined [Insel and Molland, 1991 and 1992] into viscous resistance's interference, that is  $\beta$  factor, which  $(1+\phi k)\sigma = (1+\beta k)$ . From the towing tank test results, total resistance's coefficient  $C_T$  can be calculated with formula below :

$$C_T = \frac{R_T}{0.5\rho S V^2} \quad (5)$$

which  $\rho$  is the density of water and  $S$  is the wetted surface area,  $V$  is the velocity of the ship. Total resistance can be defined as :

$$R_T = \frac{1}{2} C_T \rho V^2 S \quad (6)$$

Froude number and Reynolds number defined it as :

$$Fr = \frac{V}{\sqrt{gL}} \quad (7)$$

$$Re = \frac{VL}{\nu} \quad (8)$$

where  $L$  is the length of the ship,  $g$  is the acceleration of gravity and  $\nu$  is water kinematic viscosity. The drag reduction of pentamaran model to model *monohull* stated as :

$$DR(\%) = \left| \frac{C_T - C_{TO}}{C_{TO}} \right| \times 100\% \quad (9)$$

which  $DR$  is the percentage of Drag reduction,  $C_T$  is the coefficient of pentamaran model's total resistance.  $C_{TO}$  is the coefficient of monohull model's total resistance (displasemen monohul equal to displasemen pentamaran).

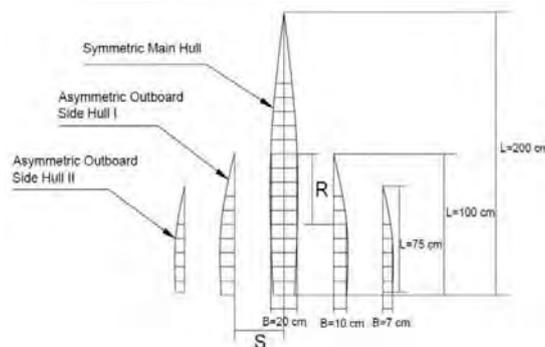


Figure 9: Configuration of asymmetrical pentamaran model

## 5. RESULTS AND DISCUSSION

### 5.1 Influence of Hull Separation (S/L) of side hull I

#### 5.1.1 Hull Separation (S/L) in The Configuration I

From the graph that shows relation between  $Fr$  and  $C_T$ , as shown in figure 12, generally, I.c configuration has the highest total resistance's coefficient value compared to the other configuration, while I.a configuration is the lowest.

#### 5.1.2 Hull Separation (S/L) in The Configuration II

From the graph below, shows relation between  $Fr$  and  $C_T$  as shown in figure 14, II.c configuration generally has the highest total resistance's coefficient value compared to the other configuration, while II.a configuration is the lowest.

#### 5.1.3 Hull Separation (S/L) in The Configuration III

From the graph below, shows relation between  $Fr$  and  $C_T$  as shown in figure 16, generally, III.a configuration has the highest total resistance's coefficient value, while III.b configuration has the lowest resistance coefficient.

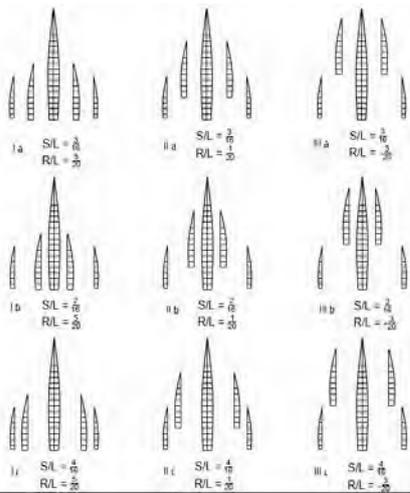


Figure 10: Separation and staggered hull configuration of side hull I

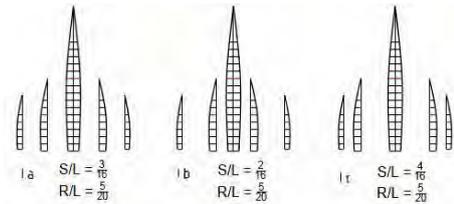


Figure 11: Hull separation (S/L) in the configuration I

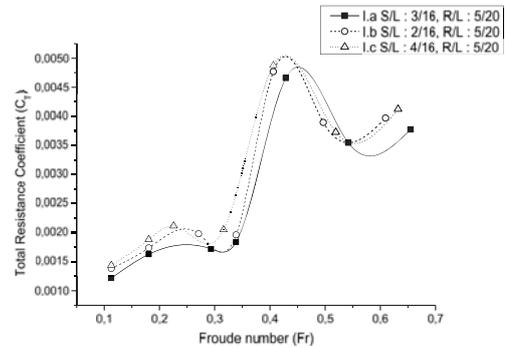


Figure 12: Comparison of Froude number (Fr) with total resistance's coefficient ( $C_T$ ) of hull separation (S/L) in the configuration I

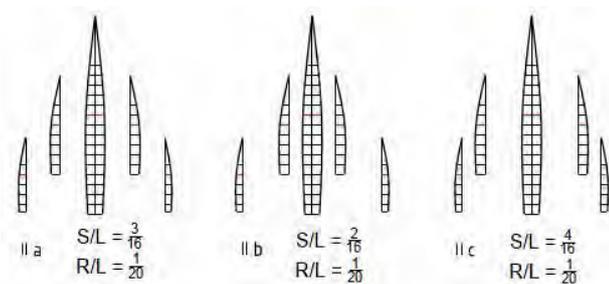


Figure 13: Hull separation (S/L) in the configuration II

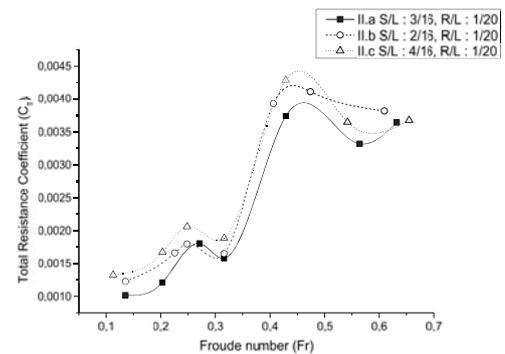


Figure 14: Comparison of Froude number (Fr) with total resistance's coefficient ( $C_T$ ) of hull separation (S/L) in the configuration II

## 5.2 Influence of Staggered Hull (R/L) of side hull I

### 5.2.1 Staggered Hull (R/L) in The Configuration (a)

From the graph below, shows relation between Fr and  $C_T$  as shown in figure 18, generally, III.a configuration has the highest total resistance's coefficient value, while II.a configuration is the lowest.

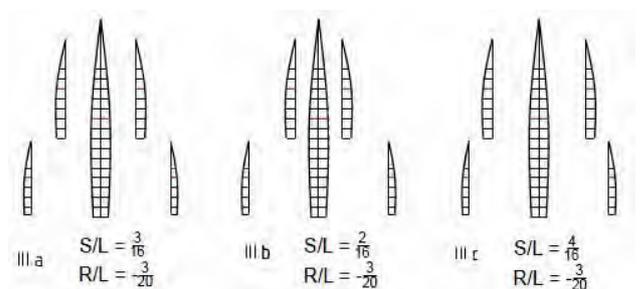


Figure 15: Hull separation (S/L) in the configuration III

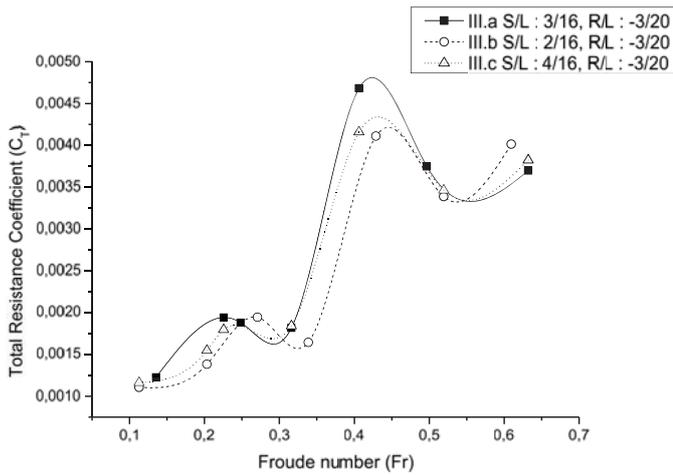


Figure 16: Comparison of Froude number (Fr) with total resistance's coefficient ( $C_T$ ) of hull separation (S/L) in the configuration III

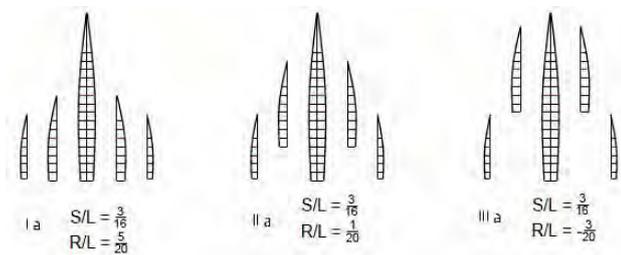


Figure 17: Staggered hull (R/L) in the configuration (a)

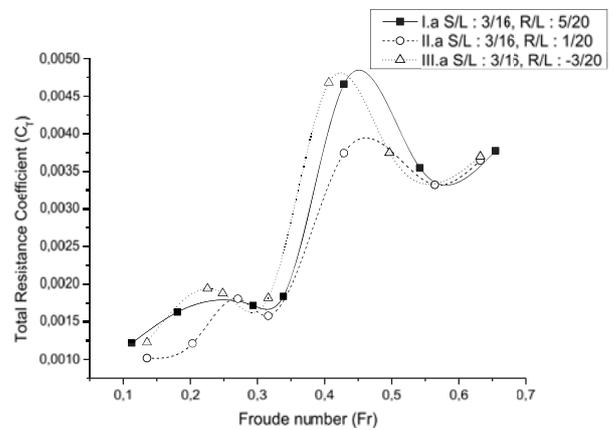


Figure 18: Comparison of Froude number (Fr) with total resistance's coefficient ( $C_T$ ) of Staggered hull (R/L) in the configuration (a)

### 5.2.2 Staggered Hull (R/L) in The Configuration (b)

From the graph below, shows relation between Fr and  $C_T$  as shown in figure 20, the characteristic of the resistance in each configurations are more varied to Froude number. When the Froude number are lower than 0,40, I.b configuration is tend to has highest resistance but when the Froude number are more than 0,40, II.b configuration has the highest resistance. The lowest resistance is belong to III.b configuration.

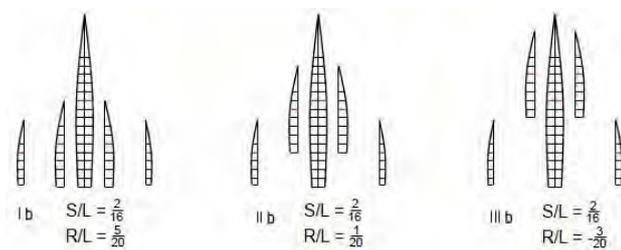


Figure 19: Staggered hull (R/L) in the configuration (b)

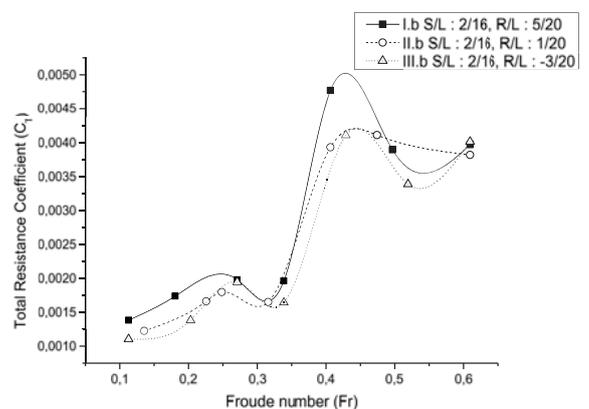


Figure 20: Comparison of Froude number (Fr) with total resistance's coefficient ( $C_T$ ) of staggered hull (R/L) in the configuration (b)

### 5.2.3 Staggered Hull (R/L) in The Configuration (c)

From the graph below, shows relation between Fr and  $C_T$  as shown in figure 22, generally in all range of Froude number I.c

configuration are tend to has highest resistance, while the lowest resistance occurred in III.c configuration.

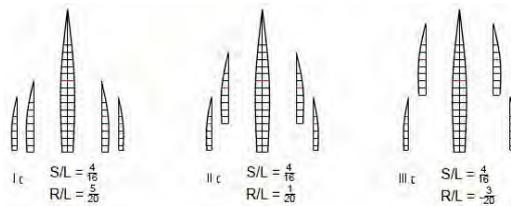


Figure 21: Staggered hull (R/L) in the configuration (c)

### 5.3 Comparison of Multihull Configuration and Monohull with Total Hull Resistance

In figure 23 and 24 show the relation between Froude number and total resistance's coefficient in each various configuration to monohull. In a low Froude number, monohull has relatively lower resistance compared to multihull pentamaran's model, it's because viscous resistance greatly affected the ship model, when the ship model's in the low velocity multihull's model has larger wetted surface area than monohull. When the velocity and Froude number increase, model's resistance of monohull rise and become higher than multihull, because the component of wave resistance is more dominant in the high velocity. In the pentamaran's multihull model which the L/B's ratio is larger (Slender Body) than monohull, will give advantage with the drag reduction of the wave's occurred, because of the L/B's ratio of the ship, wave pressure factor to the ship hull decrease and also can reduce the occurrence of transversal and divergent wave which affected by hull's shape factor. It's also clear that in the multihull's model graph appeared Hump and Hollow phenomenon, that's occurred because wave interference factor, which Hump, because of constructive interferences, so the wave resistance rise drastically, Hollow, because of destructive interferences so the wave resistance will fall drastically. In the graph of  $Fr$  vs  $C_T$ , for the transverse variations I (a,b, and c) Hump occurred dominantly around Froude number 0,40, while in the longitudinal variations II dan III (a,b, and c), Hollow, are tend to occurred dominantly in the range of Froude number between 0,30 dan 0,55. That's occurred because in the configuration I, which all of the hulls are longitudinally aligned, in the back side, there's occurred high wave resistance interferences compared when the position of side hull I more ahead. While in the medium velocities, configurations II and III, destructive interferences are tend to occurred.

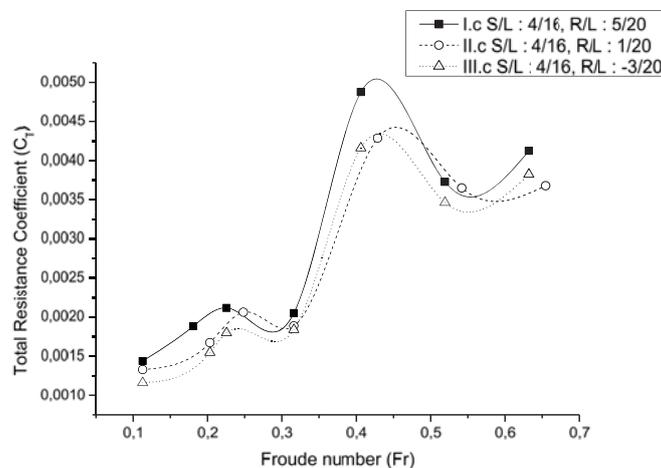


Figure 22: Comparison of Froude number ( $Fr$ ) with total resistance's coefficient ( $C_T$ ) of staggered hull (R/L) in the configuration (c)

In figure 24 shows the relation between configuration and total resistance's coefficient which shows the characteristic of each resistance in velocity levels. in the range of Froude number up to 0,35, the value of the resistance is still quite low due to hollow's occurring . then when the range of Froude number are between 0,35-0,45, a very impressive increasing of resistance-value's occurred. And it's caused by hump phenomenon, and then when the Froude number is more than 0,45, resistance's values of multihull are tend to fall because the hollow phenomenon is occurred again, but that doesn't happen in monohull, where resistance's values are still rising. The II.a configuration looks like the configuration which has the lowest resistance's values in almost all of Froude number range.

### 5.4 Drag reduction

The drag reduction in each configurations can be compared with resistances in monohull. Figure 25 shows percentage of drag reduction in each pentamaran configurations to monohull in the range of Froude number. In the low Froude number around

0,20, drag reduction are negative, these mean that in the low velocity, pentamaran's model has larger total resistance than monohull. But in the medium or high velocity, the percentage of drag reduction is tend to rise, caused by the domination of wave resistance factor so the pentamaran multihull-ship's model has lower total resistance. From that graph, we can conclude that the highest drag reduction in the low velocities (Froude number are less than 0,40) is II.a configuration with maximum percentage is 46,14 %, while in the Froude number 0,50 is III.b configuration with maximum percentage is 43,94 %, and in the Froude number more than 0,55 is II.a configuration with maximum percentage is 37,18 %. For the lowest drag reduction in the low velocities (Froude number are less than 0,40) is I.c configuration with minimum percentage is -34,26 %, while in the high velocities (Froude number are more than 0,40) is I.c configuration with minimum percentage is -12,08 %.

Those drag reduction's values are the approach to estimate drag reduction in pentamaran multihull's model. As shown in the graph that the percentages always change to Froude number, as shown in figure 25. in II.a configuration, the highest drag reduction is not always happened, in the Froude number around 0,5, III.b configuration creates higher drag reduction than the other configurations, and then when the Froude number are more than 0,55 II.a configuration creates highest drag reduction again. III.b configuration with position of side hull I is leading longitudinally and closer to main hull transversely with the distance from side hull I to side hull II is also the farthest. This configuration can create high drag reduction, because in the high velocities, waves interactions in one hull to another are so small.

## 6. CONCLUSION

- 1) Effect of variation indicates transverse configuration with  $S/L = 3/16$  have the lowest resistances on each configuration I and II, this is because the ratio of the distance side hull I by other hull was not too close so that the interaction of the incoming and outgoing waves are also more lower.
- 2) Effect of longitudinal variation more varied when compared to the transverse variation, therefore the analysis is restricted to the longitudinal variation of the transverse variation of (a) ( $S/L = 3/16$ ). In the longitudinal variation I.a, II.a, and III.a lowest resistance are II.a configuration ( $S/L = 3/16, R/L = 1/20$ ) with the position of side hull I was in the middle longitudinally. This happens may due to the configuration of the transverse and longitudinal wave interference occurred destructively when waves flow through the hull, resulting in the phenomenon that occurs Hump and Hollow is also relatively low compared to other configurations.
- 3) In the low Froude number, monohull model has relatively lower resistance than multihull pentamaran model, it happens because viscous resistance is greatly affected the ship model when its velocity is low, cause multihull model has grater wetted surface areas than monohull. In the high Froude number the resistance of monohull model is higher than multihull model because the component of wave resistance is highly dominated in the high velocity.
- 4) In the graph  $Fr$  vs  $C_T$  for longitudinal variations, I (a,b,and c), Hump are occurred dominantly in the range of Froude number around 0,40, while in the transverse variations, II and III (a,b, and c), Hollow are tend to occurred dominantly in the range of Froude number between 0,30 to 0,55. These are because configuration I, which all of the hull are aligned longitudinally in the back side, higher wave resistance interferences will be occurred than when position of the side hull I are relatively ahead.
- 5) We can conclude that the highest drag reduction in the low velocities (Froude number are less than 0,40) is II.a configuration with maximum percentage is 46,14 %, while in the Froude's value 0,50 is III.b configuration with maximum percentage is 43,94 %, and in the Froude number more than 0,55 is II.a configuration with maximum percentage is 37,18 %. For the lowest drag reduction in the low velocities (Froude number are less than 0,40) is I.c configuration with minimum percentage is -34,26 %, while in the high velocities (Froude number are more than 0,40) is I.c configuration with minimum percentage is -12,08 %.
- 6) The percentage of drag reduction the approach to estimate drag reduction in pentamaran multihull modell. In determining the optimal configuration to get the lowest total resistance on the pentamaran's hull spacing variation, is affected by its Froude number, where in the high or low velocities, waves resistance interference and viscous are varies.

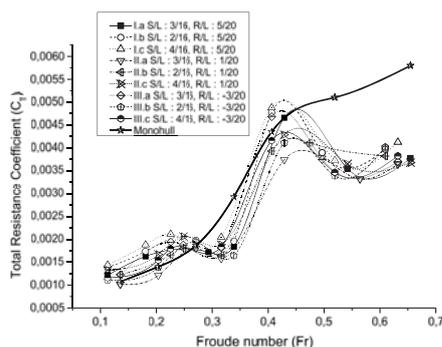


Figure 23: Comparison of Froude number ( $Fr$ ) with total resistance coefficient ( $C_T$ )

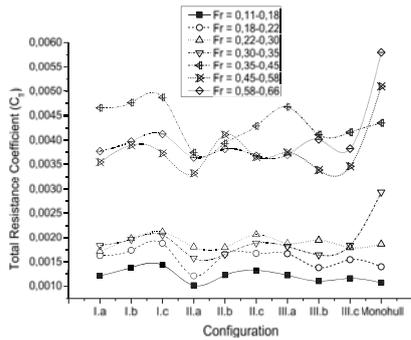


Figure 24: Comparison of configuration with total resistance's coefficient ( $C_T$ )

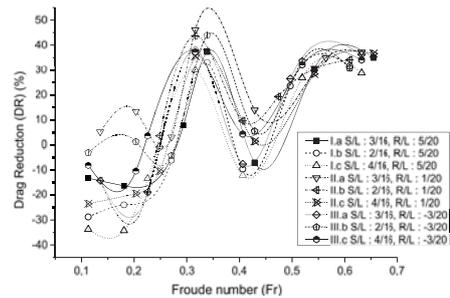


Figure 25: Comparison of Froude number (Fr) with drag reduction percentage (DR)

## 7. REFERENCES

- [1] Couser, P R, Molland, A, F, Armstrong N and Utama, I K A P. 1997. *Calm Water Powering Prediction for High Speed Catamarans*, Proc. of FAST 1997, in press, Sydney, 21-23 July.
- [2] Doctors, L.J. and Scare, R.J. (2003). *Optimization of trimaran sidehull for Minimum resistance*, *Proceeding of Seventh International Conference on Fast Sea transportation*, in press. FAST'2003, Ischia-Italy, October 2003.
- [3] Dudson, E. and Gee, N. 2001. "Optimisation of The Sea Keeping and Performance of a 40 knot Pentamaran Container Vessel," *Proc. 6<sup>th</sup> Int. Conf. on Fast Sea Transportation (FAST)*, in press. Southampton, Vol. II, pp. 71-80, The Royal Institute of Naval Architects, London.
- [4] Elcin, Zafer. 2003. *Wave Making Resistance Characteristics of Trimaran Hulls*. Naval Postgraduate School. Monterey, California.
- [5] Harvald, S A. 1983. *Resistance and Propulsion of Ships*, John Wiley and Sons, Toronto, Canada.
- [6] Hogben, N and Standing, R (1975), *Wave Pattern Resistance From Routine Model Tests*, Trans. RINA, Vol. 117.
- [7] Insel, M and Molland, A F (1991). *An Investigation into the Resistance Components of High Speed Displacement Catamarans*. Meeting of the Royal Institution of Naval architects.
- [8] Insel, M and Molland, A F (1992). *An Investigation into the Resistance Components of High Speed Displacement Catamarans*, in press. Trans RINA Vol. 134.
- [9] ITTC (2002), *Recommended Procedure and Guidelines, Testing and Extrapolation Methodisn Resistance Towing tank Tests*, ITTC 7,5-02-02-02.
- [10] ITTC (2002), *Recommended Procedure and Guidelines, Model Manufacture: Ship Models*, ITTC 7,5-01-01-01.
- [11] Jamaluddin, A., Utama, I.K.A.P., Murdijanto (2011), *Evaluation of Molland's Viscous Form Factor of Katamaran Configuration using Experimental Tank Test Results*, The 12<sup>th</sup> International Conference on QIR (Quality in Research), ISSN 114-1284, Bali, Indonesia, July 4 - 7, 2011.
- [12] Kohlmoos, A., Dudson, E. And Rambech, H.J. (2001). "Prediction of Global Wave-Induced Response for the ADX Express High-Speed Pentamaran," *Proc. 6<sup>th</sup> Int. Conf. on Fast Sea Transportation (FAST)*, in press. Southampton, Vol. II, pp. 71-80, The Royal Institute of Naval Architects, London.
- [13] Maynard T, Sahoo P K, Mikkelsen J and McGreer D (2008); *Numerical and Experimental Study of Wave Resistance for Trimaran Hull Forms*, Proceedings of Sixth International Conference on High Performance Vehicles, in press, Naples, Italy, September 2008, pp 117-127.
- [14] Molland, A.F. (2008). *A Guide to Ship Design, Construction and Operation*. The Maritime Engineering Reference Book, Butterworth-Heinemann, Elsevier.
- [15] Oller Erik LT., Vasilios Nikou LT., and Konstantinos Psallidas LTJG. 2003. *Focused Mission High Speed Combatant*. Project in New Construction Naval Ship Design. MIT, USA.
- [16] Parsons, Michael G. 2003. *Ship Design and Construction Volume II*. Jersey City : The Society of Naval Architect and Marine Engineering.
- [17] Peng, Hongxuan. 2001. *Numerical Computation of Multi-Hull Ship Resistance and Motion*. Dalhousie University, Canada.
- [18] Seif, M.S. and Amini, E. (2004). *Performance Comparison between Planing Monohull and catamaran at High Froude numbers*. Iranian Journal of Science & Technology, in press, Transaction B, Vol. 28 no. B4.

# The Study on Environmental Quality Interior, Ventilation and Indoor Air Quality Simulation

Dwinanto<sup>a,b</sup>, Nasruddin<sup>a</sup>, Ozkar F. Homza<sup>a,c</sup>, Yudhy Kurniawan<sup>a,d</sup>

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : dwinanto@ui.ac.id, nasruddin@eng.ui.ac.id, ozkar.firdausi@ui.ac.id, yudhy.kurniawan@ui.ac.id

<sup>b</sup>Faculty of Engineering University of Sultan Ageng Tirtayasa, Cilegon 42435  
E-mail : dwinanto@ft-untirta.ac.id

<sup>c</sup>School of Refrigeration and Air Conditioning, Sekayu Polytechnic, Sekayu 30711

<sup>d</sup>School of Refrigeration and Air Conditioning, Indramayu Polytechnic, Indramayu

## ABSTRACT

Formaldehyde is one of the gaseous pollutants, pollutants produced from cigarette smoke. Medically, smoke can cause health problems, irritation and even the risk of death, lung cancer. The importance of the study of air quality provides information of quantity of pollutants in the air also contains information on human health risks. Conditions actual at the site, installed one unit mechanic ventilation system simple flow hygro, in simulation were performed using transient weather conditions for locations in Mériadec, France. Sources of pollutants, formaldehyde, generated from cigarette smoke which produced by one person and five people in the room. Furthermore, pollutants placed in bedroom number 1 with the properties of the pollutants, molecular weight of 30.03 kg / kmol, another information one smoker produces 3.7 µg formaldehyde per second. By using a numerical method, quantity of pollutants will be discovered at each part of the room which determined at a specific time period. The content of formaldehyde at previous condition will be compared with conditions in tropical region, Depok, Indonesia.

## Keywords

*Formaldehyde, unit mechanic ventilation system simple flow hygro, transient weather condition, numerical method*

## 1. INTRODUCTION

The room modern architecture around the chambers made of glass, the air temperature in a room maintained at a certain temperature, equipped with air freshener, comfortable, does not cause sweating. It will unconsciously cause health problems sick building syndrome symptoms can be experienced physically as sore throat, body fatigue, dizziness, eye irritation and so commonly seen in buildings that do not noticed aspects of the ventilation. Without realizing, the source of pollution is inside the building itself. Therefore the role of ventilation is necessary here.

Residential building ventilation, especially referring to the air exchange occurs between the outside and inside, it can also refer to the air distribution between the rooms or in connection with the flow of air in the room. Indoor ventilation can occur naturally or mechanically. Natural ventilation commonly refers to movement of the air that is affected by the opening of doors and windows, also infiltration. As for mechanical ventilation, there are three types of systems; insufflation mechanical ventilation systems, mechanical ventilation systems simple flow and mechanical ventilation system double flow.

According to the study of human activity, nearly 80% of the time, used to perform activities indoor (at home, in offices, restaurants, mostly (at transport, etc.)<sup>1</sup>. Therefore it is very important to ensure the availability of fresh air for indoor areas which have good quality and sufficient quantity.

The purpose of this research studied the extraction of pollutants by using a simple flow mechanical ventilation. The reference based on the standard ASHRAE (American Society of Heating Refrigerating and Air Conditioning Engineers) 2009 Fundamentals (SI Edition).

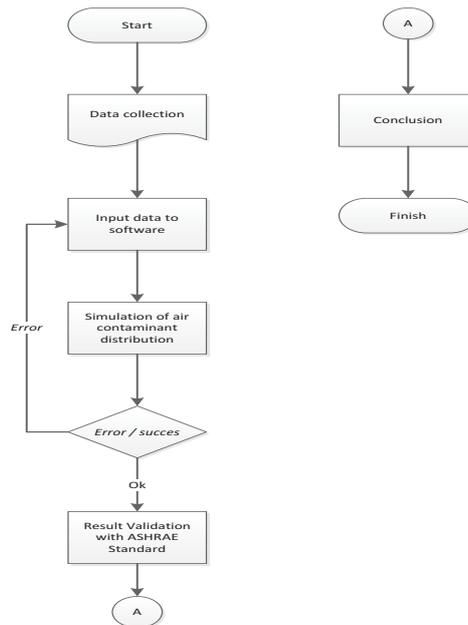


Figure 1: Simulation flowchart

In the early stages before performing numerical simulations, the first thing to do is drawing a building model for simulation. After that, input parameters with the necessary data. The data parameters can be obtained from the literature or the recommendations of previous study. Then the next step is simulating model to see the results. If there are errors, it has to do a review of the parameters entered. Further repeat the simulation to see the results running or not. If the results obtained in accordance with the ASHRAE standards, the installation of mechanical ventilation simple flow system is sufficient to extract air pollutants to outdoor.

## 2. SIMULATION ASPECT

### 2.1 Preparation of Simulation.

CONTAM is a multizone indoor air quality and ventilation analysis computer program designed to help for determine airflows, contaminant concentration and personal exposure. CONTAM version 3.0 is tools to simulate the models.

#### 2.1.1 Transient Weather Data.

The type of weather data which require for a simulation depends on the type of simulation. For this simulation using a transient airflow simulation. Transient weather data is implemented through the use of weather files or WTH files.

#### 2.1.2 Basic Model

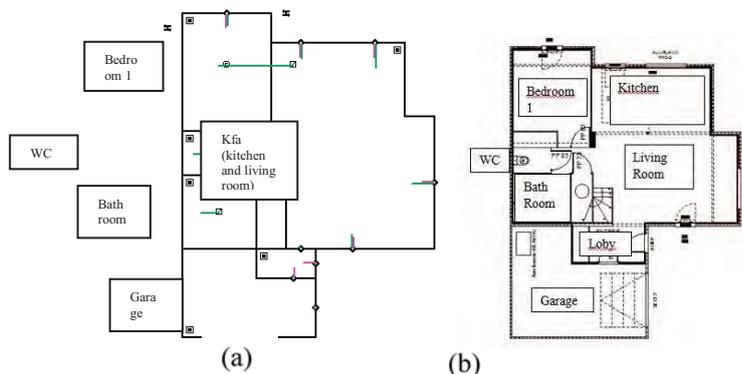


Figure 2: (a)Basic model sketch pad CONTAM, (b)Layout of the house

Basic model is a models which use in simulation.

#### 2.1.3 Elements of Airflow

Airflow paths : Airflow through various airflow elements provided by CONTAM is modeled using either a powerlaw or quadratic relationship between airflow and pressure difference across the flow path. These relationships are models

themselves, and care should be taken when implementing them to represent building features within models idealized buildings.

Leakage area : The powerlaw model can be used with the component leakage area formulation which has been used to characterize openings for infiltration calculations [ASHRAE 2001, p. 25.18]. The leakage area is based on a series of pressurization tests where the airflow rate is measured at a series of pressure differences ranging from about 10 Pa to 75 Pa. The effective leakage area is based on a rearrangement of equation (1).

$$L = \frac{Q_r \sqrt{\rho / 2\Delta P_r}}{C_d} \quad (1)$$

Where  $L$  is equivalent or effective leakage ( $m^2$ ),  $\Delta P_r$  is reference pressure difference (Pa),  $Q_r$  is predicted airflow rate at  $\Delta P_r$ ,  $C_d$  is discharge coefficient. There are two common sets of reference condition  $C_d=1$  at pressure difference 4 Pa and  $C_d=0.6$  at pressure difference 10 Pa.

The CONTAMW Library Manager, shown in the following figure, is a dialog box that is displayed when access data elements from the Data menu or by clicking on a "Library" button when editing the properties of one of the building components that utilizes library data elements. This dialog box is divided into three sections: Library File, Library Elements and Local Project Elements sections. The Library File section displays the name of the currently displayed library file and allows you to save, rename and open new and existing library files. The Library Elements section displays the data elements contained in the library file that is currently listed in the Library File section. The Local Project Elements section displays the data elements that are contained in the current project file.

### 2.2 Contaminant Source and Sink

User can define an unlimited number of contaminants within a single project with a practically limitless number of sources associated with the contaminants. CONTAM can simulate contaminant transport via airflow between zones, removal by filtration mechanisms associated with flow paths, and removal and addition by chemical reaction. CONTAM can also implement several source and sink models to generate contaminants within or remove contaminants from a zone. These models include: constant generation, pressure driven, decaying source, cutoff concentration, reversible boundary layer diffusion, and burst models.

Steady: The steady contaminant option can only be used in conjunction with steady airflows and will run until the system reaches equilibrium. Contaminant sources are modeled as continuous sources with a constant generation rate. If any sources have schedules associated with them, then schedule values will be determined by the Day Type set in the Steady State Weather Data (see Weather Properties under Working with Weather and Wind) and the Steady Simulation Time. Burst sources will be ignored. Ambient contaminant concentrations will be the Default Concentration values of each contaminant.

### 2.3 Schedule

Use this control element to apply a schedule via the control network. A schedule can be applied to airflow paths, simple air handling systems, inlets and outlets of simple air handling systems and source/sinks. Control schedules will override schedules that are defined as a parameter of an element.

Days	No. Of Smoker	Hour
Sunday	1	18 to 20
Monday	1	18 to 20
Tuesday	1	18 to 20
Wednesday	1	18 to 20
Thursday	5	20 to 22
Friday	0	-
Saturday	0	-

Figure 3: Schedule control air handling system source/sink

### 3. SIMULATION RESULT

#### 3.1 Condition Weather France

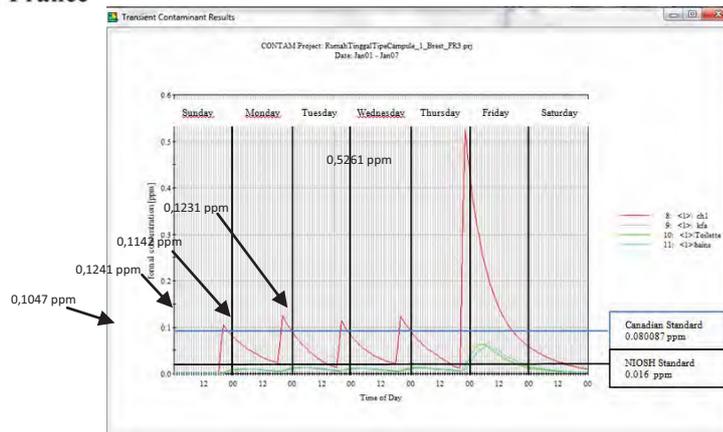


Figure 4: Transient formaldehyde result, condition weather France

#### 3.2 Condition Depok Indonesia

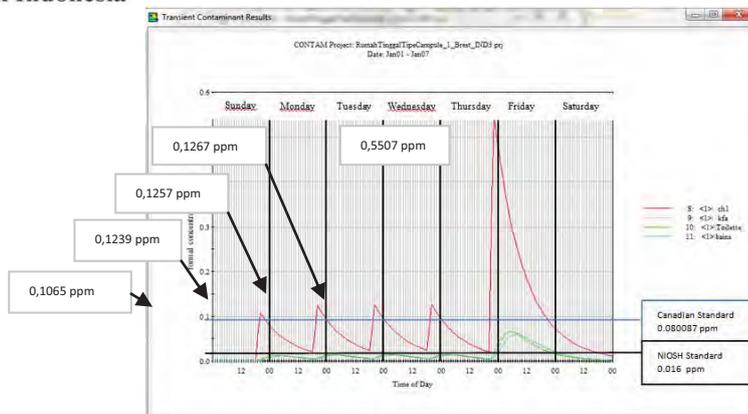


Figure 5: Transient formaldehyde result, condition weather Depok, Indonesia

### 4. DISCUSSION

At bedroom 1 from the graph above (figure 5 and figure 6), the formaldehyde content of pollutants distribution scenario shows results that vary according to the number of sources of pollutants during limited hours. For example, on Monday when the concentration reaches 0.1241 ppm formaldehyde use condition weather France and 0.1239 ppm formaldehyde at condition Indonesia. Both variable values, has passed from the standard maximum verge concentrations of formaldehyde by the Canadian standard of 0.080087 ppm and a maximum threshold set by NIOSH at 0.016 ppm. Content of formaldehyde in the air when the threshold has reached its maximum limit of the standards set, will cause the risk of eye irritation.

### 5. CONCLUSION

To solve formaldehyde levels that exceed the value limits NIOSH and Canadian standards, steps can be taken to increase the amount of fresh air into the room by opening a window. Fresh air enters the room will decrease the number of high formaldehyde levels. This process is maintained until there is no more content of formaldehyde that can be felt physically. The process of lowering the high levels of formaldehyde in the room by opening the window is classified as a type of natural ventilation.

### REFERENCES

- [1] T. Paul, D.S., "Effect of Mechanically Induced Ventilation on The Indoor Air Quality of Building Envelopes.," in *Energy and Building*, vol. 42, pp. 326-332.
- [2] George N. Walton, W. Stuart Dols, "CONTAM-User Guide and Program Documentation", NIST, Dec. 14, 2010, pp. 221
- [3] ASHRAE (2009), "ASHRAE Handbook Fundamentals"
- [4] ASHRAE (2001), "ASHRAE Handbook" pp.26.15
- [5] ASHRAE (2007), "ANSI/ASHRAE Standard 62.1-2007" Table B-1, pp.26
- [6] Dwinanto, "The Study on Environmental Quality Interior, Ventilation and Indoor Air Quality Using CONTAM Software", Thesis, Jan. 2013, unpublished
- [7] Kurniawan, Yudhy, "Study Performance of Mechanical Ventilation by Insufflation for Air Quality Indoor in Building", Thesis, Jan. 2013, unpublished

# Characteristics of Heat Transfer on Heat Sink using Cross-Flow Synthetic Jet with Frequency Variation of Sinusoidal and Square Wave

Harinaldi , Engkos A. Kosasih , Damora Rhakasywi, Aldy Andika, Arief Randy

Faculty of Engineering

University of Indonesia, Depok 16424

Tel : (021) 7270011 ext 51. Fax : (021) 7270077

E-mail : harinald@eng.ui.ac.id, engkoskosasih@eng.ui.ac.id, damora.rhakasywi01@ui.ac.id, aldy.andika91@ui.ac.id, arief.randy@ui.ac.id

## ABSTRACT

Along with rapid technological advances in the electronics industry, there are many new emerging advanced products which getting smaller in dimension with high space efficiency and work relying on components such as transistors and integrated circuit (IC). However, these conditions also cause new challenges to overcome, one of which is how to cope with the heat generated by the operation of the electronic components in the product with sophisticated cooling system. The cooling system, hence, needs less space and energy consumption but has high thermal efficiency. This is why the synthetic jet with zero net mass flux and non-zero net momentum flux sounds practicable as the new cooling system. This research will discuss the characteristics of flow and convective heat transfer in the cross-flow synthetic jet with two membranes that oscillate using combination of sinusoidal and square wave. It was conducted in two stages, computational and experimental stage. The experimental stage was executed using the function generators to drive the upper and lower membranes by sending functions of sinusoidal and square frequency variations with multiple oscillation frequency of square80 Hz-sin80 Hz, square80 Hz-sin120 Hz, square80 Hz-sin160 Hz, square120 Hz-sin80 Hz, square120 Hz-sin120 Hz, square120 Hz-sin160 Hz, square160 Hz-sin80 Hz, square160 Hz-sin120 Hz, square160 Hz-sin160 Hz at fixed amplitude of 0,002 m/s to see the characteristics of convective heat transfer on the heat sink at each trial. Computational stage was conducted by Fluent CFD software with  $k-\omega$  SST turbulence model with Tet / Hybrid Tgrid meshing elements type to see the flow distribution in cross-flow synthetic jet. The results showed the significant influence of waves mode and frequencies to the heat transfer rate of cross-flow synthetic jet, with the best result is on sin 120 Hz– square 80 Hz waves.

## Keywords

Cross-Flow Synthetic Jet, CFD Fluent, Convective Heat Transfer Rate, Function Generator,  $k-\omega$  SST turbulence model

## 1. INTRODUCTION

As we know, technology is growing rapidly in this modern era, especially in the electronics industry. Growing sophisticated technology should certainly be supported by the hardware in it. Over time, developments in the electronics industry demands products with higher efficiency & performance. One of the developments is in terms of electronic cooling systems (cooling devices). Along with the challenges of energy efficiency, we need a new system capable of fulfilling the demands. The common cooling method used today is the conventional fan / blower cooling with air as working fluid. Most medium to large scale electronic devices still use this method on the application of the cooling system for air circulation or increasing local cooling rate.

Synthetic jet is a characteristic of fluid flow in which a series of vortex rings formed by the vibration of the membrane / diaphragm in a cavity which causes the incoming and outgoing movement of fluid through the narrow opening / orifice [1]. Synthetic jets can be visually seen as in Figure 1.

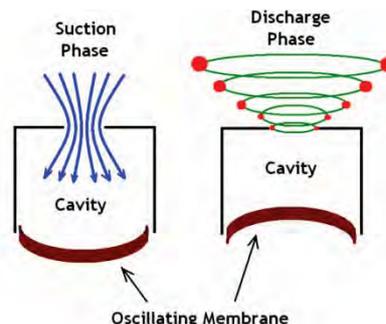


Figure 1: Working principle of Synthetic Jet

The basic principle of synthetic jet is zero net mass input of the fluid around it, but the momentum output is not zero. A synthetic jet actuator consists of cavity that contains the diaphragm, may be a piston, piezoelectric membrane, as well as electromagnetic, which moves air in it, where the fluid air move out from the cavity in the form of a series of vortex with high turbulence intensity which accelerate the rate of heat transfer and produce a cooling effect on the intended media.

Synthetic jet is currently being developed because it has advantages over conventional fan cooling system. On the conventional fan system, there is a need of supply flow of air from one place to another. Synthetic jet system offers major advantage that is just using the same air that continues circulated by the system [2]. Besides, fan is considered less efficient referring to the amount of heat rejected to the large volume of flow [3]. Another advantage of using synthetic jet cooling compared to fan for the same heat transfer performance, i.e., [4]:

- The noise level is much lower
- Better in thermodynamics efficiency, only half or less power needs
- Much better form-factor (design-friendly)
- Reliability (test stand), intrinsically higher
- Lower fouling problems, mechanics can be protected from the ambient
- Product miniaturization is easier than fan
- Have the possibility of a more simple noise reduction

But the synthetic jet is not also free of disadvantage, particularly on the impinging model. Its main weakness lies in the ease of heat containing fluid sucked back on the suction phase. This will result in the confinement effect which the heat will accumulate in synthetic jet cavity [5]. This has directed the synthetic jet research to cross-flow models in the hope of reducing the impact of the confinement effect.

## 2. METHOD

In this study, the synthetic jet actuator is required to conduct an experiment so that a prototype was designed & prepared. This prototype is expected to be able to produce synthetic jet stream that has good heat transfer coefficient. The design of synthetic jet actuator that were made and used in the experiments described in Figure 2

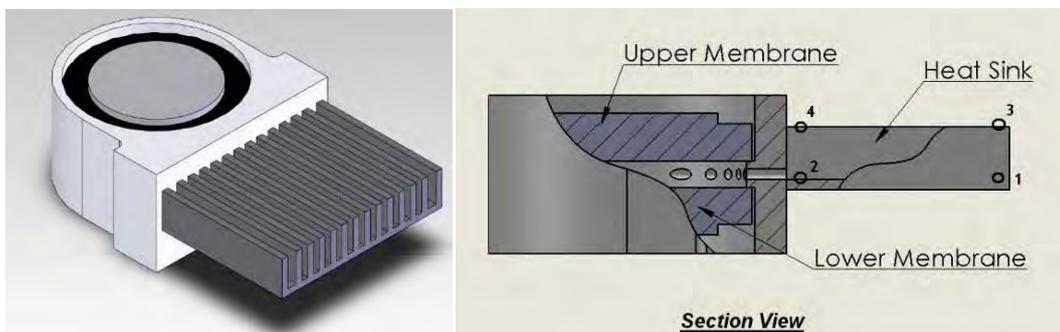


Figure 2: Synthetic jet actuator model with the points of data collection

This research has been conducted in computational and experimental stages to get the characteristics of heat transfer on the heat sink using a cross-flow synthetic jet actuator.

### 2.1 Computational Stage

Computational stage in this research is conducted in order to get an idea of the flow and thermal contour in the flow pattern of cross-flow synthetic jet. This stage is completed by using CFD Fluent software. The computational model was designed before and then meshed using the Gambit software as in figure 3

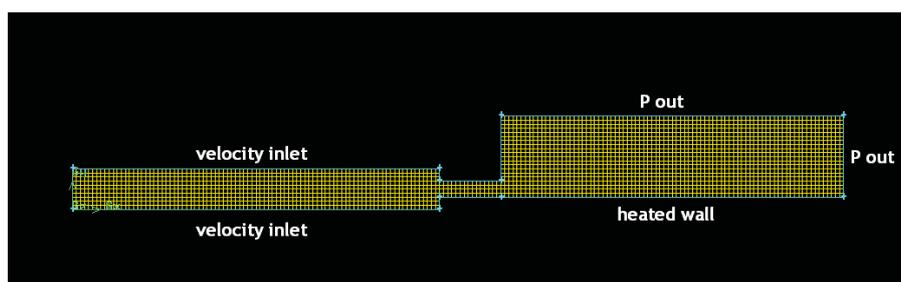


Figure 3: Overview of computational area of synthetic jet

The computational model was used to analyze the thermal contour of synthetic jet using  $k-\omega$  SST (Shear Stress Transport) mathematical model. In the work area, the air is assumed to be isothermal and incompressible. The ambient temperature is assumed 30°C and the temperature of the bottom heat sink wall is heated, maintained at an isothermal temperature of 60°C. Boundary wall on either side of the actuator is assumed to have a constant static pressure with a pressure of 1 atm. The movement of the diaphragm is modeled with a user defined function (UDF). Another detail of the computational conditions are written in Table 1.

Table 1: Computational Conditions

Computation Condition		
Model settings	2DDP, Unsteady	
Fluid	Air	
Fluid Properties	Density	1.225 kg/m <sup>3</sup>
	Viscosity	1.7894 e <sup>-05</sup> kg/m-s
	Cp	1006.43 J/kg-k
	Thermal Conductivity	0.0242 w/m-k
Boundary Condition	Velocity Inlet 1,2	UDF
	Pressure Outlet (Gauge pressure)	0 Pascal
	Heated wall	60°C
	Frequency	80 Hz, 120 Hz, and 160 Hz
	Amplitude	1 m/s

### 2.2 Experimental Stage

The experimental stage was conducted to obtain temperature data on a heat sink which is cooled using synthetic jet. Experimental system made in this study can be described in Figure 4

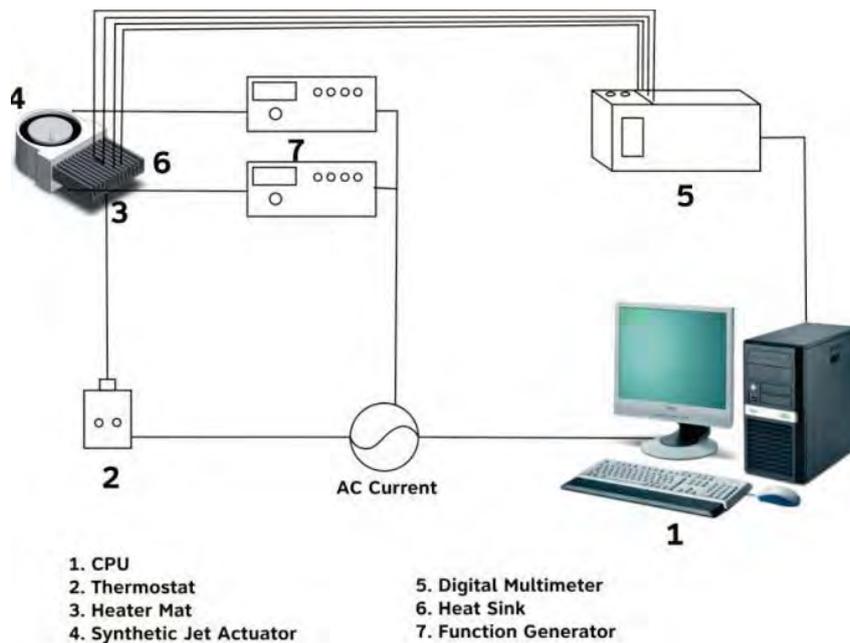


Figure 4: Experimental Set-up

Data acquisition was done by measuring the temperature of the heat sink in the four points using a digital multimeter with measurement accuracy of 0.1°C. Temperature setup was performed on the heat sink prior to the experiments. The heat source of heat sink obtained by placing the heater mat at the bottom of the heat sink with a temperature of 60°C regulated using a thermostat. Measurements were performed at 27°C ambient temperature. And after that, the membranes used in this experiment was set for sinusoidal and square waveforms, as well as arrangements of wave frequency combinations of 80 Hz, 120 Hz and 160 Hz using a function generator. After all settings were done, it was ended by placing the data acquisition thermocouple on the four-points on the heat sink which was then read using a digital multimeter. The data acquisition of experiments performed in 1 hour with one second of data interval.

### 3. ANALYSIS

At this stage of experiment, data acquisition was done by noting the temperatures changes on four test points on the heat sink due to the cross-flow cooling by synthetic jet actuator. The experiment was conducted in a closed room with ambience

temperature around 27 to 30 Celsius degrees. Test points consist of 4 areas where the thermocouples attached, as referred by figure 2. Point 1 and point 2 are located at the base of the heat sink, while point 3 and point 4 are on the top of the fins. Both thermocouple points that located at the same level were distinguished by the placement towards the orifice hole. Point 1 and point 3 are the most distant from the orifice while point 2 and point 4 were right in front of the orifice. It was considered fair enough to describe the characteristics of heat transfer on the heat sink as result of cross-flow synthetic jets cooling.

A total of 9 wave variations were executed from piezoelectric membranes on synthetic jet actuator, resulting in 36 data sets, which are distinguished from the locations of the thermocouple and wave variations. In this section, the data sets will be grouped into four graphs, which is the analysis of the graph based on the thermocouple point, point 1, point 2, point 3 and point 4.

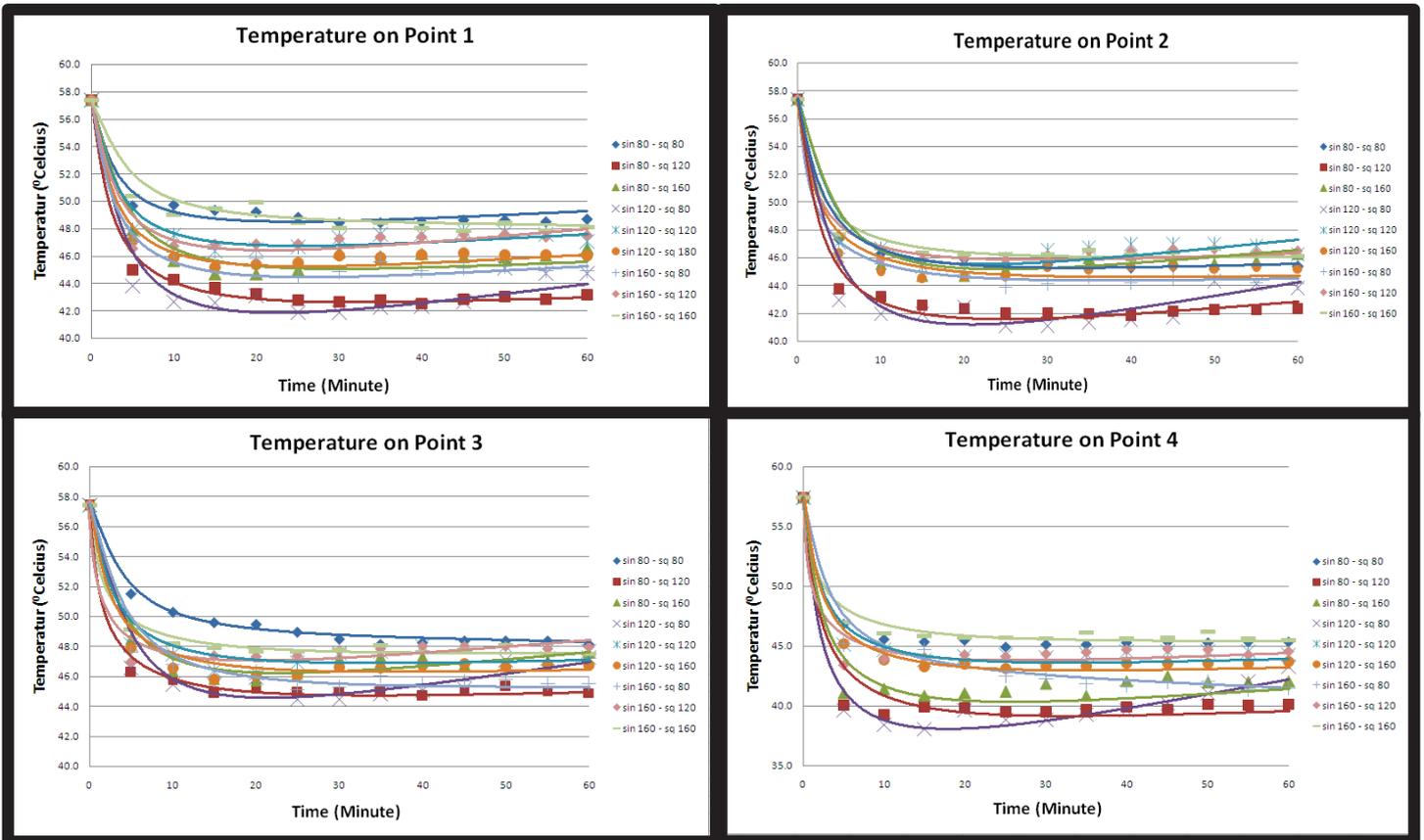


Figure 5: Heat Sink Temperature on each Test Point

The biggest temperature decrease recorded at point 1 was 15.6 Celsius degrees which occurs in wave variation of sin 120 Hz – square 80 Hz. But until the 60 minutes period the temperature in this frequency variation increased again so that the total value of reduced temperature only reached 12.7 degrees, smaller than the wave variation of sin 80 Hz – square 120 Hz which achieved total temperature reduction of 14.2 Celsius degrees.

At point 2, the largest temperature reduction was also achieved by wave variation of sin 120 Hz – square 80 Hz with the value of temperature decrease of 16.3 Celsius degrees from 57.4 degrees to 41.1 degrees. However a slight increase in temperature after 20 minutes made the value return to 43.8 Celsius degrees in the 60th minute, with an increase of 2.7 degrees.

Temperature at point 2 decline relative greater than point 1, though both of locations are set directly on the base of the heat sink. This is most likely happened due to the location of the second point is closer to the orifice than point 1, so it can also be said that the area of point 2 has higher turbulence intensity than point 1, resulting in the emergence of higher heat transfer coefficient than point 1.

The results of temperature measurement obtained at point 3 are also written in the form of graphs. At this point the highest value of temperature decrease was also achieved at sin 120 Hz - square 80 Hz wave variation, with a value of reduced temperature of 12.9 Celsius degrees. While the greatest temperature reduction achieved in 60 minutes was 12, 5 Celsius degrees at wave variation of sin 80 Hz – square 120 Hz.

The temperature decrease at point 4 due to cross-flow synthetic jet cooling is shown in graphical form of Figure 5. The biggest temperature reduction at point 4 was also achieved at sin 120 Hz - square 80 Hz wave variation which decreased the

temperature by 19.3 Celsius degrees. The biggest drop for 60 minutes achieved at sin 80 Hz – square 120 Hz which decrease the temperature by 17.3 degrees.

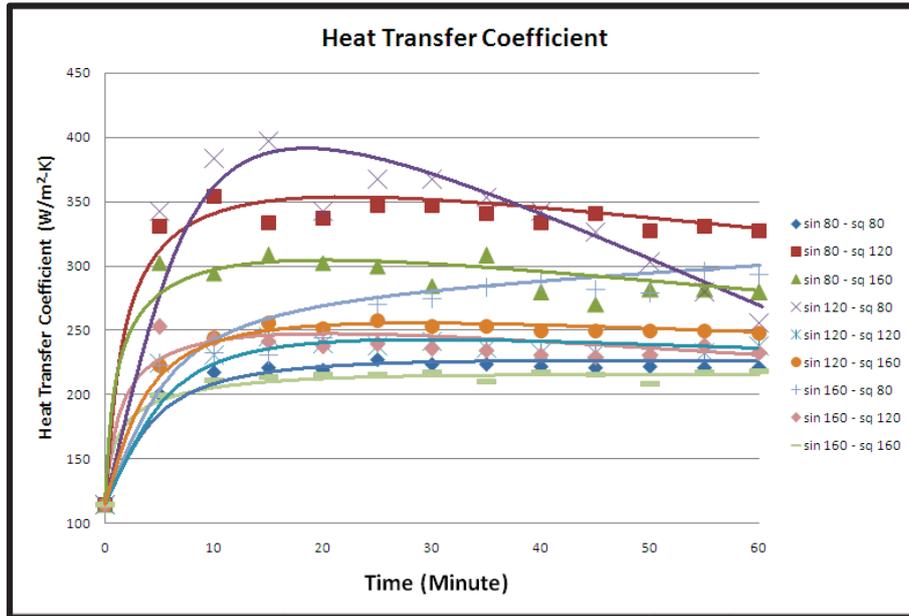


Figure 6: Heat Transfer Coefficient

Figure 6 shows heat transfer coefficient on the best test point, which is point 4. The graph shows that the value of heat transfer coefficient rose to an extreme value in the early period of synthetic jet operation, then after reaching a certain value in about 15-25 minutes, the heat transfer coefficient values showed stable character around that value. It happens to almost all of the wave variations of Sinusoidal - Square, except on sin 160 Hz – square 80 Hz which rose a little, and the variations of sin 120 Hz – square 80 Hz which showed a declining trend. The largest value of heat transfer coefficient recorded in this study was achieved by wave variation of sin 120 Hz – square 80 Hz at the 15th minute which valued 396.7 W/m<sup>2</sup>K.

At the computational stage, simulation of cross-flow synthetic jet actuator design was conducted using Fluent CFD software. This section discusses the analysis of the contours of temperature of the prototype. Synthetic jet simulated in a period of time-step of 0.025 second which is a least common multiple of signal variation and combination of 80 Hz, 120 Hz, and 160 Hz, at which time all wave ends meet in a point.

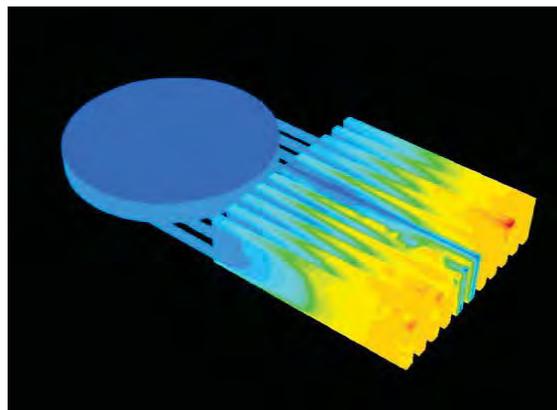


Figure 7: 3D Simulation

In the early stages of this research, computational simulation with three-dimensional computational models was conducted. But this was done only to prove that there is no significant difference in the flow pattern on the 3-three-dimensional model so that the flow can be analyzed as a two-dimensional flow to lighten the computational load and shorten iteration time. It is shown in figure 7. From the results of the 3D simulation, it was decided to further simulate on 2D because it was already sufficient to describe the heat transfer characteristics of the heat sink.

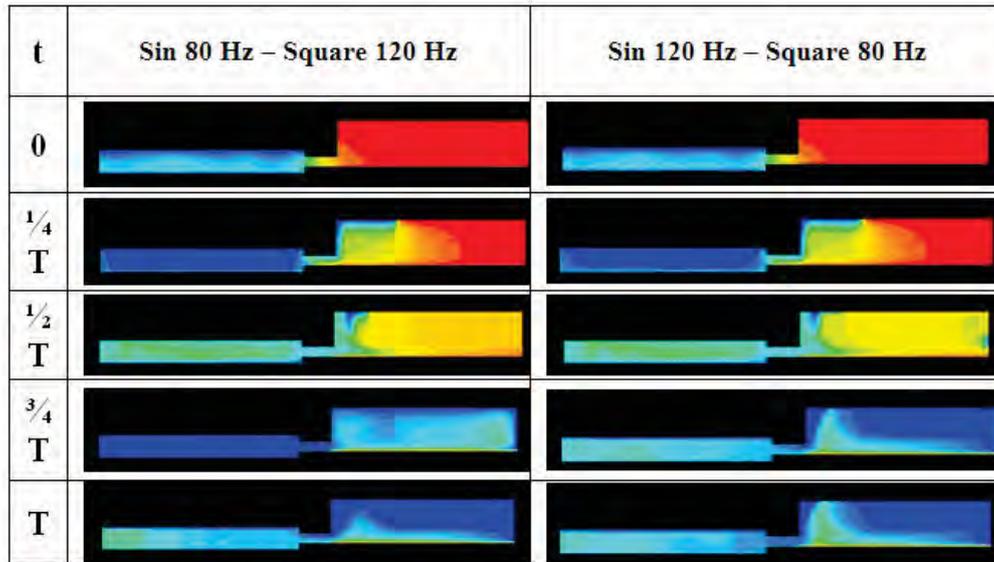


Figure 8: Temperature Contour

The temperature contour of heat sink at sin 80 Hz - square 120 Hz and sin 120 Hz - square 80 Hz wave variation is shown in figure 8. Extreme heat sink cooling on the top side of fin began in the period of 0.25 T. The start of this period to period 0.75 T shows the movement of the synthetic jet cooling to the heat sink. In the first full period of T, temperature decrease at the heat sink began to spread to all area of the heat sink significantly.

#### 4. CONCLUSION

Research on the effects of cooling and flow characteristics using a cross-flow synthetic jet actuators have been undertaken and successfully demonstrated the characteristics of heat transfer in heat sinks to variations sinusoidal and square waves at a frequency combination of 80Hz, 120Hz and 160 Hz.

The results showed that the cooling effect of cross-flow synthetic jet membrane has reached a pleasing value and can reduce the negative impact of confinement effects. The experimental result shows that membranes driven using function combination of sinusoidal 120 Hz – square 80 Hz has a better cooling effect than other frequencies wave variations. It was marked by a decrease in temperature better sinusoidal function of 120 Hz - 80 Hz square wave where the variation can lower the temperature up to 19.3 Celsius degrees.

#### REFERENCES

- [1] B.L Smith, A. Glezer, "The Formation and Evolution of Synthetic Jets." *Physics of Fluid 16*, 1998, pp. 2281-2297
- [2] Sharma, R.N. (2007, December). Some insights into synthetic jet actuation from analytical modeling. Paper presented at the 16th Australasian Fluid Mechanics Conference.
- [3] Mahalingam, R., Heffington, S., Lee, J., & Schwickert, M. (2006). Newisys server processor cooling augmentation using synthetic jet ejectors. IEEE, pp. 705-709.
- [4] Lasance, C.J.M., & Aarts, R.M. (2008). Synthetic jet cooling PartI: Overview of heat transfer and acoustics. Paper presented at the 24th IEEE SEMI-THERM Symposium.
- [5] Tesar, V., Chuan, H.H., & Zimmerman, W.B. (2005). No-moving-part hybrid-synthetic jet actuator. SNA-4850, pp. 1-11.

# Simulation Model Transient Heat Transfers in Hot Box Billet Steel

Prayudi<sup>a</sup>, Efy Yosrita<sup>b</sup>

Mechanical Engineering STT-PLN Jakarta  
prayudi.sttpln@yahoo.com

Informatics Engineering STT-PLN Jakarta  
yosrita\_ryanto@yahoo.co.id

## ABSTRACT

One of the products of PT. Krakatau Steel is a steel Billet, the raw material for the manufacture of wire in Wire Rod Mill (MRM). The average temperature at the exit of the Billet Steel Plant (BSP) about 900°C, was reduced to 130°C before entering MRM. Billet is heated again so it can be processed in WRM. Several studies have been done to reduce the rate of temperature decrease Steel Billet, including modifying the billet transportation system, which makes the system ambient temperature is kept high enough billets. With the approach of isolated cooling average rate of temperature decrease is 6.5°C per minute. From the results experiment is known that the temperature of the surrounding air and the rate of speed of the transport system effect significant decrease in temperature billet, where the temperature dropped to 450°C. The phenomenon of decrease temperature billet can be simulated using state transient conduction heat transfer equation. Decrease the temperature is at least influenced by several variables such as air temperature around, speeds pace of billet transportation system, long transport time, and the coefficient of thermal conductivity of billet. In this study created a numerical model of experiment study to determine the effect of air temperature around Billet Steel, long billet transport rate to the rate of temperature decrease. Expected outcomes of this research is derived parameters can be used to create models of Hot Box Billet to reduce the rate of decline temperature. The making design Hot Box Billet Steel that convection heat transfers from environment as little..

## Keywords

*transient heat transfer, convection boundary, billet steel.*

## 1. PREFACE

PT. Krakatau Steel is a company engaged in manufacturing steel casting. Production facilities consist of Direct Reduction Plant, Slab Steel Plant, Steel Billets Plant, Hot Steel Plant, Cold Rolling Mill, Wire Rod Mill and (WRM) [1]. In division WRM, raw materials such as steel billet cross-sectional area measuring 130mm x130 mm to 180 mmx180 mm and a length of 9m. The process of producing billets into wire rods into three phases, are reheating, deformation and transformation [1]. The Billet Steel Plant (BSP) is one plant in PT. Krakatau Steel that produces billets for the production of wire rods in the Wire Rod Mill (WRM) plant. The average billet temperature exiting the roller caster system at BSP is 900°C. In BSP cooling system, the billet heat is reduced from 900°C to 450°C, and then while waiting for transferring to WRM and charging to Reheating Furnace the billet temperature naturally goes down to 130°C. The cooling bed contributes significantly to the billet heat loss, and this heat was not utilized. The option proposed was a modification of the billet transportation system between the BSP and the WRM plants, whereby the billet temperature is kept as high as possible, before charging to reheating furnace in WRM. Three alternative systems were evaluated and the tunnel/underground transportation system was the preferred system. Three alternative billet transportation systems were considered: movable box storage/furnace, high temperature conveyor, tunnel/underground transport system. Implementation of the three alternatives will require considerable investment costs [13].

Another approach to reduce the temperature drop is making hot charging (isolated cooling) conducted by team BTP BPPT for Steel Billet automation program, that the condition is passed on certain hot tunnel. Experimental done is billet that has gone out of his way to BSP WRM with a temperature of 1000°C conditioned into a sort of tunnel or hallway can set the frequency of the tunnel is that of 10-50 Hz and the results of each frequency is different vary according to the characteristics of the frequency used. The first, the billet is heated to a temperature of 1000°C, then the calculated temperature or ambient temperature environment and recorded using a thermal imager per unit of time [3].

Hot box is designed to close the system in a state that is used as an insulator of the billet, the isolator is used to withstand the heat of the billet that has come out of the BSP so that the temperature remained high in condition before unloading. So that the billet is currently arriving at WRM still in high temperatures. In designing the isolation of the hot box, the approach used several parameters of the real condition of his (real). From the experimental results stretcher Billet temperature dropped from 700°C to 530°C [3]. This last approach, there are several variables that are used to

simulate the temperature drop at Hot Charging Steel Billet, BBPT the surrounding air temperature, high heat transfer rate. The phenomenon of the decline of billet can basically be observed using Fourier law approach. According to the Fourier law of conduction heat transfer, the rate of change of temperatures are the material thermal conductivity, heat transfer surface area, surrounding air convection coefficient, density, heat production is generated, and the specific heat of the material [4].

Research on the phenomenon of two-dimensional conduction heat transfer, particularly the decline of temperature on Steel Slab by L. Buchori, et al. In this research studied the effects of a combination of convection and radiation boundary conditions on the computational thermal cooling processes steel slabs by the computing method the finite volume. Numerical method to used solve transient heat transfer model of two-dimensional.

Based on this, it is still wide open to do some research to simulate the phenomenon of decline in billet steel heat well with the experimental and numerical simulation approach. Issues transient conduction heat transfer can be backwardly steel billet non-linear or a constant depending on the physical properties of materials, the temperature or the heat generated source (heat flux). The study of transient heat transfer event of non-linear and two-dimensional cooling events slabs of steel with a combination of convection and radiation limits had been done by L. Buchori et al. [5]. In the simulation study is the temperature drop in steel billets by applying finite difference method to solve two-dimensional heat transfer in the cooling process of steel billets with boundary convection and thermal conductivity constant. Validation of the model used experimental results that have been carried out by previous researchers.

The parameters that will be used is the temperature of the object, and thermal conductivity, specific heat, density, convection coefficient and air temperature around. Simulations performed using MATLAB program. This research is a preliminary study that is part of the research to study the phenomenon of heat drop in billet with boundary convection, radiation, conduction, and the thermal conductivity is a function of temperature.

## 2. MATHEMATICAL MODEL FOR THE STEEL BILLET

### 2.1. Conduction Heat Transfer and Convection Boundary

Heat transfer is the science of predicting the energy transfer occurs because of the temperature difference between the object or material. Heat transfer that occurs in the steel billet happen karea no significant temperature each difference between the temperature of billet material and the surrounding air. Transient heat transfer is an important phenomenon in the process of heating or cooling of billets or other metallurgical industries. In this case, there are three types of heat transfer is conduction occurs in a billet steel, convection and /or radiation from the surface of the billet to round or vice versa. In the event of heating steel billets, round billets temperature of moved to the surface by convection and / or thermal radiation, conduction and then transferred from the surface to the inside of the steel billet. The same phenomenon occurs in the cooling process of steel billets. Convection and thermal radiation will determine the heat flux through the surface of the steel billet. Type of heat transfer that occurs depending on what is most dominant phenomena, can be purely convection or thermal radiation.

In the case of steel billets transient heat transfer, the temperature drop occurs in the transport process that uses roll billets. Sectional square billet size 180mmx180mm 9m length can be very long. So the two-dimensional heat transfer occurs in the billet cross section as shown in figure 1.

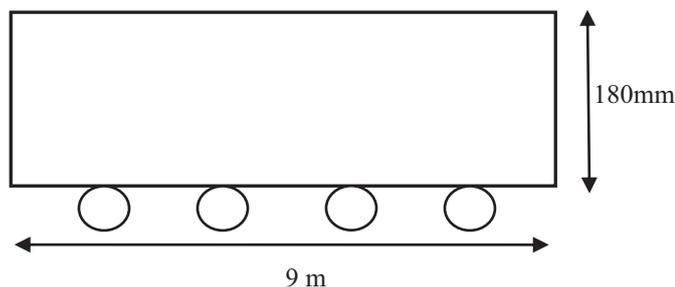


Figure 1. Dimensional Steel Billet

Heat transfer on the inside of the steel billet is conduction heat transfer given by the Fourier equation,

$$k \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) = \rho C_p \frac{dT}{dt} \quad (1)$$

In conditions of transient heat transfer, thermal konduktivitas equation (1) is essentially a function of temperature, but in this preliminary study assumed constant thermal conductivity of steel billet which is the average of the thermal

conductivity of the highest and lowest temperatures of the previous experimental results. Thermal equilibrium at the sides and the top, the convection and radiation boundary, the equation is,

$$\rho C_p \frac{dT}{dt} = hA(T_w - T_f) + F\sigma(T_w^4 - T_f^4) \quad (2)$$

As has been explained that the preliminary study, it is assumed conversion of the surrounding air is more influential than the thermal radiation [2]. With these assumptions, the second right-hand side of equation (2) is considered zero. While thermal equilibrium at the take limit is convection, thermal radiation and conduction between the bottom of the steel billet wheels roll, the equation given by.

$$\rho C_p \frac{dT}{dt} = hA(T_w - T_f) + F\sigma(T_w^4 - T_f^4) + k_r \left( \frac{\partial^2 T}{\partial r^2} + \frac{1}{r} \frac{\partial T}{\partial r} + \frac{\partial^2 T}{r^2 \partial \phi^2} \right) \quad (3)$$

From Figure 1, it appears that the surface conduction between the bottom and the top of the steel billet roll surface is quite small, the displacement factor of conduction between the billet and roll can be assumed not to exist. So at the bottom of the billet affect the heat transfer is convection, so that the second and third right-hand side of equation (2) is considered zero.

## 2.2. Mathematic Model Steel Billet

Problems mathematical model temperature distribution to be simulated in this study were transient heat transfer assuming thermal conductivity is constant and convection boundary limit. From equation (1), (2) and (3), simulating the reduced temperature steel billets used equations,

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = \frac{1}{\alpha} \frac{dT}{dt} \quad (4)$$

and

$$\rho C_p \frac{dT}{dt} = hA(T_w - T_f) \quad (5)$$

where,  $\alpha = k / \rho C_p$  called thermal diffusitas. Equation (4) also known as Fourier-Biot equation. [5]. One approach that can be used to solve partial differential equations of distribuasi temperature equation (4) and (5) is a numerical method, it is necessary for numerical discretization. Consider the volume of the object set in the case of two dimensions is divided into a few sections, and the volume element is given by Figure 2. following.

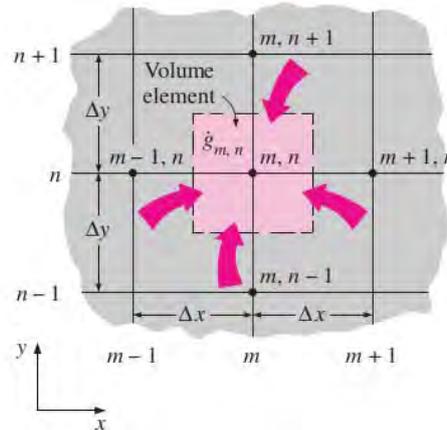


Figure 2. Element Two Dimension Volume Set

Partial derivatives, temperature gradient in (4) approximated by Taylor series expansion,

$$\frac{\partial^2 T}{\partial x^2} \approx \frac{T_{m-1,n} - 2T_{m,n} + T_{m+1,n}}{(\Delta x)^2} \quad (6)$$

$$\frac{\partial^2 T}{\partial y^2} \approx \frac{T_{m,n-1} - 2T_{m,n} + T_{m,n+1}}{(\Delta y)^2} \quad (7)$$

While the temperature gradient with time can be approximated by,

$$\frac{\partial T}{\partial t} \approx \frac{T_{m,n}^{p+1} - T_{m,n}^p}{\Delta t} \quad (8)$$

With scheme Crank-Nicolson full implicit, and when taken  $\Delta x = \Delta y$ , and to facilitate the writing, defined Biot number (Bi) and Fourier (Fo), that is  $Bi = \frac{h\Delta x}{k}$ , and  $Fo = \frac{\alpha\Delta t}{(\Delta x)^2}$  [6]. By substituting (6), (7) and (8) in (4) and condition  $Fo \leq 0.25$  equation (4) to estimate the temperature in the node (m,n), written as :

$$T_{m,n}^{p+1} = \frac{\alpha\Delta t}{(\Delta x)^2} (T_{m+1,n}^p + T_{m-1,n}^p + T_{m,n+1}^p + T_{m,n-1}^p) + \left[ 1 - \frac{4\alpha\Delta t}{(\Delta x)^2} \right] T_{m,n}^p$$

or,

$$T_{m,n}^{p+1} = Fo (T_{m+1,n}^p + T_{m-1,n}^p + T_{m,n+1}^p + T_{m,n-1}^p) + (1 - 4Fo) T_{m,n}^p \quad (9)$$

Furthermore, for the case of temperature on the sides of the steel billet with convection boundary shown in Figure 3. Following

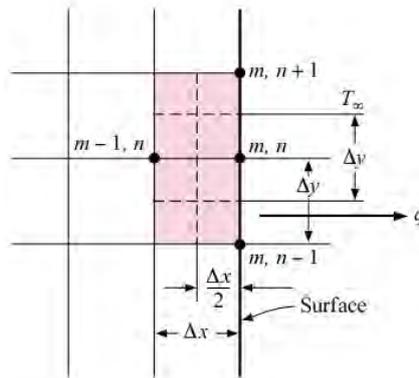


Figure 3. Convection Boundary Element Sides

In terms  $Fo(2+Bi) \leq 0.5$ , of equation (5) temperature convection boundary points (m, n) as shown in Figure 3. calculated by the formula:

$$T_{m,n}^{p+1} = \frac{\alpha\Delta t}{(\Delta x)^2} \left( 2 \frac{h\Delta x}{k} T_f + 2T_{m-1,n}^p + T_{m,n+1}^p + T_{m,n-1}^p \right) + \frac{\alpha\Delta t}{(\Delta x)^2} \left[ \frac{(\Delta x)^2}{\alpha\Delta t} - 2 \frac{h\Delta x}{k} - 4 \right] T_{m,n}^p \quad (10)$$

Using Biot numbers, Fourier equation (10) written as,

$$T_{m,n}^{p+1} = Fo (2BiT_f + 2T_{m-1,n}^p + T_{m,n+1}^p + T_{m,n-1}^p) + (1 - 4Fo - 2FoBi) T_{m,n}^p \quad (11)$$

Further to the convection boundary, specifically at the corner of a wall of steel billets as shown in Figure 4. The following

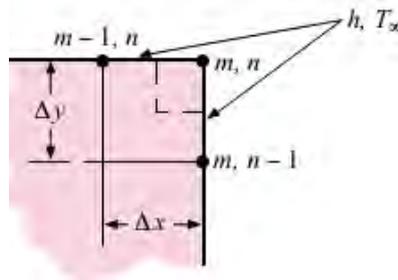


Figure 4. Corner Boundary Element Convection

In terms  $Fo(1+Bi) \leq 0.25$ , of equation (5) the temperature at the point (m, n) is shown in Figure 4. calculated by the formula.

$$T_{m,n}^{p+1} = \frac{2\alpha\Delta t}{(\Delta x)^2} \left\{ \left( 2 \frac{h\Delta x}{k} T_f + 2T_{m-1,n}^p + T_{m,n-1}^p \right) + \left[ \frac{(\Delta x)^2}{\alpha\Delta t} - 4 \frac{h\Delta x}{k} - 4 \right] T_{m,n}^p \right\} \quad (12)$$

By using Fo and Bi, equation (12) written as,

$$T_{m,n}^{p+1} = 2Fo (2BiT_f + T_{m-1,n}^p + T_{m,n-1}^p) + (1 - 4Fo - 4FoBi) T_{m,n}^p \quad (13)$$

By using equation (9), (11) and (13) further developed the system of linear equations used to estimate the temperature distribution in the steel billet.

### 3. METHODOLOGY

The research was carried out starting with a review of the results of analyzes of previous studies, followed by simulation modeling, programming with MATLAB programs, and finally analyzed by comparing the experimental results of previous studies. The analysis was done by comparing the results of model simulations with experimental results that have been obtained previously. The assumptions used are,

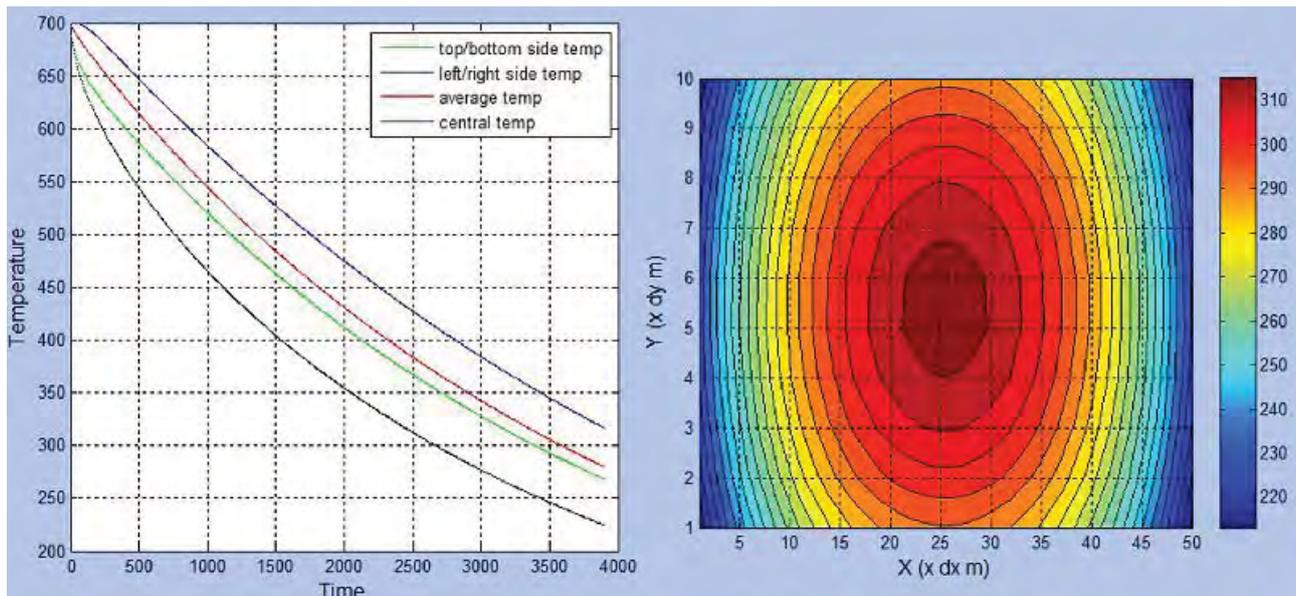
- 1). Conduction heat transfer is two-dimensional in the direction of the x axis and y axis, where  $x = 1000\text{mm}$ , and  $y = 180\text{mm}$ ,  $dx = dy = 0.02\text{ mm}$ , so that the matrix is used sized (10x50);
- 2) Physical properties and thermal homogeneous steel billets, assumed thermal conductivity  $k = 31\text{ W / m.}^\circ\text{C}$ , density  $\rho = 7795\text{ kg/m}^3$ , and  $C_p = 0.475\text{ kJ / kg}$ ;
- 3) .Ambient temperature or the temperature of the fluid is constant, not as a function of time;
- 4). Convection heat transfer coefficient  $h$  is not dependent on the fluid temperature.

By using equation (9), (11) and (13), computational algorithms are as follows

- 1.Start;
2. Read  $dt, dx, dy, \rho, C_p, k, h$ ;
3. Cek the value of  $Fo, Fo(2+Bi), Fo(1+Bi)$  ;
4. Read  $T_f, T_o$  and time
5. Set  $time=0$ ; 5.t. Set  $time < t$
6. Calculate the temperature  $T(x,y)$
7. Calculate the average of temperature
8. Print the average temperature as time function
9. Set  $time=time+dt$
10. Print temperature contour map
11. Finish

### 4. RESULT AND DISCUSSION

Assuming the physical properties of steel billets,  $\rho = 7795\text{ kg/m}^3$ ,  $k = 31\text{ W / m.}^\circ\text{C}$ ,  $C_p = 0475\text{ kJ / kg}$ , and the boundary condition  $h = 55\text{ W/m}^2.\text{K}$ ,  $dx = dy = 0.02\text{ m}$ ,  $T_f = 30^\circ\text{C}$ , and  $T_o = 700^\circ\text{C}$ , the simulation results to verify the results of previous studies for a time  $t = 3600$  seconds is given in Figure 5 below

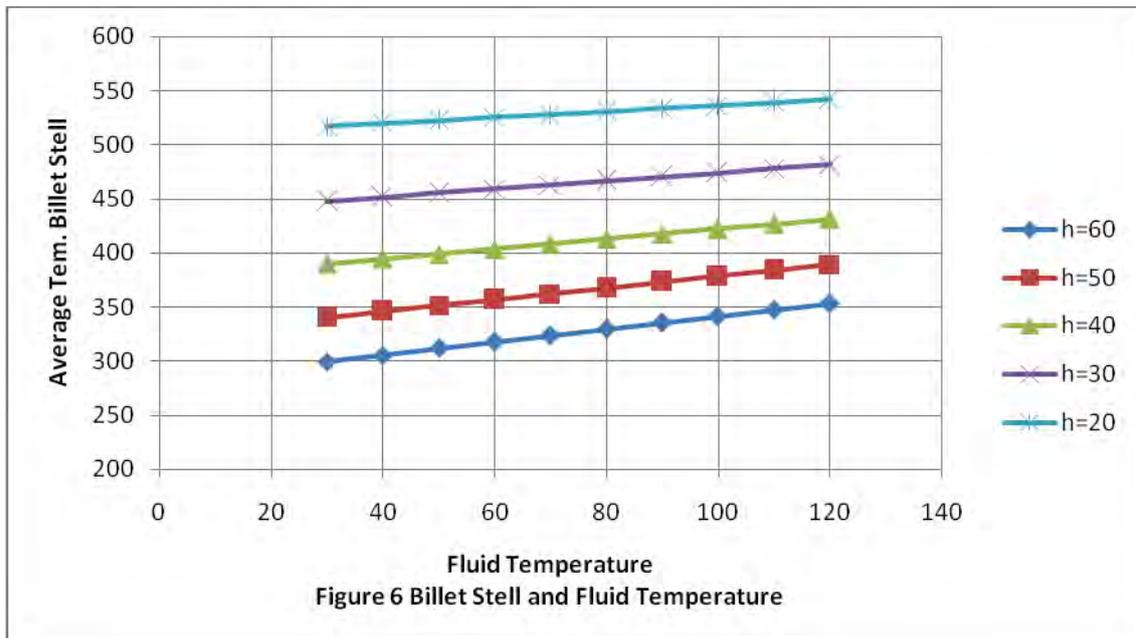


(a). Billet Temperature

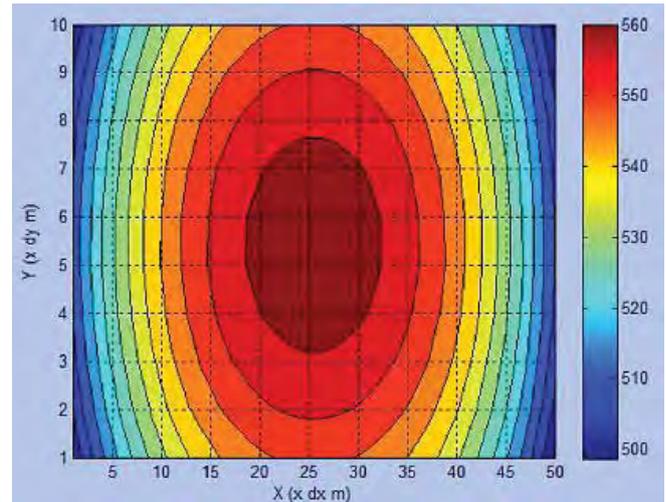
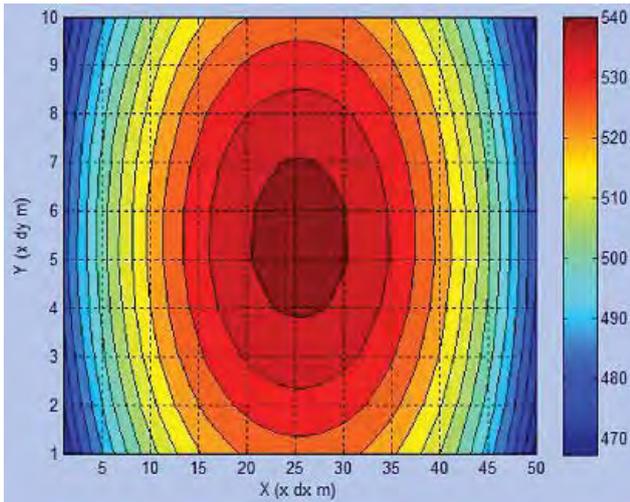
(b). Contour Temperature

**Figure 5. Simulation of Temperature Distribution,  $h=55 \text{ W/m}^2 \cdot \text{°C}$ ,  $T_f=30 \text{°C}$**

From Figure 5 (a) to the side adjacent to the outside air, the temperature went down whilst the temperature on the inside, and the average relative down not sharp. From Figure 5 (a), the average temperature of steel billets every 5 minutes down  $33,37 \text{°C}$  or  $6.671 \text{°C}$  per minutes, and after 3600 seconds, the average temperature Steel Billet is  $299,56 \text{°C}$ . The average temperature at bellow ot top Billet Stell under  $250 \text{°C}$ , at right or left side under  $300 \text{°C}$  after 3600 second. Simulation results are relevant to the research conducted by the team BBPT result that within 3600 seconds billet temperature in the Hot Box Billet down from  $700 \text{°C}$  to  $300 \text{°C}$  [3]. Mean while, from Figure 5 (b), shows that the temperature contour at time  $t = 3600$  seconds, the bottom and the top of Billet Steel, temperature ranges from  $230 \text{°C}$ - $320 \text{°C}$ , while at right or left side of steel billet temperature range between  $230 \text{°C}$ - $250 \text{°C}$ , and Billet steel on the inside of the temperature range between  $320 \text{°C}$ - $350 \text{°C}$ . The difference in temperature is due to convection heat transfer surface area at the top of Stell Billet larger than the surface area on the bottom or top Steel Billet. The results of the simulation the average temperature as a function of Steel Billet fluid temperature air around with a variety of convection coefficient, which is presented Figure 6.



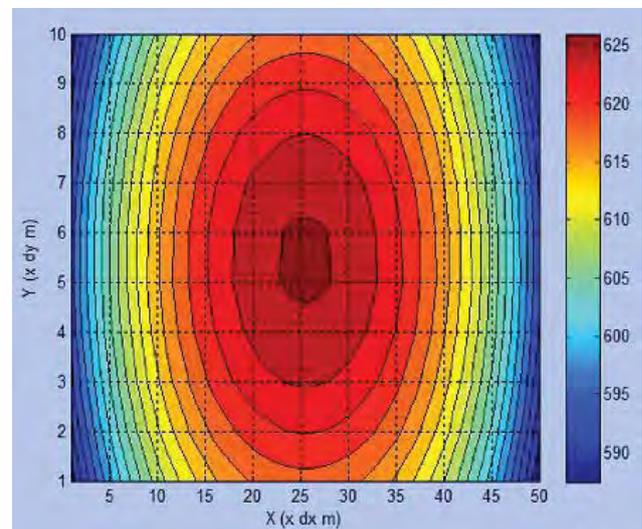
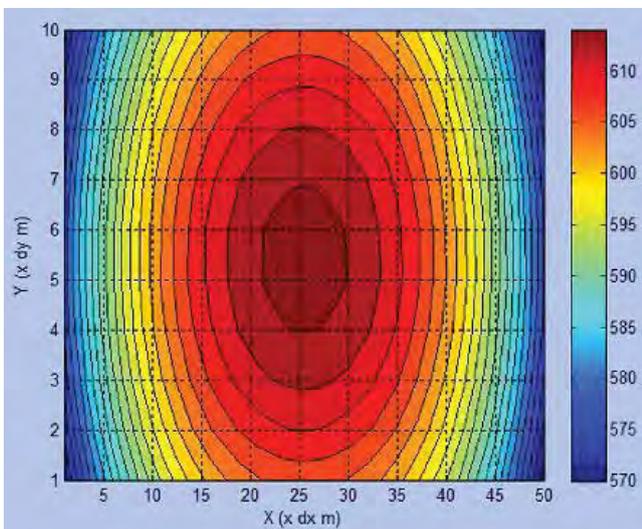
From Figure 6 shows that the air temperature around the convection coefficient and temperature effect on the decline Steel Billet. From Figure 6, every increase in temperature of  $10 \text{°C}$ , Steel Billet temperature at time 3600 seconds on average increase  $5,98 \text{°C}$  for  $h = 60 \text{ W/m}^2 \cdot \text{°C}$ ;  $5,41 \text{°C}$  for  $h = 50 \text{ W/m}^2 \cdot \text{°C}$ ;  $4,63 \text{°C}$  for  $h = 40 \text{ W/m}^2 \cdot \text{°C}$ ;  $3,76 \text{°C}$  for  $h = 30, \text{ W/m}^2 \cdot \text{°C}$  and  $2,73 \text{°C}$  for  $h = 20 \text{ W/m}^2 \cdot \text{°C}$ . Overall increase temperature of the fluid at  $10 \text{°C}$ , the average temperatures are Billet Steel at  $t = 3600$  seconds increase  $4,94 \text{°C}$ . Similarly, from Figure 6, each decrease by  $10 \text{ W/m}^2 \cdot \text{°C}$  convection coefficient, the average temperature of steel billets at time  $t = 3600$  seconds up to  $50,31 \text{°C}$ . This suggests that the increase in fluid temperature did not significantly affect the average temperature Steel Billet, while the smaller convection coefficient of heat transfer it will lead to a rise in temperature Steel Billet, that is to make so that the temperature remains high steel billets to consider is the convection transfer coefficient .



**Figure 7. Contour Temperature,  $h=20 \text{ W/m}^2 \cdot ^\circ\text{C}$ ,  $T_f=30^\circ\text{C}$**

**Figure 8. Contour Temperature,  $h=20 \text{ W/m}^2 \cdot ^\circ\text{C}$ ,  $T_f=120^\circ\text{C}$**

Furthermore, to find out on what conditions should order Hot Box didesaian Steel Billet temperature remains high, consider Figure 7 to 10. From Figure 7 and Figure 8 shows the simulated contour of temperature at time 3600 seconds with the boundary condition  $T_f=30^\circ\text{C}$  and  $T_f=120^\circ\text{C}$  with heat transfer coefficient convection respectively  $h = 20 \text{ W/m}^2 \cdot ^\circ\text{C}$ . From Figure 7 shows that the contour of temperature Steel Billet, it seems that after 3600 seconds the temperature range between  $470^\circ\text{C}$ - $540^\circ\text{C}$ , and from Figure 8 contour of temperature steel billets ranging from  $500^\circ\text{C}$ - $560^\circ\text{C}$ , seen that the difference was significant between the fluid temperature  $30^\circ\text{C}$  and  $120^\circ\text{C}$ . From the two images shows that the temperature at the bottom or the top of the Billet temperature is above  $500^\circ\text{C}$ , but in the left or right side still below  $500^\circ\text{C}$ . From Figure 7 and Figure 8, there are significant difference temperature at  $x=0.1 \text{ m}$ ,  $x=0.2 \text{ m}$ ,  $x=0.3 \text{ m}$ ,  $x=0.4 \text{ m}$  and  $x=0.5 \text{ m}$ . To according Figure 6, the average temperature simulation with  $h = 20 \text{ W/m}^2 \cdot ^\circ\text{C}$ ,  $T_f=30^\circ\text{C}$  is  $517,04^\circ\text{C}$ , and for condition  $h = 20 \text{ W/m}^2 \cdot ^\circ\text{C}$ ,  $T_f=120^\circ\text{C}$  the average temperature is  $541,61^\circ\text{C}$ , overall the average temperature above  $500^\circ\text{C}$ . Mean while, according to research results BTMP BPPT, Steel Billet to close temperature above  $530^\circ\text{C}$ , so parameters the simulation is not in accordance with experimental results.



**Figure 9. Contour Temperature,  $h=10 \text{ W/m}^2 \cdot ^\circ\text{C}$ ,  $T_f=30^\circ\text{C}$**

**Figure 10. Contour Temperature,  $h=10 \text{ W/m}^2 \cdot ^\circ\text{C}$ ,  $T_f=120^\circ\text{C}$**

While from Figure 9 and 10, showing contour of temperature at time 3600 seconds with the boundary condition  $T_f= 30^\circ\text{C}$  and  $120^\circ\text{C}$  with convection heat transfer coefficient constan  $h=10 \text{ W/m}^2 \cdot ^\circ\text{C}$ . From Figure 9, Steel Billet contour of temperature at time 3600 seconds, overall temperature range from  $570^\circ\text{C}$ - $610^\circ\text{C}$ , and from Figure 10 overall temperature range between  $585^\circ\text{C}$ - $625^\circ\text{C}$ , and there are the difference was significant between fluid temperature  $30^\circ\text{C}$  and  $120^\circ\text{C}$ . From Figure 9 and Figure 10, there are not enough significant difference temperature at  $x=0.1 \text{ m}$ ,  $x=0.2 \text{ m}$ ,  $x=0.3 \text{ m}$ ,  $x=0.4 \text{ m}$  and  $x=0.5 \text{ m}$ . The average temperature with condition  $h = 10 \text{ W/m}^2 \cdot ^\circ\text{C}$ ,  $T_f=30^\circ\text{C}$  is  $600,06^\circ\text{C}$ , and for condition  $h = 10 \text{ W/m}^2 \cdot ^\circ\text{C}$ ,  $T_f=120^\circ\text{C}$  the average temperature is  $613,48^\circ\text{C}$ . From Figure 9, Figure 10 and the average temperature, simulation shows that the temperature Steel Billet over time 3600 seconds everything above  $530^\circ\text{C}$ , that it is compliant with the experimental results, where the temperature Billet Steel after 3600 seconds is still

above 530°C. So that parameters in the simulation for this case can be used as a starting point to determine designed Hot Box Billet Steel.

On the basis of the simulation results is reduced temperature steel billets, in making design Hot Box Billet Steel to consider is the amount of convection transfer coefficient, not enough the air temperature around Billet Steel. Hot Box Design steel billets as possible to prevent a the entry of air infiltration around, so that the convection heat transfer is made as low as possible. Referring to the findings of TIM BTMP BPPT, the Hot Box isolated design prevents temperature decrease Steel Billet become 500°C after 3600 seconds [3], this suggests that the convection heat transfer is low enough temperature significantly affects Billet Steel. The existence of Hot Box or tunnel to prevent the entry of outside air infiltration and reduce the amount of convection heat transfer coefficient, it can also reduce costs for steel billet reheating so it can be processed further in the process is the next step.

## 5. CONCLUSION

Computational method finite difference method with pure implicit scheme can be used to simulate the temperature decrease Steel Billet. From the simulation results shown that the reduced temperature Steel Billet significantly affected by convection coefficient of heat transfer, and fluid temperature around Billet steel did not significantly affect the temperature decrease Steel Billet. Thus, in making design Hot Box Billet Steel that convection heat transfer from the environment as little as possible.

The numerical simulation is based on the approach of the two-dimensional model of heat transfer, convection and boundary assuming no influence of radiation and conduction heat transfer coefficient is constant. To obtain optimum results suggested the model was developed with the assumption that boundary convection and radiation, as well convection and conduction coefficient heat transfer is a function of time.

## ACKNOWLEDGMENTS

This paper is the preliminary research of the part of the research to study the phenomenon of heat drop in billet steel was supported by STT-PLN Jakarta under the contract No. 293.SK/1/1/2012. The authors thank Dr. Ir. Supriadi Legino for helping to funding this research, and Mr. Fahmi Ari Aditya for helping to install the simulation programming with Matlab Program setup

## REFERENCES

- [1] Abianto, Dwi Afiat; Sumardi, *Automatic Loop Control Pada Cantilever Intermediate Mill*, Dinas Perawatan Listrik Wire Rod Mill, Makalah Seminar Kerja Praktek, Fakultas Teknik univeritas Diponegoro, 2010.
- [2] Geni, Hindu, *Otomasi Industri Baja Pt, Krakatau Stell, Laporan Kerja Praktek*, Fakultas Teknik, Universitas Diponegoro, 2010
- [3] -----, BTMP BPPT, *Kajian Simulasi Hot Charging Billet Baja*, 2010
- [4] Cengel, Yunus A, *Heat Transfer A Pratical Approach*, Fourth Edition in S1 Unit, MacGraw Hill, Singapore, 2002
- [5] Buchori, L; Y Bindar, dan Isadi, *Komputasi Perpindahan Panas Konduksi Dua Dimensi Untuk Konveksi dan Radiasi Termal*, Proseding Seminar Nasional Rekeyasa Kimia dan Proses, Teknik Kimia Universitas Diponegoro, p.F5.1-F5.8, 2000
- [6] Holman, Jack Philip, *Heat Transfer*, Tenth Edition, MacGraw Hill, USA, 2010
- [7] Capra, Steven Cand Canale. Raymond P, *Numerical Methods for Engineers, With Programming and Software Applications*, Third Edition, MacGraw Hill, Singapore, 2006
- [8] Hoffman, Joe D, *Numerical Methods for Engineers and and Scientists*, Second Edition Revised and Expanded, Marcel Dekker, New York, 2001
- [9] Patankar, Suhas V, *Numerical Heat Transfer and Fluid Flow*, Tylor and Francis, 1980
- [10] Plam, William John; *Introdustion to Matlab 6 for Engineers*, International Edition, MacGraw Hill, Singapore, 2001.
- [12] Minkowycz, W.J; Sparrow, E.M and Murthy, J.Y, *Handbook of Numerical Heat Transfer*, Second Edition, John Wiley & Sons Inc., USA, 2006
- [13] Tusy A. Adibroto, Msc and Widiatmini Sih Winanti, *Recovering waste heat through billet transportation system Modification*, GERIAP National Focal Point for Indonesia, 2006

# Application of $Al_2O_3$ Nanofluids on Sintered Copper-powder Vapor Chamber for Electronic Cooling

Nandy Putra, Ranggi Sahmura, Cahya Tri Anggara, Wayan Nata Septiadi

Heat Transfer Laboratory, Department of Mechanical Engineering, University of Indonesia,  
Kampus Baru UI, Depok 16424,  
Indonesia  
Email: nandyputra@eng.ui.ac.id

## ABSTRACT

The development of electronic devices pushes manufacturers to create smaller microchips with higher performance than ever before. Microchip with higher working load produces more heat. This leads to the need of cooling system that able to dissipate high heat flux. Vapor chamber is one of highly effective heat spreading device. Its ability to dissipate high heat flux density in limited space made it potential for electronic cooling application, like Central Processing Unit (CPU) cooling system. The purpose of this paper is to study the application of  $Al_2O_3$  Nanofluids as working fluid for vapor chamber. Vapor Chamber performance was measured in real CPU working condition.  $Al_2O_3$  Nanofluids with concentration of 0.1%, 0.3%, 0.5%, 1%, 2% and 3% as working fluid of the vapor chamber was tested and compared with its base fluid, water.  $Al_2O_3$  Nanofluids shows better thermal performance than its base fluid due to the interaction of particle enhancing the thermal conductivity. It is expected that application of  $Al_2O_3$  Nanofluids as working fluid would enhance thermal performance of Vapor Chamber, compared to other conventional working fluid being used before.

## Keywords

Vapor Chamber, Nano-fluid,  $Al_2O_3$ , CPU cooling

## 1. INTRODUCTION

Based on Moore's law, the number of transistor in a microchip is predicted to be doubled every 24 month [1]. The prediction made by Gordon Moore, co-founder of Intel, is proven to be accurate. The Intel® i7 "Sandy Bridge" consist about one billion transistors. As the number of transistor rises, the amount of heat that is produced also rises [2]. Meanwhile the trend of computer and gadget development goes to the miniaturization of the product. It made smaller yet with high performance enables them to play high definition videos and doing intensive computing tasks like graphic design [3]. These leads to the need of a compact cooling system that is able to dissipate high heat flux.

Vapor chamber basically is a two phase heat spreading device. Similar to heat pipe, it has excellent ability of dissipating heat through the working fluid phase change, with advantages over cylindrical heat pipe as geometry adaptation and ability for much localized heat dissipation. Its flat shape made vapor chamber ready to be applied as Central Processing Unit (CPU) cooling system [4-6]. Attia and El-Assal [7] investigated the use of pure water, water with surfactant and methyl alcohol at different fill charge ratios to 2-mm high and 50-mm diameter vapor chamber. The study showed the superiority of water over methyl alcohol on the application as working fluid of vapor chamber. The use of surfactant propylene glycol added to water also decrease the thermal resistance of vapor chamber. 0.3 is discovered to be the best filling ratio for this design. Go [8] investigate the performance of vapor chamber with a metal-etched microwick using acetone as working fluid. Chen et al. [9] studied the 58 mm x 58 mm x 6 mm aluminum vapor chamber with radial grooved and sintered powders wick structure with water as working fluid. Wong [10] studied vapor chamber with parallel-grooved wick structure and found that the grooved wick shape could improve the anti-dryout characteristics. Ji [11] built and tested copper foam based vapor chamber with water, ethanol and acetone as working fluid. The result showed that vapor chamber with water showed the best thermal performance among the three variations and charge ratio as well as inclined angle influenced the thermal performance of vapor chamber. Naphon [12] used refrigerant R-141b as working fluid of vapor chamber the refrigerant yield better thermal performance than water as much as 10.73%. Li [13] used infrared thermography to study the thermal performance of plate-fin vapor chamber heat sink. It was found that by vapor chamber, the heat is being transferred with better uniformity to the base plate compared to conventional aluminum heat sink and led to the reduction of maximum temperature. Wong [14] tested vapor chamber with sintered plus mesh wick with water, methanol and acetone as working fluid. The experiment showed that the use of different working fluid has little influence on the thermal performance since the design has short cycling distance of working fluid. Naphon [15] also tested vapor chamber under real operating condition of personal computer to see the performance of vapor chamber on cooling the central processing unit (CPU). The result showed that vapor chamber could reduce the temperature of the CPU and lower the energy consumption.

Meanwhile by the writer's knowledge there is no publication studied the use of nanofluids as the working fluid of vapor chamber. Nanofluids is fluid consist of base fluid and nanometer-sized particle [16]. Its thermal performance over the base

fluid and its application on several heat exchanging devices like thermosyphon and heat pipe has already been studied. Suresh [17] studied the heat transfer characteristics of  $\text{Al}_2\text{O}_3\text{-Cu/water}$  nanofluids. The study revealed that the nanofluids added friction factor to the fluid and enhanced the convective heat transfer by increasing Nusselt number. Hung [18] evaluate the effect of  $\text{Al}_2\text{O}_3\text{/water}$  nanofluids in enhancing the thermal performance of straight heat pipe. The result showed disagreement with the concept of higher nanofluids concentration leads to the higher thermal conductivity since the heat transfer process at the heat pipe mostly happened by convection. Qu [19] evaluate the thermal performance of oscillating heat pipe (OHP) using  $\text{Al}_2\text{O}_3$  nanofluids. The result showed that the enhancement of the OHP thermal performance is mainly due to the nanofluids enhanced the boiling phenomenon at the evaporator by stabilizing the nucleation. It is showed by sedimentation of  $\text{Al}_2\text{O}_3$  nanoparticle at evaporator side. Teng [20] study the use of alumina nanofluids as straight heat pipe working fluid. It was said that the use of alumina nanofluids enhanced the thermal efficiency of heat pipe and there were optimum parameters in each different experimental condition like tilting angle, charge ratio and nanofluids concentration. Saleh [21] investigated the effect of concentration and particle size of  $\text{ZnO}$  nanofluids to the thermal conductivity and to the heat pipe thermal performance. The experiment showed that up to 0.5% fraction volume, the increment of  $\text{ZnO}$  particle concentration on nanofluids enhanced thermal conductivity and larger particle size increased the conductivity. The experiment also showed that the enhancement of thermal conductivity positively affected the thermal performance of the heat pipe. Putra [22] tested five different nanofluids on screen mesh wick heat pipe. The test revealed that  $\text{Al}_2\text{O}_3\text{-water}$  nanofluids has the best influence to the thermal performance of heat pipe and there was a significant coating of nanoparticles found at the screen mesh, produced good capillary structure.

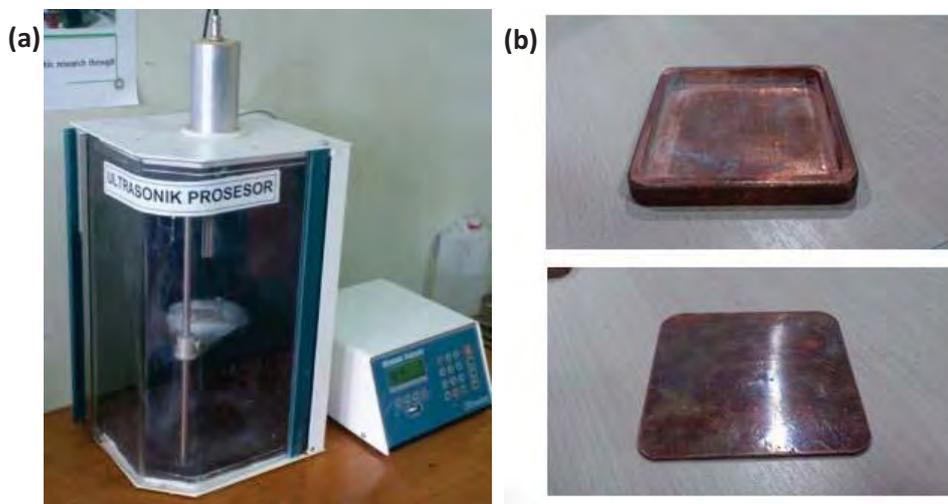


Figure 1 : (a) Ultrasonic processor; (b) Vapor Chamber Container and Top Plate

This study evaluated the effect of  $\text{Al}_2\text{O}_3\text{-water}$  nanofluids to the thermal performance of sintered copper-powder wick vapor chamber. The nanofluids were given at different volume fraction concentration and the inclination effect of vapor chamber were also tested.

## 2. METHODS

### 2.1 Preparation of vapor chamber and nanofluids

The  $\text{Al}_2\text{O}_3$  nanofluids being used in this experiment was produced and tested by the same method being used by Putra [22].  $\text{Al}_2\text{O}_3$  nanoparticles were dispersed in the base fluid of distilled water by ultrasonically for 30 minutes in ultrasonic processor (Figure 1a). The volume fraction concentration of nanoparticle in nanofluids is calculated by using equation (1):

$$\% \text{ volume fraction} = \frac{\frac{W_{np}}{\rho_{np}}}{\frac{W_{np}}{\rho_{np}} + \frac{W_{bf}}{\rho_{bf}}} \quad (1)$$

where  $W_{np}$  and  $\rho_{np}$  are the weight and the density of nanoparticle, and  $W_{bf}$  and  $\rho_{bf}$  are the weight and the density of base fluid respectively.

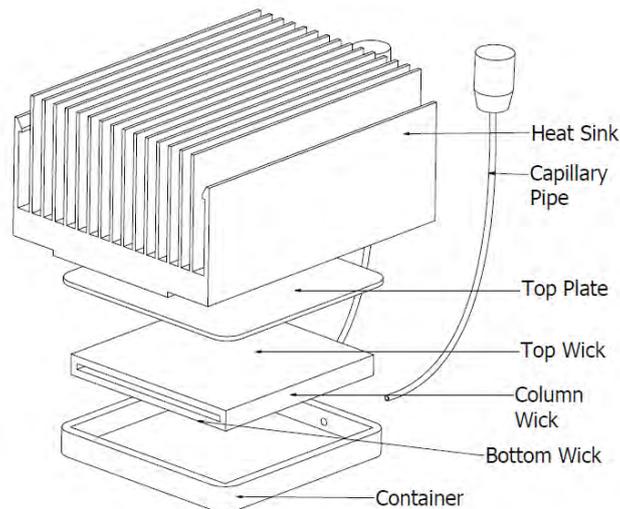


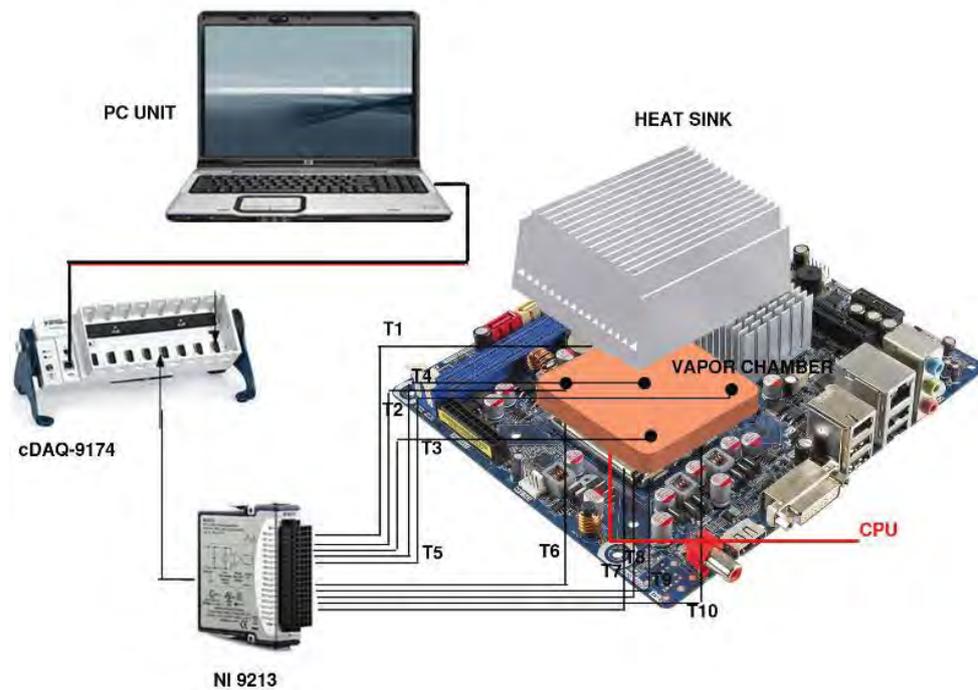
Figure 2 : Vapor chamber assembly for the experiment

Vapor chamber designed for this experiment made from copper with total dimension of 60 mm x 60 mm x 8 mm, assembled of bottom container, top plate and wick structure (Figure 1b) The evaporator and condenser thickness were 1.2 mm with 2 mm sintered copper-powder wick on the inner side of both, creating the bottom and the top wick. The sintered copper-powder made from copper-powder with the mesh of 300  $\mu\text{m}$ . The bottom and the top wick were connected by column wick providing path for the liquid to flow back from the evaporator to the condenser (see figure 2). The bottom container and the top plate were welded together along with capillary pipe attached to insert the working fluid and do the vacuum process. The heat sink fan being used in this experiment is the standard heat sink fan for microprocessor Intel® Pentium 4 socket 478. The heat sink was grooved so the vapor chamber can fit in snugly. The fluid insertion and vacuum process helped by vacuum pump model VE110 1/8 HP. The working fluid injected to the vapor chamber has charge volume ratio of 0.6 or 3.45 ml. The vacuum process itself was conducted at the special vacuum chamber device at the Applied Heat Transfer Research Group Laboratory.

## 2.2 Experimental setup

The evaluation of vapor chamber thermal performance was conducted by arranging the experimental setup as shown in figure 3. The vapor chamber integrated heat sink fan was plugged to the standard heat sink holder to ensure the same condition for all parameter variations. At the evaporator of the vapor chamber, central processing unit (CPU) of Intel® Pentium 4 socket 478 2.4GHz were placed as the heat source. Having 13.1 Watt at the idle condition and 48.3 Watt at the maximum load condition, the CPU was being loaded by running software called Prime95. This software could set the CPU to its maximum working capacity, thus maximum heat load. The thermocouples being used is the type K thermocouple, five mounted on the surface of the CPU and five at the condenser surface of vapor chamber. To minimize the thermal gap at the junction of the vapor chamber

and to ensure the validity of the data being acquired, the surface of the CPU and the condenser were grooved to the size of the



thermocouple. All the

Figure 3: Experimental Setup

thermocouples were connected to the high precision NI 9213 data acquisition module. As the experiment undergone, the ambience temperature is being kept at  $25 \pm 0.5$  °C.

The variations of nanofluids volume fraction concentration were 0.1 %, 0.3%, 0.5%, 1%, 2% and 3% to see the effect of concentration to the enhancement of thermal performance. The inclination angles being used are 0° or horizontal position, 45° and 90° or the vertical position.

### 3. RESULT AND DISCUSSION

#### 3.1 Effect of working fluid to the thermal performance

To evaluate the effect of working fluid in thermal performance of vapor chamber, different working fluid was tested. Firstly, vapor chamber without working fluid was tested at CPU with no load for 10 min, continued with full load condition for 20 min and back to the no load condition for 10 min. Then, water and  $\text{Al}_2\text{O}_3$ -water nanofluids were tested with the same loading condition. The result then compared with cooling performance of conventional heat sink without vapor chamber. The result is presented in Figure 4.

It can be observed from Figure 4a. that vapor chambers vividly have better thermal performance than conventional cooling system heat sink fan, shown by the lower CPU temperature with  $\Delta T$  around 3°C at no load condition. But can be seen that at the effect of working fluid has not significantly give impact to the thermal performance of vapor chamber at no load condition. This is due to the heat transfer phenomenon that was dominated by conduction and free convection. At this level of load, the heat from the CPU was not enough to ignite the boiling phenomenon inside the vapor chamber. Thus, the heat transfer was being conducted mostly by conduction and, in the small amount, by free convection. Since dominated by conduction, the effect of working fluid become less impactful, which can be seen from the result that empty vapor chamber produced only slightly higher CPU temperature than fluid-charged vapor chamber. This also validated by the fact that nanofluid-charged vapor chamber did not yield better performance than water-charged vapor chamber. Although nanofluids has better conductivity than its base fluid, the vapor chamber works efficiently when the phase change occurs so the enhanced thermal conductivity of nanofluids only had small effect on this loading condition.

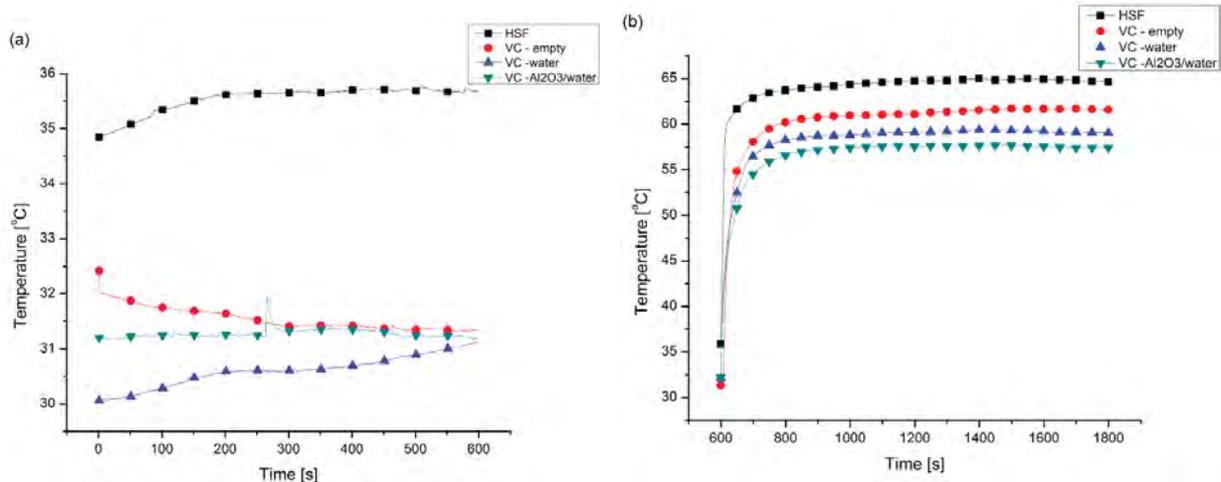


Figure 4 : Effect of working fluid to the thermal performance of vapor chamber at (a) no load, and (b) full load condition

While at the full load CPU operating condition, shown by Figure 4b, the effect of working fluid was greatly impact the thermal performance of vapor chamber. At this loading condition, it can be seen that vapor chamber without working fluid shows worse thermal performance than the vapor chamber with working fluid as can be seen from its higher CPU temperature compared to that on the vapor chamber with working fluid. The average CPU temperature for empty vapor chamber and water charged vapor chamber is 61.36 °C and 59.12 °C respectively. This happened because at this loading condition, the heat from the CPU intensifies the boiling phenomenon inside the vapor chamber, making the heat transfer at the fluid-charged vapor chamber undergone efficiently. While at the empty vapor chamber, the heat transfer depended only on conduction, increasing the thermal resistance. It also can be observed that nanofluid-charged vapor chamber shows better thermal performance than water-charged vapor chamber at this loading condition, producing average CPU temperature of 57.52 °C. This indicates that the enhancement of thermal characteristics of nanofluids affected the thermal performance at the greater amount on high heat load condition, rather than at low heat load condition. As the enhancement of thermal conductivity only affected the performance at the small amount, the other improvement of the nanofluids over its base fluid should be analyzed.

### 3.2 Effect of nanofluids concentration

To observe the nanofluids enhancement to the thermal performance of vapor chamber, variations of volume fraction concentration of Al<sub>2</sub>O<sub>3</sub>-water nanofluids were being tested. The volume fraction concentration of 0.1%, 0.3%, 0.5%, 1%, 2% and 3% were tested under the same CPU loading condition. The result is presented in Figure 5. From Figure 5a. can be observed that at no load condition, increment of volume fraction concentration of Al<sub>2</sub>O<sub>3</sub>-water nanofluids from 0.1% up to 1% did not give significant effect on vapor chamber thermal performance as the temperature of CPU scattered randomly at the temperature range of 29.8 °C – 31.5 °C. But at the volume fraction concentration of 2% and 3%, significant improvement of thermal performance was noted. At these volume fractions of nanofluids, CPU temperature fell below 29 °C. This showed that at certain amount of nanoparticles suspended at the base fluid, nanofluids can increase significantly the thermal performance by enhancing the heat transfer by conduction greatly. At the concentration of 2% and 3%, there were denser formations of nanoparticles at the evaporator so the thermal conductivity were greatly increased and reduce the thermal resistance. This help the heat transfer and reduce the average CPU temperature.

At the full load condition, shown by Figure 5b, it can be observed that along with the increment of volume fraction concentration of nanofluids, the thermal performance increased. The 3% nanofluids concentration yields the best thermal performance, producing average CPU temperature of 54.64 °C. The lower nanofluids concentration produces higher average CPU temperature, that is 57.31 °C, 57.52 °C, and 57.94 °C for 2%, 1% and 0.5% volume fraction concentration. The 0.3% and 0.1% nanofluids concentration produced no significant improvement of thermal performance, showed by the slight difference in average CPU temperature compared to water as working fluid.

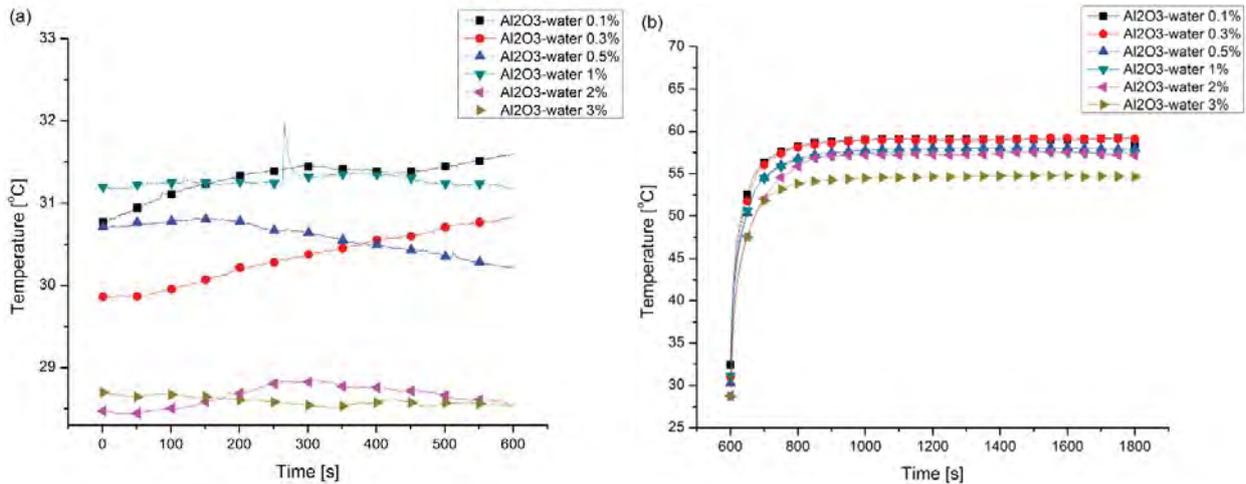


Figure 5 : Effect of Al<sub>2</sub>O<sub>3</sub>-water nanofluids concentration to the thermal performance of vapor chamber at (a) no load, and (b) full load condition

The 0.3% and 0.1% nanofluids concentration for vapor chamber working fluid produced average CPU temperature of 59.02 °C and 59.04 °C respectively, while water produced 59.12 °C. Since the thermal conductivity only affects the thermal performance at the small amount in this loading condition, the enhancement brought by the nanofluids were explained by the improvement of boiling phenomenon at evaporator. As discussed by Qu [19], the nanoparticles suspended at base fluid can enhance and stabilize the nucleation at the evaporator and increase the bubble release frequency, decreasing the thermal resistance of evaporator. This phenomenon increased as the concentration of nanofluids increased. This explained the higher thermal performance showed by the higher nanofluids concentration.

### 3.3 Effect of inclination angle

As its application for CPU cooling system, the effect of inclination angle to vapor chamber thermal performance has to be observed since the use of electronic device tend to be mobile and at many possible angle of operating position. The investigation conducted by testing vapor chamber with two different nanofluids concentration at three different inclination angles. The result is presented in Figure 6.

The results shows that for both concentration, inclination angle brought similar effect on the thermal performance of vapor chamber. For 2% nanofluid concentration, inclination angle of 45° only brought slight increase at the average CPU temperature over the horizontal position. Average temperature of CPU at horizontal position and at 45° inclination angle is 56.06 °C and 56.34 respectively. While at the vertical position or 90° inclination angle, vapor chamber produce significantly higher average CPU temperature as much as 57.32 °C. The same trend happened for the 3% nanofluids concentration. Vapor chamber charged with 3% Al<sub>2</sub>O<sub>3</sub>-water nanofluids yielded average CPU temperature of 53.72 °C, 53.83 °C, and 53.93 °C for horizontal, 45° inclination angle and vertical position. This is due to the different amount of working fluid available at the evaporator at different inclination angles. At horizontal position, evaporator is flooded with working fluid, ensuring the availability of fluid which absorbs heat and doing the phase change process. This made the heat transfer undergone efficiently and prevented dry-out. At 45° inclination angle, the working fluid of the evaporator decreased due to gravity. The working fluids were moved to the lower side of vapor chamber. Less working fluid means less amount of mass undergone the phase change, leading to the less amount of heat absorbed. This also multiply the possibility of dry-out, which happened because of the gravity hamper the ability of wick to pump liquid. The phenomenon is getting worse for the 0° inclination angle since the gravitational force become larger. At this vertical position, there was very little amount of working fluid left at the evaporator side, letting the heat transfer dominated by conduction and increasing the thermal resistance.

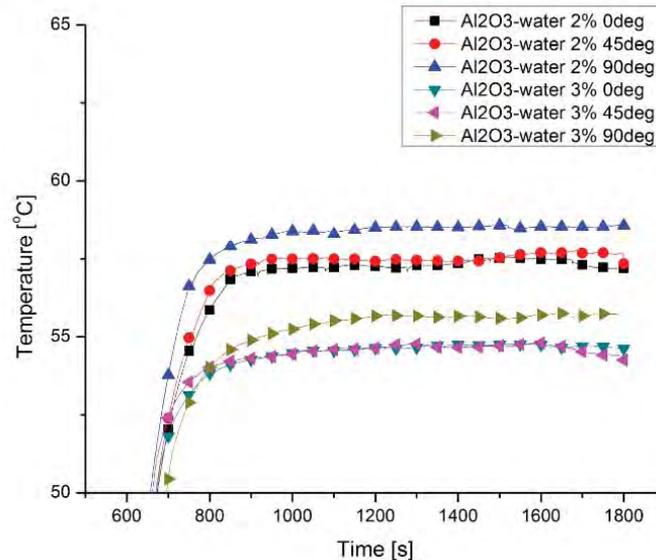


Figure 6 : Effect of inclination angle on thermal performance of vapor chamber

#### 4. CONCLUSION

The effect of working fluid on the vapor chamber was investigated. It was revealed that at a lower heat load, effects of working fluid are small due to the domination of conduction in vapor chamber heat transfer process. The effects become more and more significant as the higher heat load applied. The higher heat load intensify the boiling process and made the heat transfer process undergone efficiently. The effect of nanofluids concentrations were also observed. It was discussed that higher concentration of nanofluids enhance the thermal performance of vapor chamber due to the nanoparticles suspended at the working fluid enhancing and stabilizing the nucleation process, increasing the bubble release frequency and improving boiling phenomenon at the evaporator. This reduce thermal resistance and increase the thermal performance of vapor chamber. The effect of inclination angle was also observed that the effect of gravitational force made the horizontal position as the best working position for vapor chamber.

#### REFERENCE

- [1] R.R.Schaller. *Moore's law: past, present and future* Spectrum, IEEE Vol 36 (2002) 52-59
- [2] L.B. Kish. *End of Moore's law: thermal (noise) death of integration in micro and nano electronics*. Physics Letters A 305 (2002) 144-149
- [3] R. Godwin-Jones. *Emerging Technologies Mobile-Computing Trends: Lighter, Faster, Smarter*. Language Learning & Technology Volume 12, Number 3 (2008) 3-9
- [4] S.C. Wong, K.C. Hsieh, J.D. Wu, W.L. Han. *A novel vapor chamber and its performance*. International Journal of Heat and Mass Transfer 53 (2010) 2377 – 2384
- [5] Y.S. Chen, et al. *Numerical simulation of a heat sink embedded with a vapor chamber and calculation of effective thermal conductivity of a vapor chamber*. Applied Thermal Engineering 29 (2009) 2655-2664
- [6] Y. Wang, K. Vafai. *Transient characterization of flat plate heat pipes during startup and shutdown operations*. International Journal of Heat and Mass Transfer 43 (2000) 2641-2655
- [7] A.A. Attia, B. El-Assal. *Experimental investigation of vapor chamber with different working fluids at different charge ratios*. Ain Shams Engineering Journal 3 (2012) 289-297
- [8] J.S. Go. *Quantitative thermal performance evaluation of a cost-effective vapor chamber heat sink containing a metal-etched microwick structure for advance microprocessor cooling*. Sensors and Actuators A 121 (2005) 549-556
- [9] Y.T. Chen, S.W. Kang, Y.H. Hung, C.H. Huang, K.C. Chien. *Feasibility study of an aluminum vapor chamber with radial grooved and sintered powders wick structures*. Applied Thermal Engineering 51 (2013) 864-870
- [10] S.C. Wong, K.C. Hsieh, J.D. Wu, W.L. Han. *A novel vapor chamber and its performance*. International Journal of Heat and Mass Transfer 53 (2010) 2377-2384
- [11] X. Ji, J. Xu, A.M. Abanda. *Copper foam based vapor chamber for high heat flux dissipation*.
- [12] P. Naphon, S. Wiriyaart. *Study on the vapor chamber with refrigerant R-141b as working fluid for HDD cooling*. International Communications in Heat and Mass Transfer 39 (2012) 1449-1452
- [13] H.Y. Li, M.H. Chinang, C.I. Lee, W.J. Yang. *Thermal performance of plate-fin vapor chamber heat sinks*. International Communication in Heat and Mass Transfer 37 (2010) 731-738
- [14] S.C. Wong, S.F. Huang, K.C. Hsieh. *Performance tests on a novel vapor chamber*. Applied Thermal Engineering (2011) 1757-1762
- [15] P. Naphon, S. Wongwises, S. Wiriyaart. *On the thermal cooling of central processing unit of the PCs with vapor chamber*. International Communications in Heat and Mass Transfer 39 (2012) 1165-1168
- [16] Z.H. Liu, Y.Y. Li. *A new frontier of nanofluid research – Application of nanofluids in heat pipes*. International Journal of Heat and Mass Transfer 55 (2012) 6786-6797

- [17] S. Suresh, K.P. Venkitaraj, P. Selvakumar, M. Chandrasekar. *Effect of  $Al_3O_3$ -Cu/water hybrid nanofluid in heat transfer*. Experimental Thermal and Fluid Science 38 (2012) 54-60
- [18] Y.H. Huang, T.P. Teng, B.G. Lin. *Evaluation of the thermal performance of a heat pipe using alumina nanofluids*. Experimental Thermal and Fluid Science 44 (2013) 504-511
- [19] J. Qu, H.Y. Wu, P. Cheng. *Thermal performance of an oscillating heat pipe with  $Al_2O_3$ -water nanofluids*. International Communications in Heat and Mass Transfer 37 (2010) 111-115
- [20] T.P. Teng, H.G. Hsu, H.E. Mo, C.C. Chen. *Thermal efficiency of heat pipe with alumina nanofluid*. Journal of Alloys and Compounds 5045 (2010) 5380-5384
- [21] R. Saleh, N. Putra, S.P. Prakoso, W.N. Septiadi. *Experimental investigation of thermal conductivity and heat pipe thermal performance of ZnO nanofluids*. International Journal of Thermal Science 63 (2013) 125-132
- [22] N. Putra, W.N. Septiadi, H. Rahman, R. Irwansyah. *Thermal performance of screen mesh wick heat pipes with nanofluids* Experimental Thermal and Fluid Science 40 (2012) 10-17

# Effect of Orifice Shape to Convective Heat Transfer of Impinging Synthetic Jet

Harinaldi<sup>a</sup>, Christoforus Deberland<sup>a</sup>, and Damora Rhakasywi<sup>a</sup>

<sup>a</sup> Departemen Teknik Mesin Fakultas Teknik Universitas Indonesia,  
Kampus UI-Depok, Jawa Barat, 16424, Indonesia  
E-mail : harinald@eng.ui.ac.id , christoforus.deberland@ui.ac.id ,damora.rhakasywi@ui.ac.id

## ABSTRACT

Nowadays, a greater heat load due to miniaturization of electronic products causes the need for a new cooling system that works more efficient and has a high thermal efficiency, Synthetic jet is potentially useful for cooling of electronic components. This paper reports the results of our experimental studies, the influence of orifice shape for Impinging Synthetic Jet cooling performance. The effect of shape of the orifice of an impinging synthetic jet assembly on apparatus cooling of a heated surface is experimentally investigated. It will be seen the characteristics of convective heat transfer by moving the piezoelectric membrane. The prototype of synthetic jet actuator with two piezoelectric membrane that operate by 5 volt electrical current and creates a sinusoidal wave. The orifice shapes considered are square and circular. The results showed the significant influence of orifice shape and sinusoidal wave frequencies to the heat transfer rate that obtained. The temperature drop with a square orifice is found to be larger than that with circular shapes. Square orifice has larger covered area if compared to circular orifice at the same radius, thus resulting in larger entrainment rate that leading to an increase of heat transfer performance.

## Keywords

Cooling, Impinging Synthetic Jet, Orifice, Temperature drop

## 1. INTRODUCTION

Today, the requirement for proper thermal management which is perhaps the most crucial part of the electronic system design due to miniaturization is emphasized. One of the major causes for failure of electronic devices is thermal overstressing. A major challenge for thermal engineers is to create new alternative cooling system for such high heat flux components. In this study, synthetic jet with impingement type which can potentially be used for cooling of hot-spots is investigated. Synthetic jet works as jet of vortex generated from the continues vibration of the piezoelectric membrane which is driven by function generator to produce flow separation at the outlet of a cavity. A synthetic jet can be defined as zero-net-mass flux device commonly formed by suction and blowing of fluid from a small cavity [1]. Due to pulsating nature of the flow, the entrainment of ambient fluid into the jet is high as compared to that in a continuous jet, which helps in effective cooling mechanism [2]. Synthetic jet was driven by a piezoelectric actuator membrane that has a zero net mass input but produce non-zero momentum output.

In previous study about orifice parameter, Gulati et al. [3] discussed the effect of shape of orifice on local heat transfer enhancement for different jet impinging distance and Reynolds numbers. Moreover, Amitay et al. [4] experimentally investigated the efficiency and mechanism of cooling at constant heat flux surface by impinging synthetic jet. In their measurements, high frequency (1200 Hz) jets were found to be more effective at smaller axial distances and the low frequency (420 Hz) jets were found to be more effective at larger axial distances. In that work, a comparison with continuous jet was also presented. Chaudhari et al. (2010) discussed the effect of different shapes of orifice on the heat transfer characteristics of impinging synthetic jet. It was noticed that the rectangular orifice gives better heat transfer performance as compared to both square and circular orifice, at small axial distances. However, at large axial distances the square orifice outperformed other orifice shapes investigated. Lee et al. [5] studied the influences of orifice diameter on impinging jet heat transfer and fluid flow. They reported that local Nusselt numbers in the region corresponding to  $0 \leq r/d \leq 0.5$  increased with increasing orifice diameter. Many prior studies were focused on the role of orifice parameter on impingement heat transfer. Lee et al. [6] investigated the effect of orifice configuration for  $l/d$  of 0.2 with three different types of profiles at orifice exit, i.e., square edged, standard edged and sharp edged orifices. The tests were carried out for unconfined air jets impinging normally on smooth flat surface and the heat transfer results agree that at stagnation region sharp edged orifice performs better than others. Convective heat transfer is a very important aspect in synthetic jet cooling system since the generated vortices tend to dissipate the heat from surface to be cooled. McGuinn et al. [7] investigated synthetic jet as a current potential technology for microelectronics cooling with focusing on the distribution of flow and heat transfer characteristics from jet sprayed on the surface by blowing with jet at the Reynolds number range of 1100-4900 and orifice diameter of 1-6 mm, as result is a deal between measured average and fluctuating heat transfer distributions and local acceleration of synthetic jet. Travnicek and

Tesar [8] recommended that the basic goal in convective heat transfer is to mobilize the cooling fluids as near as the surface to be cooled and the synthetic jet impinging mechanism are influenced by the actuator configuration such as the orifice and cavity parameters.

In the present work, a comprehensive study was done by computational and experimental method on an original design of synthetic jet actuator that operate based on piezoelectric membrane which driven by function generator. In the current stage, the main focus of the study was to characterize the temperature field of an impinging flow configuration with variation of orifice shape and driving frequency of membrane to generate turbulence flow.

## 2. METHODS

The present study was done comprehensively by computational and experimental works in order to investigate effect of orifice shape to cooling performance of an impinging synthetic jet in cooling system for microeletronic component. The detail of each works are explain in detail as follows.

### 2.1 Computational work

This computational model is used to analyze the thermal flow at synthetic jet by using a mathematical model k- $\omega$  SST (Shear Stress Transport). Ambient temperature is assumed 27 °C and the temperature of the bottom wall is heated, maintained at isothermal temperature of 60 °C. Boundary walls on both sides of the actuator is assumed to have a constant static pressure with a pressure of 1 atm.

After that, the movement of the diaphragm is modeled with a user defined function (UDF). In this modeling, it will be seen some turbulent flow regions, while others remain at the laminar flow conditions indicated by the low value of Reynolds. The parameters used at this simulation are model arrangement, fluid properties and the boundary conditions.

At the beginning ( $t = 0$ ), the position of the diaphragm is at the bottom of the cavity. The diaphragm movement is assumed equal to the movement of the piston in a cylinder, in which upper membrane uses variation of square Waves and lower membran uses variation of sine waves. The motion of upper and lower membran are approached with equation (1) to (4).

Deflection of upper membran expressed as

$$Y(t) = \frac{4k}{\pi} \left( \sin(2\pi ft) + \frac{1}{3} \sin(2\pi ft) + \frac{1}{5} \sin(2\pi ft) \right) \quad (1)$$

Therefore, velocity of upper membrane expressed as,

$$V(t) = \frac{4k}{\pi} \left( 2\pi f \cos(2\pi ft) + \frac{2\pi f}{3} \cos(2\pi ft) + \frac{2\pi f}{5} \cos(2\pi ft) \right) \quad (2)$$

Whereas, deflection of lower membrane expressed as

$$Y(t) = k(\sin(2\pi ft)) \quad (3)$$

And, Velocity of lower membrane expressed as

$$V(t) = k(2\pi f \cos(2\pi ft)) \quad (4)$$

where k represented maximum velocity actuated by oscillated motion of membrane in a cavity, t is time operation both of membrane and f is frequency of wave function that given by function generator.

### 2.2 Experimental work

The quality of cooling results is verified by time history of convective heat transfer studies, and the results are validated against existing experimental data. Experimental activities were carried out by measuring the temperature at the heatsink using a digital thermometer for 120 minutes. The heatsink module used in this study has circular form with 32 fins. The material was made of aluminum. The heatsink diameter was 11 cm and height of 5 cm. Heat source was obtained from the heater mat at 60°C which was controlled by using a thermostat. Measurements were performed using k-thermocouple under open conditions at ambient temperature 30°C. The impinging synthetic jets modul used in this study were constructed in the form of a cylinder cavity having two piezoelectric membrane at the top and bottom. Piezoelectric wass working to move the surrounding fluid in order to remove the air from the nozzle, with square and circular shape of orifices. The casing was made of nylon material that could be assembled easily. Sinusoidal and square wave function was generated by a sweep function generator with the frequency of 80 Hz, 120 Hz and 160 Hz. The experimental work was conducted using variation of orifice shape, that is square and circular orifice at the same diameter, 2 mm.

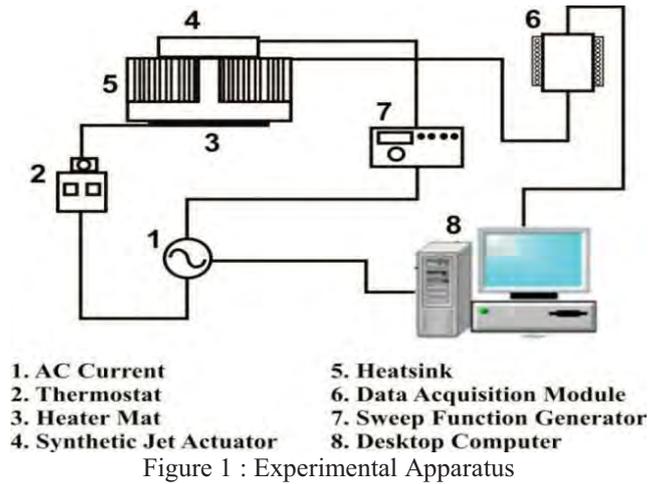


Figure 1 : Experimental Apparatus

Figure 1 shows the detail of the experimental apparatus used in this study which consisted of the thermostat, heater mat, impinging synthetic jet module, heat sink and DAQ (Data Acquisition). More detail for Synjet cooling apparatus was depicted in Figure 2.

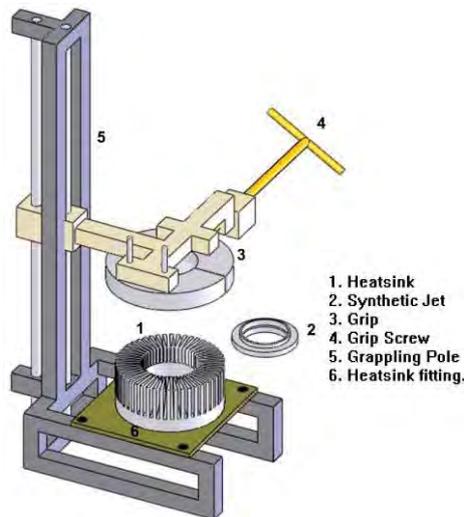


Figure 2 : Synthetic Jet Cooling Apparatus

### 3. RESULTS AND DISCUSSION

#### 3.1 Computational work

Figure 3 depicted static temperatur contour inside cavity, inside heatsink, and outer field outside the heatsink using circular orifice with 120 Hz of Sinusoidal wave function. Simulation was made for 1/16 condition with the assumption that suction phase and blowing phase was uniformly at every nozzle.

In Figure 3, it can be seen that heat flow moving up from cavity heatsink toward heatsink fins. At condition  $\frac{1}{4}$  cycle, heat that produced by heater mat starts to move up inside the heatsink. And then, at condition  $\frac{1}{2}$  cycle, it seems that heatflow is move toward heatsink fins. Furthermore, at condition  $\frac{3}{4}$  cycle, heatflow moves faster than before to go out from heatsink fin. And at 1 cycle, heatflow is released from heatsink to environment gradually.

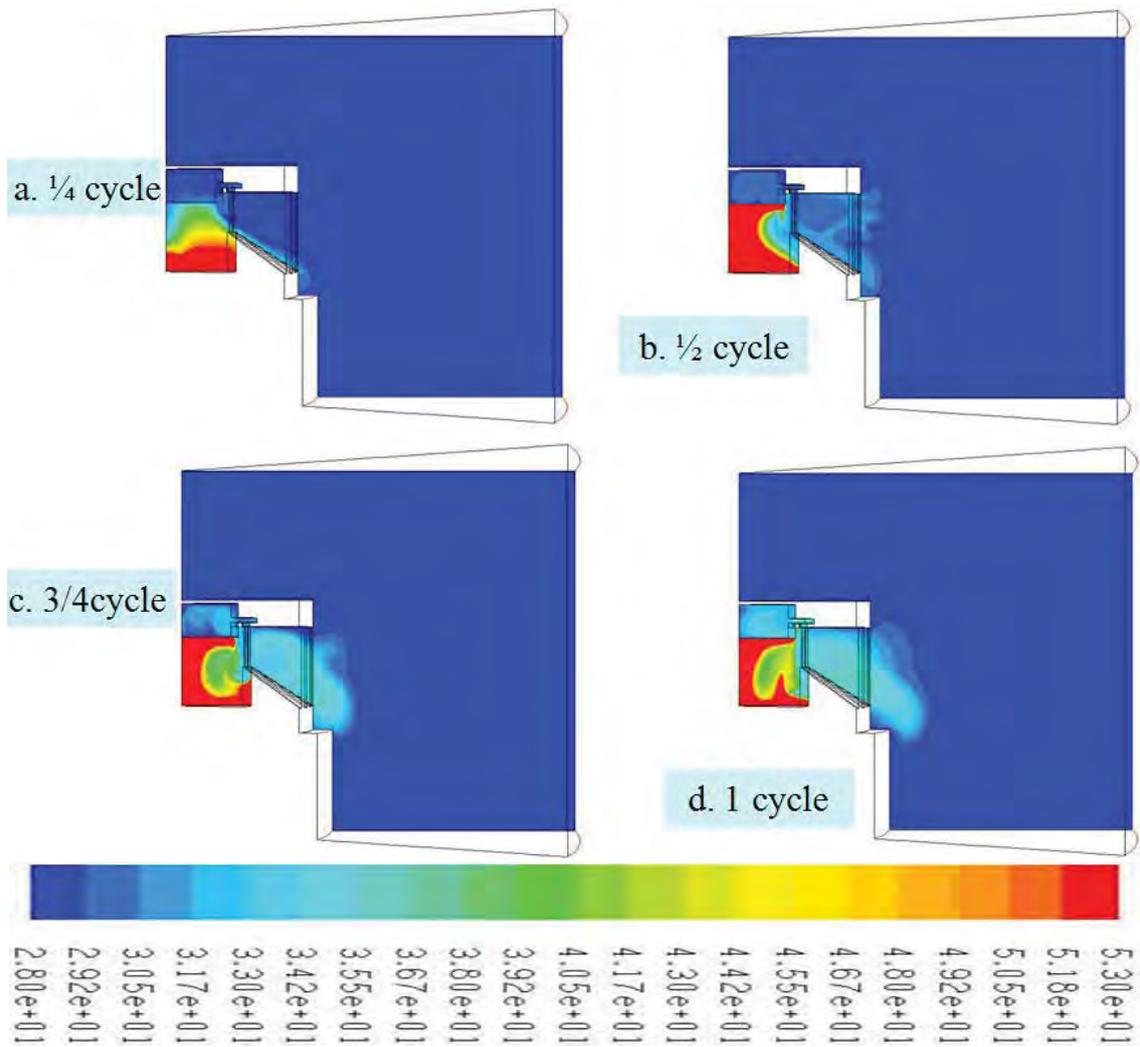


Figure 3 :Temperature Contour with Circular orifice (120 Hz of square Function).

Figure 4 shows static temperature contour inside cavity, inside heatsink, and outer field outside the heatsink using square orifice with 120 Hz of square wave function. Simulation was made for 1/16 condition with the assumption that suction phase and blowing phase was uniformly at every nozzle.

In Figure 4, seen that heat flow move up from cavity heatsink toward heatsink fins but faster if compared with sinusoidal wave function. At condition 1/4 cycle, 1/2 cycle, and 1 cycle was seems like using sinusoidal wave function but with faster moving fluid and contour of static temperature inside cavity, inside heatsink was more dominated with low temperature region if compare with sinusoidal driven membrane.

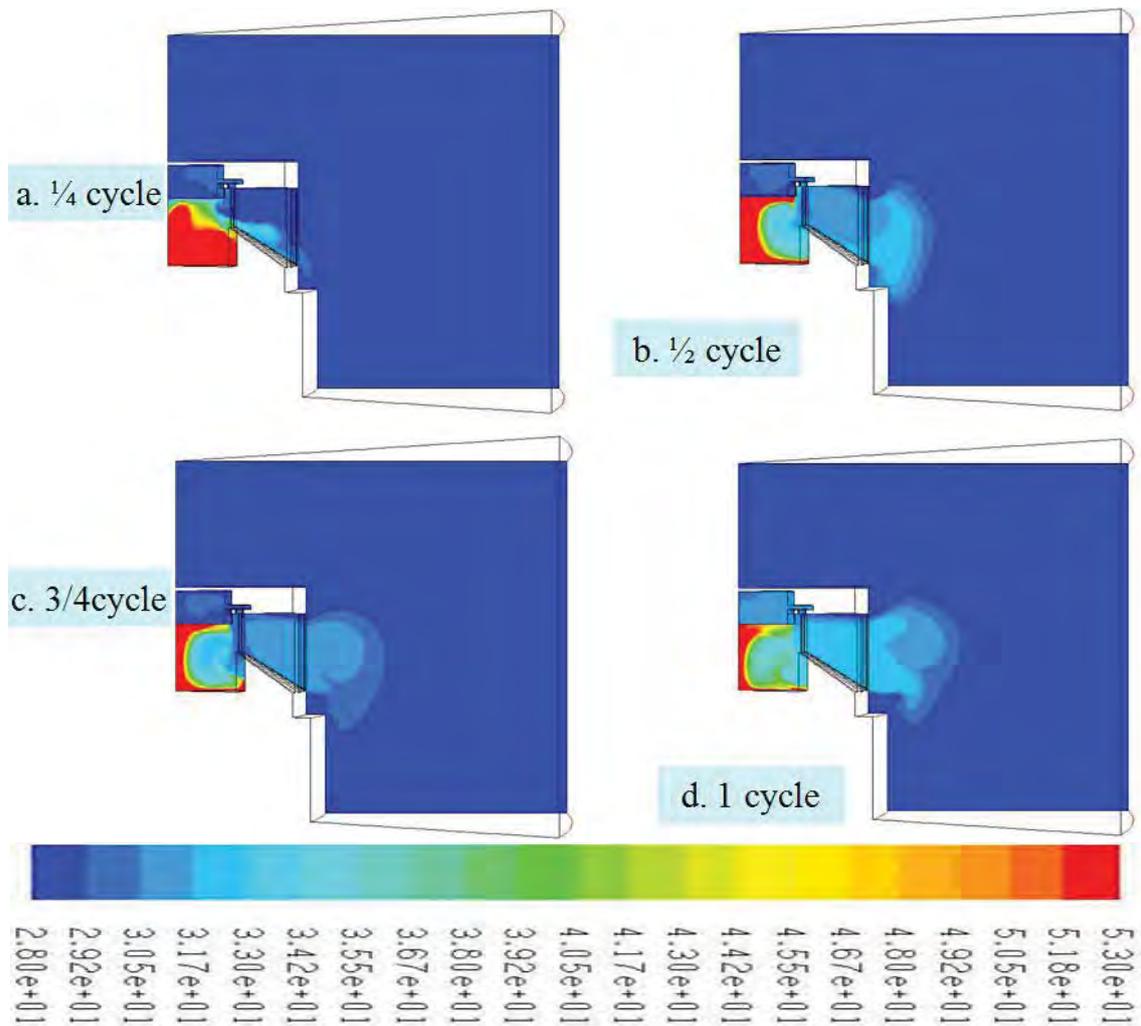


Figure 4. Temperature Contour with square orifice (120 Hz of square Function).

### 3.2 Experimental work

Figure 5 shows the temperature history for 3600 seconds experiment with variation of orifice shape at the same diameter using 120 Hz of square wave function. In that figure, it can be seen that at both of orifice shape, cooling performance become remarkable after 1000 seconds activation of synthetic jet. Apparatus with square orifice is decrease 2.8°C temperature during the experimental work while circular orifice at the same diameter decrease 1.5°C. Moreover, after 2500 seconds with circular orifice, the temperature of heatsink tend to rise, whereas with square orifice, temperature of heatsink still decrease although with lower temperature gradient. So it follows that 120Hz of square with square orifice has better cooling characteristics than circular orifice at the same condition. The tendency of temperature to rise as well as the cooling performance with lower gradient temperature at any given time indicate significant effects of recirculation due to confinement effect. Agrawal et al. [9] have explored that confinement effect can be decreased if we increase the impinging distance at a certain number. However, at larger axial distances, the jet velocity reduces due to entrainment of still ambient air, which again reduces the heat transfer coefficient. Gulati et al. [3] have discussed that besides recirculation, another possible reason and need to be investigated later for the higher cooling performance with square orifice at small distances is that the Nusselt number contours retain the shape of the orifice from which the flow emerges at lower axial distances. So that, a larger surface area is covered by the flow with a square orifice at smaller axial distances if compared to circular orifice with same radius. From the previous investigation by Grinstein and DeVore [10], the entrainment rate for the square orifice is significantly larger than those for circular orifice. Due to a large entrainment, square orifice attains a larger mass flux at the same distance from the orifice. The mass flux has a direct bearing on momentum and heat transport between jet and surrounding. This is a possible reason of square orifice synthetic jet outperforming its circular orifice counterpart.

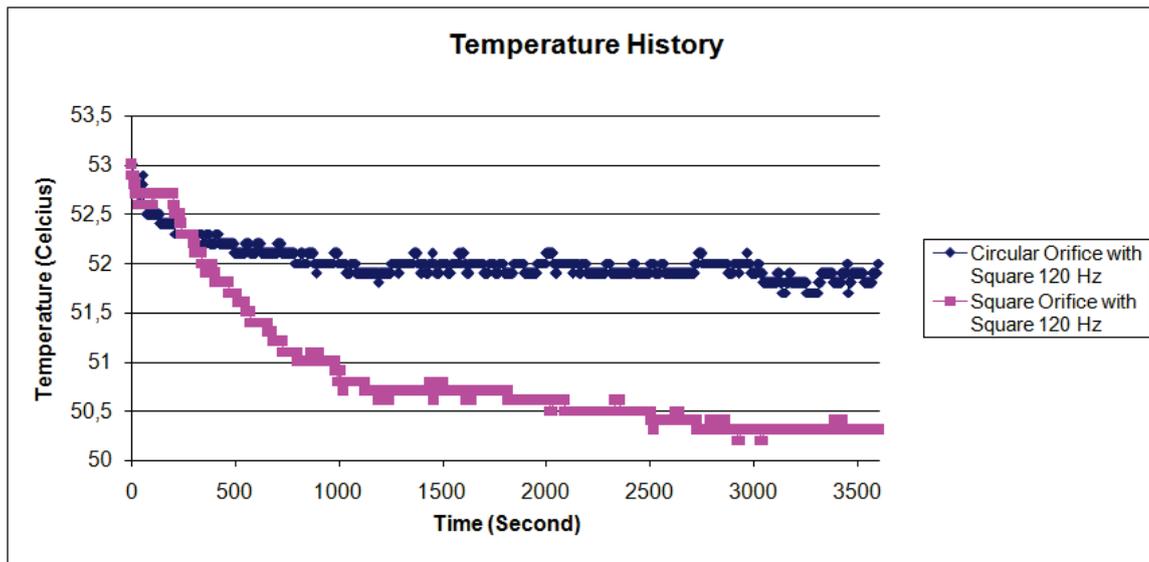


Figure 5 : Temperature History of Experiment with square and Circular orifice (120 Hz of square Function).

#### 4. CONCLUSION

The heat transfer experiments and CFD simulation are conducted using synthetic jet with various type and frequency of wave function and shape of orifice. From variation of sinusoidal and square 80 Hz, 120 Hz, and 160 Hz and orifice shape variation square and circular orifice, it is found that cooling effect for 60 minutes measurement was optimum with 120 Hz square function and square orifice. Both of experimental and computational results revealed that using shape orifice variation on same aspect ratio give significant effect to develop synthetic jet as new alternative cooling system of microelectronic components. Square orifice has larger covered area if compared to circular orifice at the same radius, thus resulting in larger entrainment rate that leading to an increase of heat transfer performance.

#### ACKNOWLEDGMENT

This work was supported within the DRPM-UI program of the University of Indonesia (project number 1927/H2.R12.2.1/HKP.05.00/2012).

#### REFERENCES

- [1] B.L Smith, A. Glezer, "The Formation and Evolution of Synthetic Jets." *Physics of Fluid* 10, 1998, pp. 2281-2297
- [2] M. Chaudhari, B. Puranik, A. Agrawal, Heat transfer characteristics of synthetic jet impingement cooling, *International Journal of Heat and Mass Transfer*, heat mass transfer. 2009.11.005
- [3] Gulati, P., Katti, S., Prabhu, V., 2009. Influence of the shape of the nozzle on local heat transfer distribution between smooth flat surface and impinging air jet. *International Journal of Thermal Sciences* 48 (3) pp. 602-617.
- [4] Pavlova, A., Amitay, M., 2006. Electronic Cooling Using Synthetic Jet Impingement. *Journal of Heat Transfer* 128 (9) pp.897-907.
- [5] Lee, D.H., Song, J., Myeong, C.J., 2004. The effect of nozzle diameter on impinging jet heat transfer and fluid flow. *Journal . Heat Transfer* 126, pp. 554-557.
- [6] Lee, J., Lee, S.J., 2000. The effect of nozzle configuration on stagnation region heat transfer enhancement of axisymmetric jet impingement. *International Journal Heat Mass Transfer* 43, pp. 3497-3509.
- [7] A.McGuinn, T. Persoons, P. Valiorgue, T.S. O'Donovan and D.B. Murray, "Heat Transfer Measurements of an Impinging Synthetic Air Jet With Constant Stroke Length," *The 5th European Thermal Sciences Conference*, The Netherlands, 2008.
- [8] Z. Travnicsek and V. Tesar, "Pulsating and Synthetic Impinging Jets," *Journal of Flow Visualization*, vol. 8, no. 3, pp.201-208, 2005.
- [9] Agrawal, Amit., Puranik, Bhalchandra., Chaudari, Mangesh., "Effect of Orifice Shape in Synthetic Jet Based Impingement Cooling" *International Journal of Experimental Thermal and Fluid Science* 34, Elsevier Ltd, 2010, pp. 246-256
- [10] F.F. Grinstein, C.R. DeVore, Dynamics of coherent structures and transition to turbulence in free square jets, *Physics of Fluids* 8 (1996) 1237-1251.

# Effects of Welding Parameters in Micro Friction Stir Lap Welding of Aluminum A1100

Ario Sunar Baskoro<sup>a</sup>, A.A.D. Nugroho<sup>a</sup>, D. Rahayu<sup>a</sup>, Suwarsono<sup>a</sup>, Gandjar Kiswanto<sup>b</sup>, Winarto<sup>c</sup>

<sup>a</sup>Mechanical Engineering Department, Faculty of Engineering  
Universitas Indonesia, Depok, Indonesia (16424)  
Tel : (+62 21) 7270032 ext 203. Fax : (+62 21) 7270033  
E-mail : ario@eng.ui.ac.id

<sup>b</sup>E-mail : gandjar\_kiswanto@eng.ui.ac.id

<sup>c</sup>Metallurgical and Materials Engineering Department, Faculty of Engineering  
Universitas Indonesia, Depok, Indonesia (16424)  
Tel : (+62 21) 7863510. Fax : (+62 21) 7872350  
E-mail : winarto@metal.ui.ac.id

## ABSTRACT

Technology of Friction Stir Welding (FSW) as a technique for joining metal is relatively new. In some cases on Aluminum joining, FSW gives better results compared with the Arc Welding processes, including the quality of welds and less distortion. FSW can even use milling machine or drilling machine, by replacing the tools and the appropriate accessories. The purposes of this study was analysis the effect of process parameters on micro Friction Stir Lap Welding to the tensile load of welds, in this case using A1100 Aluminum material, with thickness of 0.4 mm. Tools material are HSS material, which are shaped with micro grinding process. Tool Shoulder diameter are 3 mm, while the diameter pin 2 mm and a length of pin 0.7 mm. The parameter variation used in this study were the variable of spindle speed (2300, 2600, and 2900 rpm), variable of tool tilt angle (0, 1, 2 degree) and a variable of Feed rate (50, 60, 70 mm/min). Where the variation of these parameters will affect to the mechanical properties of welds (as response) was the tensile load. Analysis and to find the optimum parameters of the correlation between the microFSLW parameters with the tensile load of welds, using a Response Surface Methods (RSM).

### Keywords:

Micro Friction Stir Lap Welding, Thin plate, Response Surface Methods

## 1. INTRODUCTION

Friction stir welding technology (FSW) is a metal joining technique is relatively new. FSW technology into the aluminum alternative joining process is relatively simple, even in some cases has advantages when compared with conventional joining process (e.g.: welding process, Riveting processes). FSW can even use milling machine or drilling machine, with replacing appropriate tools, jigs and fixtures.

The development of micro systems in the industrial community has been impressive in both their pace and diversity of new applications. The trend of more compact and sophisticated Microsystems requires miniaturized, high precision, and high quality mechanical means for device bonding, assembly and packaging [1]. Shoulder usually involves local heating, where heating sources derived. This technique requires contact with the electrodes, it is less favored in the application of micro-systems packaging. When laser welding is often used for a variety thin products such as biomedical tools, cigarette lighters, a search tool springs, laminated motor / transformer, battery cans and packages of hybrid circuits. As an alternative, FSW can be used in applications for thin metal connecting electronic, medical and micro equipment in order to limit damage from excessive heat [1]. Scialpi *et al.* [2] have successfully applied FSW on thin plastic. For joining a thin aluminum plate (<1mm) FSW technology and equipment needs special technology and devices. Thin plate and research related parameters called micro Friction Stir Welding.

Research of FSW process on thin material urgently needs to be done because of joining thin plate are often worked in the workshop. It is necessary to study the jig and joining techniques, the optimum parameters and their impact on the quality of welds, surface quality and stability of the welding results. The purpose of this study was to analyze the effect of welding parameters on the welds shear strength of Friction Stir Spot Welding connection (FSSW) on A1100 aluminum plate, with a thickness of 0.4 mm. The variation of the FSSW parameters used in this study were:

1. Tool rotation (spindle speed)
2. Plunge speed
3. Pin diameter

Further analysis of the interaction between the welds properties and Friction Stir welding process parameters to obtain the optimum response, carried out by applying *Response Surface Methodology* ((RSM)

## 2. BASIC THEORY

Friction Stir Welding (FSW) was invented at The Welding Institute (TWI) of the United Kingdom in 1991 as a solid-state joining technique and was initially applied to aluminum alloys. The basic concept of FSW is remarkably simple. A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and subsequently traversed along the joint line. Then, the material is heated and melted around the tool, causing plastic deformation and solid-state bonding occurs between the surfaces of the sheet up and down. FSW is a solid-state joining process in which the material being welded is not completely melted during the process, and this process is applied at the time we want to preserve the character of the beginning of the base material. Figure 1 illustrates process definitions for the tool and workpiece. Most definitions are self-explanatory, but advancing and retreating side definitions require a brief explanation. Advancing and retreating side orientations require knowledge of the tool rotation and travel directions. In Fig.1, the FSW tool rotates in the counterclockwise direction and travels into the page (or left to right). In Fig.1 the advancing side is on the right, where the tool rotation direction is the same as the tool travel direction (opposite the direction of metal flow), and the retreating side is on the left, where the tool rotation is opposite the tool travel direction (parallel to the direction of metal flow) [1].

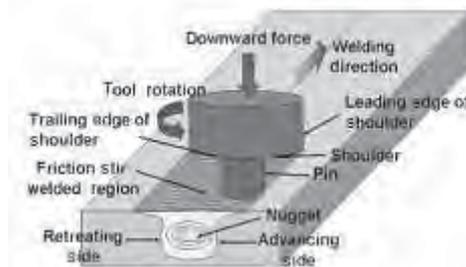


Figure 1: Schematic drawing of FSW [1]

There are two considerations the speed of tool to be done on FSW; how fast spindle speed and how fast travel speed. These two parameters have a great role and be selected carefully to ensure a success and efficient welding. The relationship between the speed of welding and heat input during welding is very complex. But in general, it can be said that the increase in rotational speed or lower traverse speed will result in a hotter weld. In order to produce a success weld it is necessary that material around tool is hot enough to enable the flow of plastic required and minimize forces acting on tool. If material is too cold will make the cavity or other defects can arise in slurry zones, and in extreme cases the tool may break off [3].

During the tool plunge, material displaced by the pin is fed into the cavity within the tool shoulder. This material serves as the start of a reservoir for the forging action of the shoulder. Forward movement of the tool forces new material into the cavity of the shoulder, pushing the existing material into the flow of the pin. Proper operation of this shoulder design requires tilting the tool  $2^\circ$  to  $4^\circ$  from the normal of the workpiece away from the direction of travel; this is necessary to maintain the material reservoir and to enable the trailing edge of the shoulder tool to produce a compressive forging force on the weld [1].

The Advantages of FSW process are:

- Improved safety due to the absence of toxic fumes or the spatter of molten material.
- No consumables — A threaded pin made of conventional tool steel, *e.g.*, hardened H13, can weld over 1000m of aluminum, and no filler or gas shield is required for aluminum.
- Easily automated on simple milling machines — lower setup costs and less training.
- Can operate in all positions (horizontal, vertical, *etc.*), as there is no weld pool.
- Generally good weld appearance and minimal thickness under/over-matching, thus reducing the need for expensive machining after welding.
- Low environmental impact.

Disadvantages of Friction Stir Welding process:

- Exit hole left when tool is withdrawn.
- Large down forces required with heavy-duty clamping necessary to hold the plates together.
- Less flexible than manual and arc welding processes (difficulties with thickness variations and non-linear welds).
- Often slower traverse rate than some fusion welding techniques, although this may be offset if fewer welding passes are required

This process is mostly used in large-sized aluminum material in which the material conditions are not easy for the Heat-treatment after welding to restore the initial properties. Kawasaki Heavy Industries (Japan) are using friction stir spot welding to attach stringers to roof panels. They developed a new aluminium car body shell, which is assembled by this method. Main

reason for Kawasaki Heavy Industries is the fact that it improves the fatness and visual appearance of the skin panels because of the low heat input [3].

Some researchers try to know the correlation of FSW parameters process. Rajakumar *et al.* [5] developed a mathematical model using the RSM to analyze the influence of process parameters and the parameters of FSW tools on the material tensile strength of aluminum AA7075. Lakshminarayanan and Balasubramanian [6] also studied the effect of FSW welding parameters on tensile strength of the connection handle is made of aluminum alloy AA7039 using Taguchi's parametric design approach. Rajakumar [7] investigated the mechanical properties of the empirical relationship to describe the tensile strength and hardness are the mechanical properties that are considered important. Scialpi [2], Wang [8] and Baskoro [9,10] studied FSW on thin plate (thickness < 1 mm)

Study the parameter effect of *micro Friction Stir Lap Welding* process to the shear strength of the weld, in this case using A1100 Aluminum material, with a thickness of 0.4 mm. Tools Material are made from material HSS, which is the pin shape processed with micro grinding. Tool Shoulder diameter are 3 mm, with a cylindrical pin of 0° angle, while the diameter pin 2 mm and a length of pin 0.7 mm. The parameter variations used in this study are the variable of spindle speed (2300, 2600, and 2900 rpm), variable of *tool tilt angle* (0°, 1°, 2°) and a variable of *Feed rate* (50, 60, 70 mm/min). The variation of these parameters will affect to the mechanical properties (as response), *i.e.* the tensile strength of welds joint. Analysis of the interaction between the welds and spot welding process parameters to obtain optimal weld strength, carried out by applying Response Surface Methods (RSM). Research Specimen were aluminum plate A1100 (Table 1) and cut in a size of 100 mm x 50 mm. At welding process, the specimens were stacked with a width of 40 mm overlap as shown in Fig. 2.

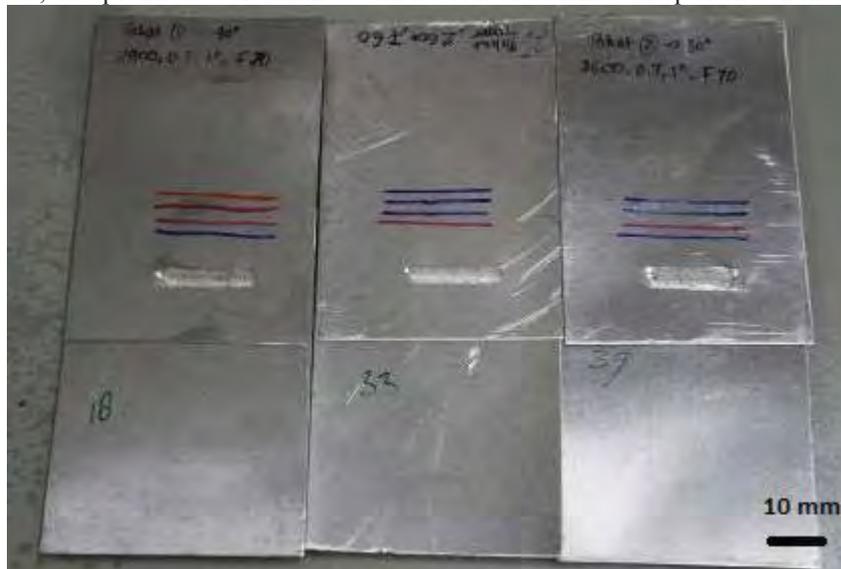


Figure 2: Specimens of micro FSLW

The machines that used in the FSW process was CNC Vertical Milling Machine, Model EMCO type VMC-200. The holder of the workpiece on the machine table used a fixture as shown in Fig. 3. To control the spindle speed of mini grinder used digital photo tachometer, and adjusted manually.

Table 1: Chemical composition of Aluminum A 1100

Composition	Percent
Cu	0-0.05 %
Mg	0-0.05 %
Si	0-0.25 %
Fe	0-0.40 %
Mn	0-0.05 %
Zn	0-0.07 %
Ti	0-0.05 %
Al	balance

*Weld* Specimens that have been processed, cut using wire cut, with a width of 25 mm, for tensile testing sample. The shear strength of the specimen tested using the tensile test Machine merk Galdabini and the maximum load that can be tested is 2500 N, with a withdrawal rate of 5 mm/min. The tensile test, used JIS standard (JIS.2201-1999) as shown in Fig. 4.

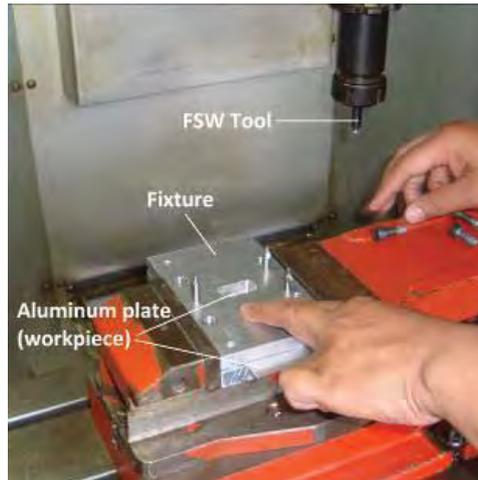


Figure 3: Fixture setup for holding aluminium plates



Figure 4: Tensile testing of micro FSLW Specimens

### Regression models

Researcher want to determine the value of the parameter input process in which the optimum response. Optimum can be either minimum or maximum specific functions in terms of input parameters. *Regression Models* is a collection of mathematical and statistical techniques useful for analyzing problems where several independent variables affect the dependent variable or response and the goal is to optimize the response [12]. In many experimental conditions, it is possible to represent an independent factor in quantitative form as given in equation (1). Then these factors can be considered as having a functional relationship or response as follows:

$$Y = \phi(x_1, x_2, \dots, x_k) + e_r \quad (1)$$

Between the response  $Y$  and  $x_1, x_2, \dots, x_k$  factors quantitative  $k$ , the function  $\Phi$  is called *the response surface* or *the response function*. residual  $Er$  measure experimental error. For the set of independent variables, response surface characteristics. When the mathematical form of  $\Phi$  is unknown, it can be expected in the experimental area with a polynomial. In this investigation, Regression Models applied to develop a mathematical model in the form of a multiple regression equation for the quantitative characteristics of aluminum alloy FSW. In applying Regression Models, the independent variable is seen as a mathematical model fitted surface. Represent the tensile strength of welds TS, the response is a function of tool rotation speed (N), the angle of the tool (A), and feed rate (F), can be expressed in Table 2.

The design of experiment uses a model of a three-level factorial design. Factorial designs are widely used in the experiment, when researchers need to evaluate the combined effect of several controllable factors in the response.  $3^q$  factorial design is factorial arrangement with  $q$  factors, each at three levels. Rate factor referred to as low, medium, and high, represented by a “-1” (low), “0” (intermediate), and “1” (high). When measuring the response variable contains all possible combinations of factor levels, type of experimental design is called a full factorial experiment (complete factorial experiment) [13].

### 3. RESULTS AND DISCUSSION

Designs of experiment for  $\mu$ FSSW and parameters process are showed in Table 2. Because of the difficulties to find the contact area, then the data used are *Tensile Load peak*.

Table 2: DoE and Shear strength of  $\mu$ FSLW

No	Tilt angle [°]	Feed rate [mm/ menit]	SpindleSpeed [rpm]	Code A [Tilt angle]	Code B [Feed rate]	Code C [Spindle Speed]	Load Peak [N]
1	0	50	2300	-1	-1	-1	120.5
2	0	50	2600	-1	-1	0	197.8
3	0	50	2900	-1	-1	1	142.9
4	0	60	2300	-1	0	-1	87.1
5	0	60	2600	-1	0	0	104.8
6	0	60	2900	-1	0	1	83.7
7	0	70	2300	-1	1	-1	246.6
8	0	70	2600	-1	1	0	169.3
9	0	70	2900	-1	1	1	170.8
10	1	50	2300	0	-1	-1	190.5
11	1	50	2600	0	-1	0	205.4
12	1	50	2900	0	-1	1	168.1
13	1	60	2300	0	0	-1	139.9
14	1	60	2600	0	0	0	177.6
15	1	60	2900	0	0	1	308.9
16	1	70	2300	0	1	-1	146.1
17	1	70	2600	0	1	0	150.3
18	1	70	2900	0	1	1	218.3
19	2	50	2300	1	-1	-1	254
20	2	50	2600	1	-1	0	56.5
21	2	50	2900	1	-1	1	121.5
22	2	60	2300	1	0	-1	172.2
23	2	60	2600	1	0	0	181.6
24	2	60	2900	1	0	1	430.2
25	2	70	2300	1	1	-1	280.9
26	2	70	2600	1	1	0	67.2
27	2	70	2900	1	1	1	196.4

The results of Response Surface Methods (RSM) analysis of tensile test data (tensile strength) produces equation (2), and plotted in Fig. 5.

$$Y_{ts} = 202.9 + 29.3.A + 11.3.B - 26.6.C + 3.1.A.B - 16.5.A.C - 14.2.B.C - 12.6.A^2 - 21.5.B^2 - 2.1.C^2 \quad (2)$$

Equation 2 gives the mathematical model of the FSSW parameters interaction on tensile load of welds, and Fig. 5 shows the 2 parameters correlation to tensile load. There are 2 parameters (A, B) that influence positively to response. Parameter C has negative effect to the response. It shows that Tilt angle (A) will increase the Tensile load. There are similarities between the results of FSW on thin plate and FSW on thick plate, which is tilt angle parameter has positive correlation with tensile load [10]. Otherwise, by the increases of Spindle speed (C) it will decrease the tensile load.

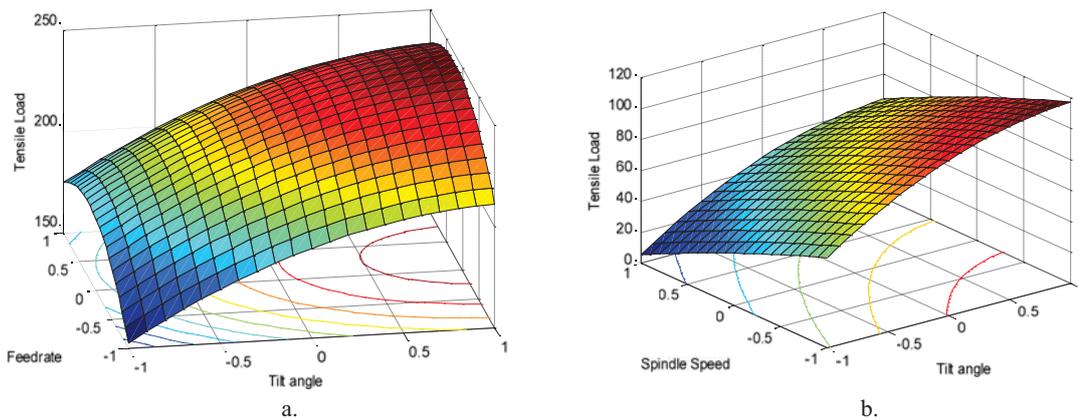


Figure 5: 2 parameters correlation to tensile load. a. Tilt angle-Feed rate to tensile load. b. Tilt angle-Spindle Speed to tensile load.

#### 4. CONCLUSION

From the experiment, it can be concluded that:

- a. The important welding parameter in Micro FSW Lap welding process is tilt angle.
- b. Research of FSW need to be done on a wider parameter range, and more variation of material.
- c. There are many potential applications in micro friction stir welding and its advantages of low temperature.
- d. FSW is a promising *green* technology.

#### ACKNOWLEDGMENT

Financial assistance for this work was granted by Directorate Research and Public Service, Universitas Indonesia, through the project no. 1915/H2.R12.1/HKP.05.00/2012 entitled "Pengembangan Sistem Advanced Micro Friction Stir Welding (Micro-FSW) Pada Pengelasan Plat Tipis Aluminium".

#### REFERENCES

- [1] R.S. Mishra, M.W. Mahoney, "Friction Stir Welding and Processing," ASM International, 2007.
- [2] A. Scialpi, AD. Giorgi, LAC. Filippis, R. Nobile, FW. Panella, "Mechanical analysis of ultra-thin friction stir welding joined sheets with dissimilar and similar materials", Materials and Design 29 (928–936), 2008
- [3] D. Lohwasser, Z. Chen, "Friction Stir Welding," CRC Press, 2010.
- [4] T. Khaleed, "An Outsider Looks At Friction Stir Welding," Federal Aviation Administration, Lakewood, California, 2005.
- [5] S. Rajakumar, C. Muralidharan, V. Balasubramanian, "Optimization of the friction-stir-welding process and the tool parameters to attain a maximum tensile strength of AA7075-T6 aluminium alloy," J Eng Manuf, 2010;224:1175–91
- [6] A.K. Lakshminarayanan, V. Balasubramanian, "Process parameters optimization for friction stir welding of RDE-40 aluminium alloy using Taguchi technique," Journal of Materials Engineering and Performance, 2008; 18:548–54.
- [7] S. Rajakumar, C. Muralidharan, V. Balasubramanian, "Predicting tensile strength, hardness and corrosion rate of friction stir welded, AA6061-T6 aluminium alloy joints," Materials and Design 32 (2011) 2878–2890.
- [8] DA. Wang, CW.Chao, PC. Lin, JY. Uan, "Mechanical characterization of friction stir spot microwelds," Journal of Materials Processing Technology 210 (1942–1948), 2010.
- [9] A.S. Baskoro, A.A.D. Nugroho, Deden R., Suwarsono, Gandjar K., Winarto, "Rekayasa mesin micro Friction Stir Welding dan Kajian Pengaruh Parameter Proses Spot Welding Terhadap Kekuatan Tarik Lasan pada Aluminium 1050," Seminar Tahunan Teknik Mesin XI, 16-17 September 2012, Yogyakarta.
- [10] A.S. Baskoro, A.A.D. Nugroho, Deden R., Suwarsono, Gandjar K., J. Istiyanto, S. Supriyadi, Winarto, "Implementation of Friction Stir Welding Technology in Automotive Industry," 1<sup>st</sup> Conference ICEAST, 3-4<sup>th</sup> December 2012, Bali.
- [11] A.S. Baskoro, M.R. Dirhamsyah, S. Suardi, Suwarsono, Gandjar Kiswanto, "Pengaruh Parameter Friction Stir Welding Terhadap Kualitas Mekanik Las pada Aluminium AC4CH," Seminar Tahunan Teknik Mesin X, 2-3 November 2011, Malang
- [12] D.C. Montgomery, "Design and Analysis Of Experiments 5<sup>th</sup> ed.," John Wiley & sons., 2001.
- [13] N. Bradley, "The response surface methodology," thesis, Department of Mathematical Sciences, Indiana University of South Bend, 2007.

# Thickness and Fiber Content Optimization in VARTM Method For High Speed Craft

Sunaryo<sup>a</sup>, Gerry Liston Putra<sup>b</sup>, Sri Maharani Lestari<sup>c</sup>

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424

E-mail : naryo@eng.ui.ac.id

<sup>b</sup>Faculty of Engineering University of Indonesia, Depok 16424

E-mail : gerrylistonp@gmail.com

<sup>c</sup>Faculty of Engineering University of Indonesia, Depok 16424

E-mail : ranikapal@gmail.com

## ABSTRACT

To improve production efficiency and quality in fiber boatyard many research have been done both through technology as well as management aspects. One of these developments is Vacuum Assisted Resin Transfer Molding (VARTM) which is claimed to have high strength and material efficiency. This method has not much been applied in Indonesian boatyards, most of them are still using conventional hand lay-up. The research is aimed to investigate the strength of the composite and the optimum amount of materials to obtain the required strength for its application on boat building. Experimental approach was conducted in the research using 800 biaxial and 900 unidirectional E-glass for reinforcement, and vinylester (RIPOXY R-802-EX-1) resin for the matrix. The ultimate tensile strength and Young's modulus of the composites are obtained through tensile and flexural test based on ASTM D 3039 and ASTM D 790 standards. The data obtained are used to determine the optimum number of layers and fiber content on certain locations of the boat hull structure in order to comply with the requirements of classification rules.

### Keyword:

Vacuum Assisted Resin Transfer Molding, boat, fiber content, strength

## 1. INTRODUCTION

### 1.1. Background

Composite technology has been developing very rapidly including its application on boatbuilding. Researches have been carried out to improve the production efficiency and quality of boatbuilding, including the application of materials and production processes. Vacuum Assisted Resin Transfer Molding (VARTM) is claimed could increase material efficiency and strength in many applications [1], but this method has not been widely applied in Indonesian boatyards, most of them still use conventional hand lay-up method [2]. It is expected that the claim would also applicable for boatbuilding.

### 1.2. Research objectives

The research is aimed to investigate the role of Vacuum Assisted Resin Transfer Molding (VARTM) in improving the efficiency and quality boat production, to obtain tensile and flexural strength data of the composite, to determine the optimum thickness and fiber content of the material to be applied in boatbuilding as required by the classification rules.

## 2. RESEARCH METHODOLOGY

Experimental and analytical approaches were conducted in the research using 800 biaxial and 900 unidirectional E-glass for reinforcement, and vinylester (RIPOXY R-802-EX-1) resin for the matrix. The ultimate tensile strength and Young's modulus of the composites are obtained through tensile and flexural test based on ASTM D 3039 and ASTM D 790 standards [3]. Ansys software was used to simulate the optimum thickness and fiber content of the material for its application on boatbuilding based on the data obtained from the experiment and the requirements of classification rules.

### 2.1. The materials

For reinforcement two types of E-glass were used in the experiment; unidirectional fabric 0° with specific density of 894.56 g/m<sup>2</sup>, the orientation was made 45° and 90°, and biaxial fabric +45°/-45° with specific density of 841.89 g/m<sup>2</sup>. Vinyl ester Ripoxy R-802 EX-1 was chosen for the matrix with the following specifications: specific density 1.12 gr/cm<sup>3</sup>, tensile strength 78 Mpa, Tensile modulus 3.38 Gpa, Flexural Strength 127 Mpa, Flexural modulus 2.75 Gpa, elongation 6 %, Heat distortion temperature 100°C. Vinyl ester was mixed with 10% monomer, 0.5% promoter, and 2% catalyst. Vinyl ester was chosen due to its high strength, hardness, and high resistance to heat and corrosion compared to polyester and epoxy [4].

## 2.2. Vacuum assisted resin transfer molding (VARTM) method

In Vacuum Assisted Resin Transfer Molding (VARTM) prior of its laminating process all the reinforcement fiber is laid on the mold, covered with plastic sheet and sealed to prevent the mold from leaking during the vacuum process, and the resin is prepared in a container and connected to the mold via plastic hose through a special entrance hole. Vacuum pressure was utilized to take the air out of the laminate. The pressure difference between the atmosphere and vacuum provides driving force for infusing the resin into the laminate and to compact the fiber reinforcement to prevent its orientation from shifting during curing process [5].



Figure 1 : Vacuum Assisted Resin Transfer Molding Process

## 2.3. Tensile and flexural strength

Tensile strength test was carried out based on ASTM D 3039 standard with the following specimen dimensions: length 250 mm, breadth 25.4 mm, two-layer biaxial E-glass thickness 1.33 mm and two-layer unidirectional E-glass thickness 1.5 mm, minimum tab length 38 mm. The test conditions standard were: room temperature  $23 \pm 1^{\circ}\text{C}$ , humidity  $50 \pm 10\%$ , tensional speed 16.7 m/s and 33.4 m/s.

Flexural strength test was carried out based on ASTM D 790 standard for thickness less than 1.6 mm the specimen dimensions are: length 50.8 mm, breadth 12.7 mm, minimum pointer radius 3.2 mm. The test conditions standard were: room temperature  $23 \pm 2^{\circ}\text{C}$ , humidity  $50 \pm 10\%$ .

Theoretically the tensile strength and modulus of the composite could be obtained from the following calculations, even though laboratory test is still needed to compare their accuracy:

$$\text{Tensile strength} = 1800 W_f^2 - 1400 W_f + 510 \text{ (N/mm}^2\text{)} \quad (1)$$

$$\text{Tensile modulus} = (130 W_f^2 - 104 W_f + 39) 10^3 \text{ (N/mm}^2\text{)} \quad (2)$$

Where:  $W_f$  is fiber content

The same approach is also applied for obtaining the flexural strength and modulus:

$$\text{Flexural strength} = 502 W_f^2 + 106.8 \text{ (N/mm}^2\text{)} \quad (3)$$

$$\text{Flexural modulus} = (33.4 W_f^2 + 2.2)10^3 \text{ (N/mm}^2\text{)} \quad (4)$$

## 2.4. Minimum hull thickness

There are some approaches available to determine the minimum composite thickness for boat hull include using scantling number [6], pressure forces to the boat parts from various directions [7], and other empirical formulas introduced by some classification societies such as American Bureau of Shipping (ABS) [8], Det Norske Veritas (DNV) [9], and Lloyd's Register of Shipping (LR) [10].

The minimum thickness is obtained from the sum of laminate layers that form the composite based on the required strength at the specific parts of the boat. The thickness of single laminate layer is obtained from the following formula:

$$t = m_f (S_f / W_f - (S_f - S_r)) / (1000 \cdot S_f \cdot S_r) \quad (5)$$

Where:  $m_f$  is fiber weight;  $S_f$  is density of the reinforcement; and  $S_r$  is the density of the matrix.

## 2.5. Fiber content

Fiber content is the amount of fiber reinforcement in the composite. In hand lay-up method the reinforcement usually consists of CSM (Chopped Strand Mat) and WR (Woven Roving), while in VARTM method multiaxial fiber is used for the reinforcement [11]. Following are fiber ratio of the reinforcement:

Table 1 Fiber Ratio of Reinforcement

Reinforcement Type	Glass Content
CSM (Hand Lay Up)	0.28
WR (Hand Lay Up)	0.35
Multiaxial (VARTM)	0.7

And therefore the weight of each laminate of the composite formed is obtained from the following formula:

$$\text{Weight per laminate} = (\text{fiber weight} \times \text{Fiber/Resin ratio}) + \text{fiber weight} \quad (6)$$

### 2.6. Optimum thickness and fiber content

The optimum thickness and fiber content of the composite to be applied in a specific boat using VARTM method are determined based on its tensile and flexural strength of the material that is required to withstand the forces work to a particular part of the boat such as bottom hull, side hull, and deck [12]. The tensile and flexural strength of E-glass 800 biaxial and 900 multi-axial used in the experiment are as follows:

Table 2 Tensile and Flexural Strength and Modulus of reinforcement

Material	Tensile Strength (N/mm <sup>2</sup> )	Tensile Modulus (N/mm <sup>2</sup> )	Flexural Strength (N/mm <sup>2</sup> )	Flexural Modulus (N/mm <sup>2</sup> )	Thickness per layer (mm)
800 Biaxial	412	29900	352.78	18566	0.61
900 Multi-axial	318	23400	288	14244	0.69

Since the strength of a composite is based on its reinforcement therefore the required fiber content in hand lay-up method is used as reference for the composite's strength, and the optimum thickness is derived based on this requirement.

### 3. CASE STUDY

To investigate the efficiency improvement by using VARTM compared to conventional hand lay-up a case study was carried out by applying both methods to a chosen boat design with the same material thickness required by certain classification society. The boat being chosen for the experiment is a patrol boat with the following main particular:

- Loa = 28 m
- Lwl = 26.9 m
- B = 5.4 m
- H = 3.42 m
- T = 2.95 m
- V = 30 knot

The results of analytical calculations of hand lay-up and VARTM methods for the bottom hull and side hull of the chosen boat are as follows:

Table 3 Analytical Calculation results

Hand lay-up							
Boat part	Thickness (mm)	Fiber content	Tension to break (N)	Tensile strength (Mpa)	Tensile Modulus (Gpa)	Flexural strength (Mpa)	Flexural Modulus (Gpa)
Side hull	15	8400	1673100	110	9.5	190.00	7.7
Bottom hull	26	14400	2944000	115	9.7	192.50	8
VARTM							
Side hull	15	18700	4682977	339	24.8	302.4	15.2
Bottom hull	26	33100	8188792	329	24.2	295.7	14.7
Efficiency Improvement							
Side hull		222.61%	180 %	308.18%	261.05%	159.16%	197.40%
Bottom hull		229.86%	178 %	286.08%	249.48%	153.61%	183.75%

Since the strength of the composite is in its reinforcement therefore the optimization of the composite thickness and fiber content is conducted by maintaining the value of hand lay-up's fiber content as reference of strength, which is around 45% of the VARTM method. For safety reason the thickness is multiplied by 1.5 as safety factor, and therefore for the chosen boat the proposed thickness of the side hull will be 10 mm, and the bottom hull will be 18 mm.

#### 4. CONCLUSION

The application of VARTM method in boat building has proven the improvement of efficiency both in using of material and production process, and increase the quality of the composite. By maintaining the fiber content as required by certain classification rules for hand lay-up the thickness of the composite could be optimized whereas the strength of the composite is still higher than hand lay-up method.

In the case study application on a 28 m patrol boat the composite thickness efficiency of the VARTM method could reach as high as 45% compare to hand lay-up method, and this will also affect the production cost of the boatyard.

#### REFERENCES

- [1] Santoso, Abdul Wahid Al Adami. (2010). *Project Overview 20 m Fiber Composite Vessel Shipyard*. Jakarta.
- [2] Windyandari, Aulia. (2008). *Prospek Industri Galangan Kapal Dalam Negeri Guna Menghadapi Persaingan Global*. Jurnal UI.
- [3] ASTM. (2000). ASTM D3039-00, Standard Test Method For Tensile Properties Of Polymer Matrix Composite Materials. West Conshohocken, PA: American Society of Testing and Materials.
- [4] Eric Greene Associates, Inc. (1999). *Marine Composite*. EGA.
- [5] Pirvu Anca, Douglas J. Gardner, R. Lopez Anido. (2004). Carbon fiber-vinyl ester composite reinforcement of wood using the VARTM/SCRIMP fabrication process. *Composites: Part A* 35, pp 1257–1265.
- [6] Geer, Dave. (2000). *The Element of Boat Strength for Builders, Designers, and Owners*. McGraw-Hill.
- [7] Det Norske Veritas. (2010). *Standard for Certification of Craft*. Bærum. Det Norske Veritas.
- [8] American Bureau of Shipping (ABS). (1991). *Guide for Building and Classing High-Speed Craft*. Paramus NJ : ABS.
- [9] Det Norske Veritas. (2011). *Rules for Classification of High Speed, Light Craft and Naval Surface Craft*. Bærum. Det Norske Veritas.
- [10] Lloyds Register of Shipping. (1983). *Rules and Regulations for the Classification of Yachts and Small Craft*. London : Lloyds Register of Shipping.
- [11] Mohd Yuhazri et al. (2010). *A Comparison Process Between Vacuum Infusion and Hand Lay-Up Method Toward Kenaf/Polyester Composite*. *International Journal of Basic & Applied Sciences* vol.10, No. 3, pp 63 - 66.
- [12] Wonderly Christopher et al. (2005) Comparison of mechanical properties of glass fiber/vinyl ester and carbon fiber/vinyl ester composites. *Composites: Part B* 36, pp 417–426.

## Tube Forming Technology for Lightweight Components Manufacturing

**Ken-ichi Manabe**

Graduate School of Science and Engineering  
Tokyo Metropolitan University, 1-1 Minamiosawa Hachoji, Tokyo 192-0397 Japan  
Tel : +81(042) 677-2712. Fax : +81(042) 677-2701  
manabe@tmu.ac.jp

### ABSTRACT

*Weight reduction and materials saving are one of the key priorities from a viewpoint of global environmental conservation. In the 1970s to 1980s, tube forming (TF) technology was in the second technological innovation for improving automotive fuel economy. In recent over one decade, TF technology, especially, tube hydroforming (THF) technology has become a popular method, in the automotive industry, for producing complex three-dimensional structural shapes because of its enormous advantages over the more traditional materials processes. Nowadays, global environmental issues are intensifying worldwide, and the further reduction of automotive weight and lightening of transport vehicles is one of the most urgent and key technological issues in the realization of a low-carbon society. The effect of reducing automotive weight is estimated to be, a reduction of about 17 to 20 kg of CO<sub>2</sub> emissions per kg of weight reduction over a vehicle's lifetime for every 10 percent reduction in automotive weight. This review article describes the state of the art in TH technologies mainly in Japan*

### **Keywords:**

*Weight reduction, light metal tube, hydroforming, novel process, tubular components*

# Development And Testing of 5 kn Micro Forming Machine for Micro Part Manufacturing

Gandjar Kiswanto, Aida Mahmudah, Sugeng Supriadi

Dept. of Mechanical Engineering, Universitas Indonesia  
 gandjar\_kiswanto@eng.ui.ac.id

## ABSTRACT

Microforming machine is used to make micro-scale products. The development of this machine is necessary for microforming technology research. In this study, a microforming machine with a capacity of 5 kN is developed. The machine is driven by an electric motor that transfers to the ram using ball screw to change rotational into translational motion. Strength analysis of the machine structure is performed on a static and maximum loading condition since the operating condition is performing at a low speed and load. Machine performance was measured by analyzing geometrical tolerances of the machine, movement and stroke resolution, and verification using experiment to produce forming products of sheet metal made from aluminum, brass, copper, and steel. The result of this research shows that the 5 kN Micro Forming Machine with maximum loading is applicable to be implemented for micro forming process.

### Keywords

Micro forming, micro forming machine, sheet metal

## 1. INTRODUCTION

Micro-electro-mechanical systems (MEMS) technology receives great attention due to the increasing market and application fields in micro devices, such as electronic, medical care, biotechnology etc. The estimated rise in turnover from 15 to 35 billion US\$ in the last 7 years [1] shows a growing demand on micro technical products, which is mainly driven by a rising trend of miniaturization of products. However, this technology is faced with the enormous challenges to be implemented in the industry.

Currently, micro device was fabricated by using semiconductor process. There are several difficulties and limitations of fabrication MEMS parts using semiconductor process such as equipment expense is comparatively high, applicable materials are limited and production of 3D structural components is difficult. The manufacture of micro parts is very advanced in lithographic technologies, especially in LIGA-processes. Bulk production with high accuracy can be realized by these technologies, but costs are comparably high and the number of different materials is quite limited [2].

For a solution to these problems, the micro-metal-forming technology is introduced for producing sub-millimeter-scaled microparts. Nevertheless, the fundamental knowledge and technological data have not been satisfied. Therefore, the establishment of design manuals and codes for materials, machine, tools, and process conditions is crucial for realizing high-precision microforming process. In this study, development of micro forming machine was introduced.

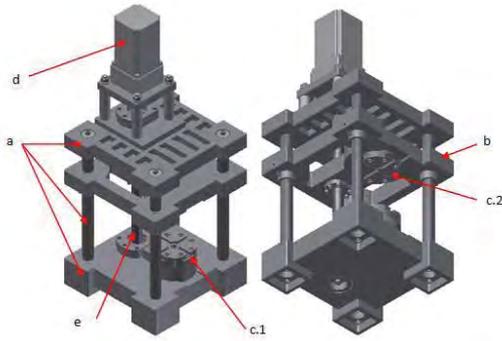
## 2. DEVELOPMENT OF 5 kN MICRO FORMING MACHINE

### Machine design

The design is conducted using VDI 2222 Design Method and Advanced Decision Matrix Method based on the Robust Decision Making [3]. The micro forming machine that consists of several sub-functions is assembled as shown in Fig. 1. The main components that construct micro forming machine are lower and upper base, guide pillar, upper and lower bolster, ram, motor spacer, ball screw, and stepper motor.

The working principle of this machine is driven by stepper motor (d) that transfers to rotating ball screw (e). The ball screw drive ram (b) to move up and down and control stroke motion. Movement is directed by guiding set (a). The tooling system (punch and dies) is mounted on the upper and lower bolster.

Part Name	Selected Material
-----------	-------------------



<b>Lower Base</b>	Low carbon steel: S45C
<b>Motor spacer</b>	
<b>Bolster_upper</b>	High carbon steel: SKD11
<b>Bolster_lower</b>	
<b>Ram</b>	
<b>Guide Pillar</b>	

Table 2. Result of Material Selections

Figure1 :Sub-Function of Micro Forming Machine; a). Guiding pillar , lower and upper base, b). Ram, c). Bolster,d).Stepper motor, e). Ball screw

**Material selection**

Material selection of micro forming machine components are selected by using Ashby method [4]. Table 2 shows material selection results for micro forming machine. Material properties of selected material is used for loading analysis to determine geometry of the parts.

**Loading analysis**

The analysis is conducted under maximum static loading. The loading scheme that occurs in the machine shown in the free body diagrams shown in Fig. 2. The loading force (F) is under maximum load capacity of the machine at 5 kN.

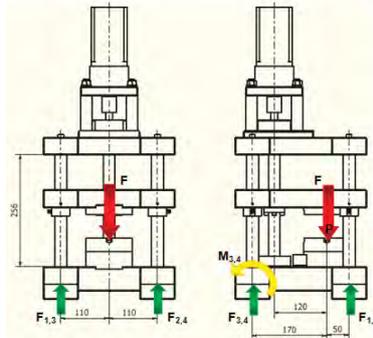


Figure2 : Free Body Diagram of Micro Forming Machine

By using static loading assumption, the force for each guide roll (F<sub>1</sub>, F<sub>2</sub>, F<sub>3</sub>, F<sub>4</sub>) were calculated as follows:

$$\sum F_y = 0 \tag{1}$$

$$F_1 = \frac{F}{4} \tag{2}$$

**Safety factor (FS)[19]**

The safety factor can be quickly estimated on the basis of estimated variations of the five measures previously discussed, i.e. material properties, stress, geometry, failure analysis, and desired reliability.

The simplest way to present this technique is to associate a value greater than 1 with each of the measures and define the factor of safety as the product of these five values:

$$FS = FS_{material} \cdot FS_{stress} \cdot FS_{geometry} \cdot FS_{failure\ analysis} \cdot FS_{reliability} \tag{3}$$

where,

$FS_{material} = 1,1$  because the material properties are known from a handbook or manufacturer's values.

$FS_{stress} = 1,3$  because the nature of the load is defined in an average manner, with overloads of 20–50%, and the stress analysis method may result in errors less than 50%.

$FS_{geometry} = 1,0$  because the manufacturing tolerances are tight and held well

$FS_{failure\ theory} = 1,1$  because the failure analysis to be used is derived for the state of stress, as for uniaxial or multiaxial static stresses

$FS_{reliability} = 1,3$  because the reliability is an average of 92–98%.

### Material strength

Material strength inspection is conducted to the components which are considered critical. For the material strength of lower base plate and ram, failure theory of Von Mises is used, since the materials are ductile. Von Mises equations used are as follows:

$$\left(\frac{\sigma_1}{\sigma_e}\right)^2 - \left(\frac{\sigma_1}{\sigma_e} \times \frac{\sigma_2}{\sigma_e}\right) + \left(\frac{\sigma_2}{\sigma_e}\right)^2 \leq 1 \quad (4)$$

With  $\sigma_e = \sigma_{yp}/FS$ , then

$$\left(\frac{\sigma_1}{\sigma_{yp}/2,5}\right)^2 - \left(\frac{\sigma_1}{\sigma_{yp}/2,5} \times \frac{\sigma_2}{\sigma_{yp}/2,5}\right) + \left(\frac{\sigma_2}{\sigma_{yp}/2,5}\right)^2 \leq 1 \quad (5)$$

Principle Stress:

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} \quad (6)$$

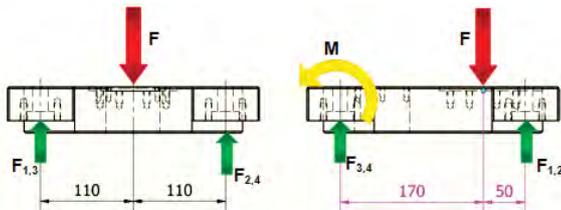
$$\sigma_2 = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Shear stress:      Normal stress:

$$\tau_{xy} = \frac{F}{A} \quad \sigma_y = \frac{Mc}{I} \quad (7)$$

#### 1. Lower base

The lower base serves as the base of press machine components at the bottom of the machine. Material used is S45C, with ultimate strength = 569 MPa and a yield strength = 343 MPa. Fig. 3 shows the free body diagram of the lower base. The result of stress analysis for lower base is shown in Fig. 4. In the figure shows that higher stress is lower than critical stress to induce failure.



$$F_1 = F_2 = F_3 = F_4 = 1,25 \text{ kN}$$

Figure 3 : Free Body Diagram of Lower Base

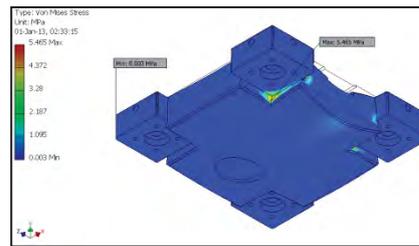


Figure 4 : Stress Distribution of Lower Base  
(continued)

#### 2. Ram

Ram serves as the base of moving components at press machine, and transmits the compressive force on the tool when pressing the workpiece. The material used is SKD11, with a yield strength = 1650 MPa. Fig. 5 shows the free body diagram of the ram. Fig. 6 shows stress distribution on the ram. Highest stress concentrations are located on the ball screw. Since ball screw is push and pull ram.

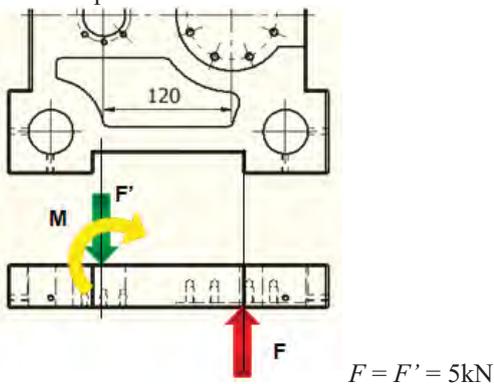


Figure 5 : Free Body Diagram of Ram

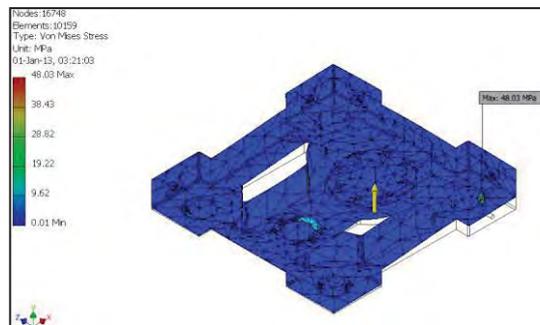
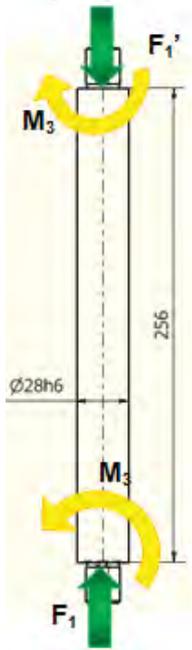


Figure 6 : Stress Distribution of Ram (continued)

#### 3. Guiding rod

Guiding rod is part of the guiding set that serves to direct the movement of the ram. The material used is SKD 11 with a yield strength = 1650 MPa. Fig. 23 shows the free body diagram of the guiding rod.

Because of the bending moment on the guiding rod, then the equations used to inspect the strength of guiding rod component are [5]:



From free body diagram that is shown in Fig 23:

$$F_1' = F_1$$

$$M_3' = M_3$$

Axial stress  $f_a$  dan permission axial stress [5]:

$$f_a = \frac{P}{A} = \frac{F_1}{\pi \times 14^2}$$

$$\text{So, } \frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1$$

can be used.

Bending stress  $f_b$  [16]:

$$f_b = \frac{Mc}{I} = \frac{M_3 \times r}{(\pi \times r^4)/4}$$

Permission bending stress  $F_b$  [16]:

$$F_b = \frac{83 \times 10^3 \times C_b}{(l \times d) / A_f}$$

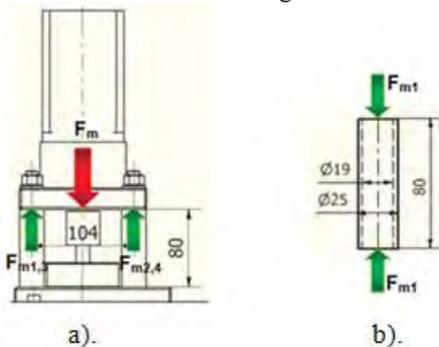
$$\frac{f_a}{F_a} + \frac{f_b}{F_b} \leq 1$$

So, the construction can resist the maximum loading.

Figure 7 :  
Free Body  
Diagram Guiding Rod

#### 4. Motor spacer

Motor spacer serves as a spacer between stepper motor bracket to the upper base. Material used is S45C with elastic modulus 205 GPa. Fig. 8 shows the free body diagram of the motor spacer. By calculate critical compressive force, the construction can resist the maximum loading.



$$F_m = (w_{motor} + w_{motor\ bracket}) \times g$$

$$F_{m1} = F_{m2} = F_{m3} = F_{m4} = \frac{F_m}{4}$$

$$I = \frac{\pi}{4} \times (r_o^4 - r_i^4)$$

Critical compressive force that can lead to buckling is:

$$P_{cr} = \frac{\pi^2 \times E \times I^9}{L^2}$$

$$P_{cr} > F_{m1}$$

Figure 8 : Free Body Diagram a). Motor; b). Spacer

#### Structure assembly of micro forming machine

Assembly structure is shown in Fig.9. In general, all the components are divided into fixed part (i.e., components that are not moving) and moving parts (i.e., the moving components).

#### Motion system

The selection of driven system is based on consideration for translational motion accuracy that required in micro forming process. The following driving components are used: Ball screw R25-5T3-FSI-500L, Stepping motor A140K – G599 – GB5, Driver MD5 - HF 28, Controller PMC – 1HS – USB. Fig. 9 shows a prototype micro forming machines that have been installed with moving controller.

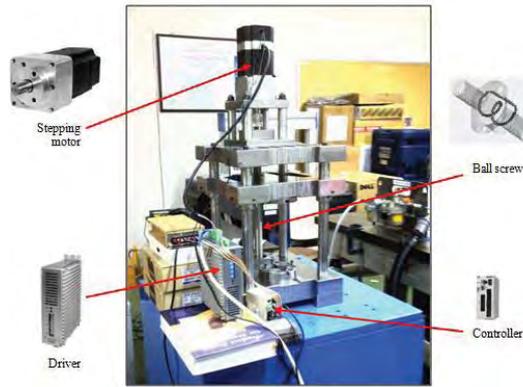


Figure 9.5kN Micro Forming Machine

### 3. EVALUATION OF MICRO FORMING MACHINE

The testing was consisting of geometric measurement, accuracy motion machine, and forming experiment to produce specific product. Geometric measurement is conducted based on Fig. 10. The experiment with predetermined product shape and dimension was performed to measure the performance of machine, as well as the handling for tools and material in the adequate working space with available supporting means. The concept of one piece loading was implemented for loading and unloading of material. The concept required workpiece was manually placed on the die one by one. Geometries of the assembled machine were verified using CMM Mitutoyo Crysta 544. The measurement results show good agreement with design.

#### Process experiment

Process experiment is carried out to determine whether the machine can function well in the forming process, ease of tool handling, loading and unloading of material with one piece loading method on the available working area. Therefore, the experiment required micro forming tool and sheet plate as raw material.

The experiment was conducted with scheme as shown in Fig. 10, and the detail drawing of the product is shown in Fig. 11. Then, based on the detail drawing of the product, it was made a micro forming tool with outer size 40x90x60, 5 mm. Micro forming tool was then mounted to the machine with a clamping unit provided. Material products to be made is aluminum, brass, copper and steel, with  $t = 0.1$  mm.

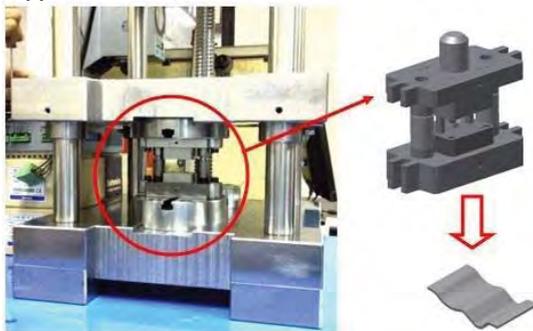


Figure 10 :Micro Forming Process Testing Scheme

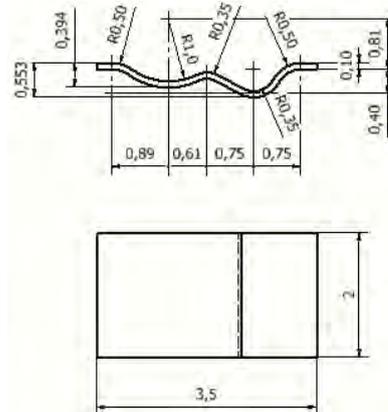


Figure 11: Detail Drawing of Product

At the time tool was placed in the machine (tool insertion), there was no difficulty. Difficulties arised when raw material was stored to the tool . This is due to the lack of locator height to place the raw material on the die. The locator height is 0.1 mm. In addition, the preparation of raw material to be formed was quite difficult because of its small size.

#### Operation position setting

The position of the operation consists of raw material loading position and forming process position (working position). The following is a description of each setting position:

##### 1. Raw Material Loading Position

The important considerations in this position are the area and the sufficient lighting for operators to store raw materials in the die. For that reason, it is determined the distance between the bottom surface of the ram with the top surface of the lower base

is 200.5 mm. So that the distance between the bottom surface of the bush on the micro tool with the shim ring is 100 mm. With a resolution position of  $2\mu\text{m}/\text{pulse}$ , the amount of transmitted pulse to reach this distance is:

In this experiment, stroke velocity was determined  $V = 50$  pps or  $V = 100 \mu\text{m}/\text{s}$ , and the holding time was 5 seconds. The results of this experiment have been observed using a contour measuring instrument detector with type COUNTERECCORD1710SD3 (ACCURETECH). Then, the results of measurement are processed by image processing (Fig. 34) to get the dimensions of the actual product. Fig.12 shows the comparison of the actual contours with the designed contour, and in table 4 is shown a summary of the radius measurement products.

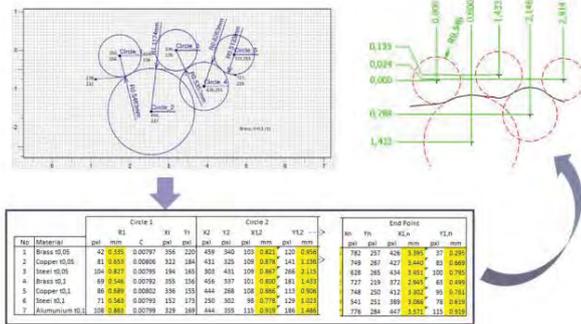


Figure 12 : Image Processing

Table 4. Summary of Radius Products Measurement

		Average Radius Deviation			
		Aluminium	Copper	Steel	Brass
		$t = 0,1$			
Radius of Designed Produk (*)	R1 0.4	0.13	0.29	0.16	0.11
	%	32.6%	72.3%	40.8%	28.3%
	R2 0.45	0.18	0.11	0.27	0.18
	%	39.2%	25.1%	61.0%	39.2%
	R3 0.25	0.12	0.17	0.21	0.29
	%	47.5%	66.2%	85.7%	114.3%
	R4 1.1	0.27	0.14	0.41	0.02
	%	24.5%	12.5%	37.6%	1.6%
	R5 0.4	0.30	0.18	0.39	0.15
	%	73.9%	44.0%	97.6%	36.6%
Deviation Average		43.5%	44.0%	64.6%	44.0%

From figure 35 and table 4, it can be concluded that Material brass, copper, and aluminum, resulting product contours nearing the expected designed product, while the steel materials produce different contours. Since the steel yield strength of the material is the biggest (1646 MPa). In addition, the sizes of the radius product were not sharp and did not consider the effect of material spring back. So that none of the material dimensions meet to the designed products. The smaller the radius, the larger deviation of the size that occurred. This can be seen in the size of the radius at  $R_3 = 0.25$ , deviation was very large, and almost happens on every material.

The results of the forming experiment were also observed using an electron microscope, and then the actual product shape was compared with the designed product as shown in Fig. 13. From these pictures, it can be seen that the product came closest to the desired shape was the product from aluminum. While the product contour from steel was the most different from the designed product. The results of these observations showed the same results with measurements using a contour measuring instrument detector.

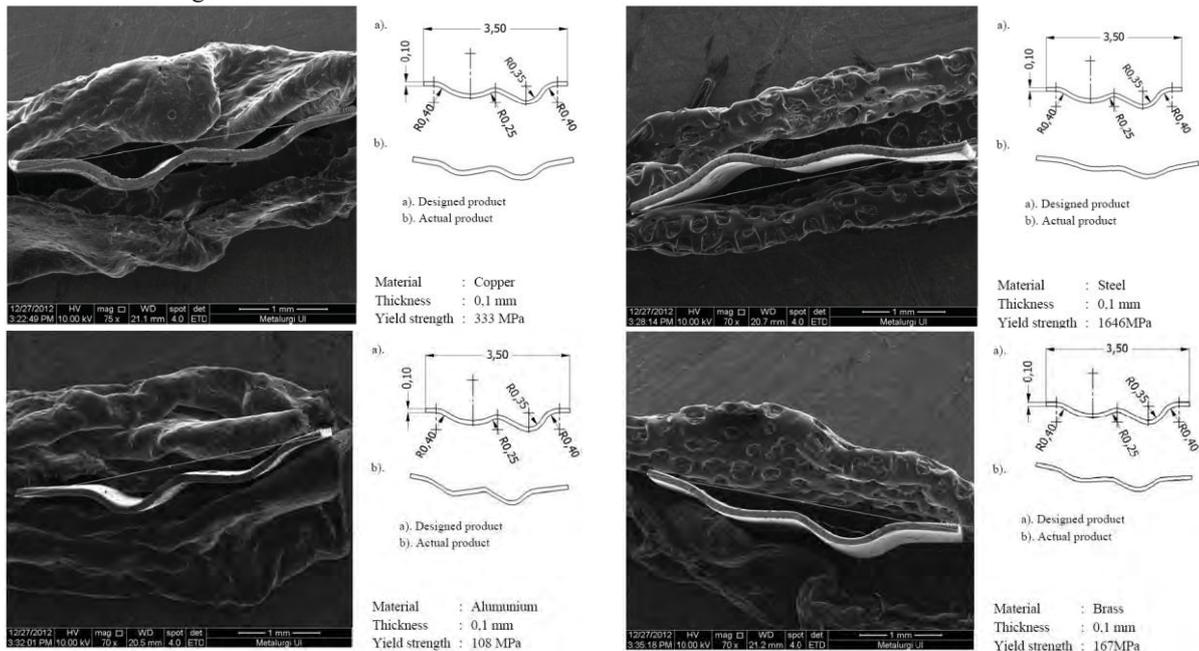


Figure 13: Brass  $t=0,1$  mm

#### 4. CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

##### Conclusion

From the research conducted it can be concluded some of the following result. The 5kN Micro Forming Machine has been produced successfully. Evaluation of the machine was carried out to produce a specific product with radius ranging from 0.25 mm - 1.1 mm. Working area meet the needs of an insertion tool. Preparation and loading of raw materials was difficult, because of its small size and lack of the locator height. Therefore several improvement activities are needed to improve machine performance such as; the additional components to be attached on the seat of bolster on lower base and ram, the addition of counter weight to compensate the ram weight and advanced control systems that meets the needs of micro-forming process.

##### REFERENCE

- [1] N. Association, *Market Analysis for MEMS and Microsystems III 2005-2009*: NEXUS ASSOCIATION, 2005.
- [2] A. Gillner, D. Hellrung, A. Bayer, F. Schepp, and R. Erhardt, "Miniaturisierung von Bauteilen und Komponenten," presented at the 7. Umformtechnisches Kolloquium Darmstadt, Darmstadt, 2000.
- [3] D. G. Ullman, *The Mechanical Design Process*: McGraw-Hill Higher Education, 2009.
- [4] M. F. Ashby, *Materials Selection in Mechanical Design*: Elsevier Science, 2004.
- [5] E. P. Popov, S. Scott, and E. E. R. Institute, *Egor P. Popov*: Earthquake Engineering Research Institute, 2001.

# A Modified Rotor Model to Approach the Dynamic Responses of Anisotropic Rotor with Different Shaft Orientation

Jhon Malta

Department of Mechanical Engineering, Faculty of Engineering,  
 Andalas University, Kampus Limau Manis Padang 25163  
 E-mail : jhonmalta@ft.unand.ac.id

## ABSTRACT

*This research deals with a modification of anisotropic rotor model in order to approach the experimental results of the dynamic responses of anisotropic rotor. The prototype of an anisotropic rotor with two disks is supported by four quasi-rigid bearings. In the experimental studies, the dynamic responses of disks are recorded in horizontal and vertical directions at constant angular speed from 1 to 80 Hz with an incremental speed of 1 Hz. In the numerical studies, two mathematical models are developed by using a minimal number of discrete elements. The dynamic responses of the models are solved by using the Runge-Kutta method of fourth order. In the first model, the mass of shaft is negligible. In the second model, the mass of shaft is taken into account. Comparing the numerical and the experimental results, the natural frequencies of the numerical results of the first model is rather higher than the experimental results. The better results which closed to the experimental results are obtained in the second rotor model, whereas the mass of shaft contributes to reduce the natural frequencies. In the other results, the dynamic responses of the rotor both in simulation and in experiment show the instability area in a wide range.*

## Keywords

*Anisotropic rotor, shaft orientation, Runge-Kutta method*

## 1. INTRODUCTION

Many rotor models have been developed in order to investigate the real rotors in industry fields [1]-[7]. For a simple real rotor, a Jeffcott rotor model can be used to approach the rotor, but for a more complicated rotor system, it must be modeled by a more complicated rotor model too. In case of an anisotropic rotor, the directions of principal axes of shaft cross sections can be different along the shaft. Especially in case of a twisted anisotropic rotor, the directions of principal axes of cross sections change along the shaft. In this case, the rotor model must be modeled by discrete elements [8]. Actually, some existing methods e.g. finite element method can be used to develop the mathematical rotor model [9]-[11]. However, those methods should be modified due to the existing of the different element orientations along the shaft. In this paper, an alternative method is developed by using strain energy method for asymmetric bending of a beam in order to obtain the minimum number of shaft elements of rotor model.

An anisotropic rotor can be modeled in fixed or rotating reference frame. In fixed reference frame, the shaft stiffness of rotor model varies with time. In the rotating reference frame, the differential equations are speed-dependent. In dynamic analysis, the time-variant system is more complicated than the speed-dependent system. However, in the speed-dependent rotor system, the dynamic analysis should be simulated step by step at each frequency. The dynamic responses of the rotor model are solved by using the Runge-Kutta method. Further, the amplitudes of the dynamic responses of the rotor model are benchmarked by the experimental results.

## 2. DESCRIPTION OF THE ROTOR

### 2.1 Prototype of the rotor

In this research, the dynamic behavior of the rotor is investigated both in experimental and numerical simulation analyses. In the experimental studies, a prototype of the anisotropic rotor has been designed and manufactured as depicted in figure 1. The main rotor consists of a steel shaft (X90CrMoV18) with a diameter 8 mm and a total length of 626 mm. Nevertheless, the effective shaft length is assumed 540 mm that is the shaft length between the first bearing and the fourth bearing. The shaft is divided into three sections, in which each section has a 180 mm of shaft length. Along 166 mm of the shaft section the thickness of the cross section is 5 mm. The three sections of anisotropic shaft have different orientations of shaft with the orientation of each section is defined to be  $\beta_1=0^\circ$ ,  $\beta_2=30^\circ$ , and  $\beta_3=60^\circ$ , respectively. Two rigid disks are attached on the shaft. Each disk has 1.153 kg of mass. The ratios of mass moment of inertia are  $\Theta_{p1}=\Theta_{p2}=1.90$ . Near of each disk, an external damper is attached on the shaft. The main rotor is supported by four quasi-rigid bearings. The type of bearings is self-aligning ball bearing. The dynamic responses of the rotor are recorded by using two eddy current displacement sensors at each disk, in which the V-position of two sensors spans an angle of  $90^\circ$ . The displacement of disk in horizontal and vertical direction can be measured by using a rotary transformation of  $45^\circ$ .

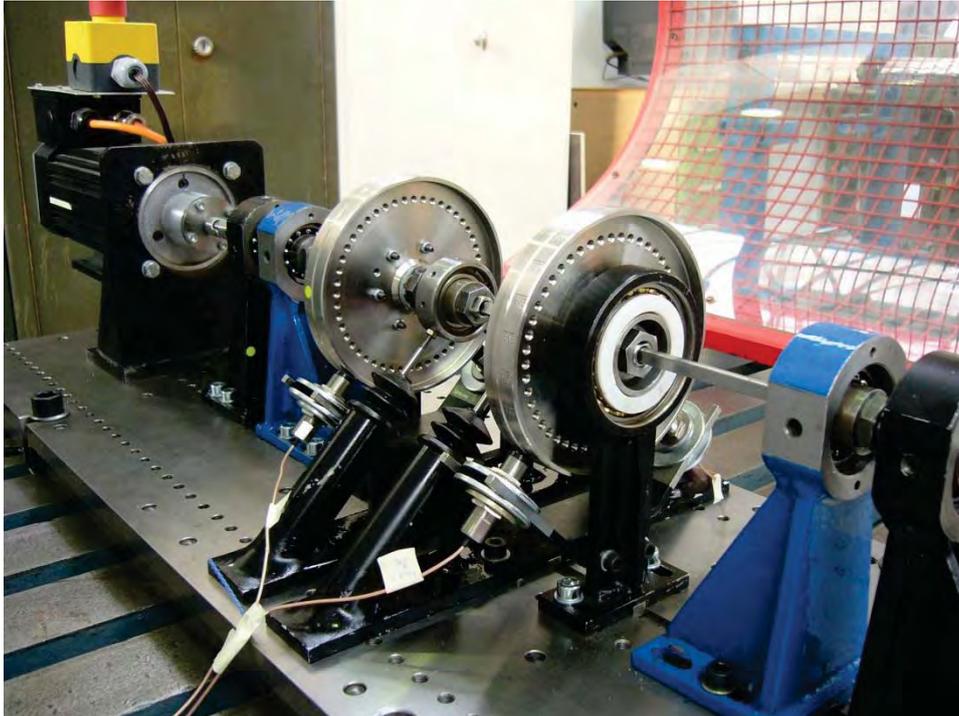


Figure 1: Prototype of anisotropic rotor supported by four quasi-rigid bearings

The rotor is operated at constant angular speed from 1 Hz until 80 Hz with an incremental speed of 1 Hz. The signals of the four displacement sensors are acquired by using the dSpace hardware type DS1103. The MATLAB software is used to control the dSpace and to process the signal data. The signals are filtered by a fourth order lo-pass butterworth filter in MATLAB with a cut off frequency at 100 Hz. The experimental data in time domain are transformed into the frequency domain by using Fast Fourier Transform (FFT).

## 2.1 Mathematical models of the rotor

Generally, the differential equations of rotor motion can be derived both in a fixed and rotating reference frame. If the rotor is modeled in a rotating reference frame, where the coordinate system follows the rotation of the shaft, then the differential equations of the system become speed-dependent. Hence, at constant rotational speed, the dynamic parameters of the rotor can be considered constant.

Furthermore, based on the experimental test-rig, whereas the two disks rotor system is supported by four quasi-rigid bearings must be modeled by multi degrees of freedom of rotor model. By using the minimal number of discrete shaft elements, for the first mathematical rotor model, the shaft is divided into five discrete elements as shown in figure 2. The parameters of the rotor model 1 are listed in table 1. The mass of shaft is negligible. The shaft orientations of the shaft element 1 and 2 are  $\beta_1 = \beta_2 = 0^\circ$ . Further, the shaft orientations of the shaft elements 3, 4, and 5 are  $\beta_3 = 30^\circ$ ,  $\beta_4 = \beta_5 = 60^\circ$ , respectively. For external damper, an approach of proportional damping due to absolute velocity of disk can be used. In the rotor model 1, the coefficients of the proportional external damping and internal damping are assumed  $d_a = 0.18$  and  $d_i = 0.001$ , respectively. Furthermore, the differential equations of the rotor motion can be arranged as in [12]-[13] as

$$[[M_T] + [M_G]]\{\ddot{q}_w\} + [[D_T] + [D_G] + [D_a] + [D_i]]\{\dot{q}_w\} + [[K_T] + [K_G] + [K_a] + [K_w]]\{q_w\} = \{\{p_T\} + \{p_a\} + \{p_g\}\} \quad (1)$$

or in a simple form, the eq.1 is written as

$$[M]\{\ddot{q}_w\} + [D]\{\dot{q}_w\} + [K]\{q_w\} = \{p\}, \quad (2)$$

where  $[M]$ ,  $[D]$ , and  $[K]$  are mass, damping, and stiffness matrices, respectively. These matrices are  $4N \times 4N$  of matrix size, with  $N$  is the number of disk. The  $\{q_w\}$  is the column matrix of displacement of disks and the  $\{p\}$  is the force column matrix. The subscript T and G are to define the derivation matrices of translatory inertia and rotary inertia, respectively. Further, the  $[D_a]$ ,  $[D_i]$ , and  $[K_a]$  are the external damping, internal damping, and proportional stiffness matrix of derivation of external damping matrix, respectively.

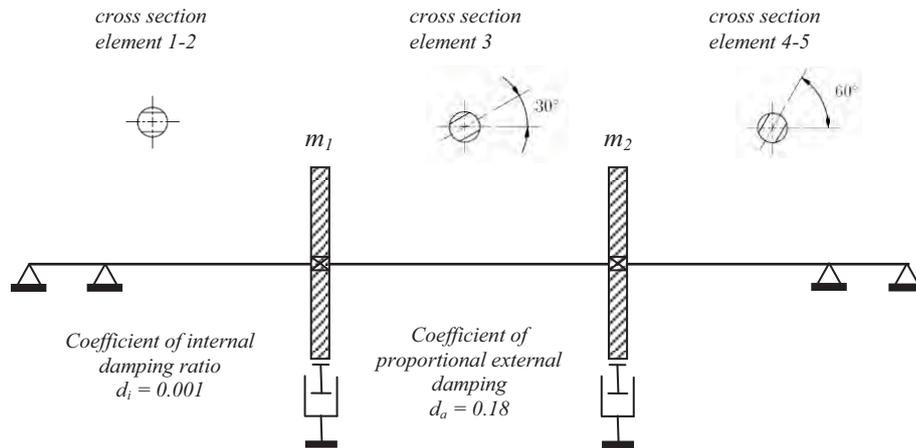


Figure 2: Mathematical model 1 of the rotor (mass of shaft is negligible)

Table 1: Parameter of discrete shaft element (model 1).

No. element	Length of element [m]	Modulus of elasticity [MPa]	Orientation of shaft element [degree]	Mass of disk/shaft element [kg]	Polar mass moment of inertia, $\Theta_p$ [ $\text{kgm}^2$ ]	Axial mass moment of inertia, $\Theta_a$ [ $\text{kgm}^2$ ]
1	0.050	210E+9	0	-	-	-
2	0.130	210E+9	0	-	-	-
-	-	-	-	$m_1 = 1.153$	0.002572	0.001356
3	0.180	210E+9	30	-	-	-
-	-	-	-	$m_2 = 1.153$	0.002572	0.001356
4	0.130	210E+9	60	-	-	-
5	0.050	210E+9	60	-	-	-

Furthermore, the stiffness matrix  $[K_W]$  can be arranged based on the Strain-Energy method [14]. The mathematical model in figure 2 is solved to obtain the reaction forces of all supports and the distribution of bending moment for each force or external bending moment acting at node.

For the second mathematical rotor model, the mass of shaft is taken into account. The mass of each discrete shaft element in the rotor model 1 is assumed as small and very thick disk as shown in figure 3 and the parameter of these shaft elements in table 2. Because a disk must be attached at a node, thus a point of mass of shaft element is placed in the center of each discrete shaft element; therefore, in the rotor model 2 a discrete shaft element as in the model 1 is divided into two discrete shaft elements. The other parameters in the rotor model 1 are the same with the parameters in the model 2.

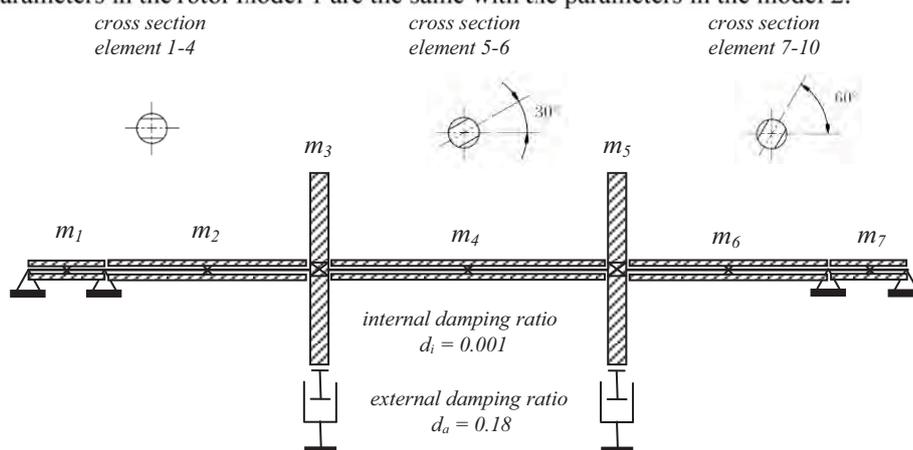


Figure 3: Mathematical model 2 of the rotor

Table 2: Parameter of discrete shaft element (model 2).

No. element	Length of element [m]	Modulus of elasticity [MPa]	Orientation of shaft element [degree]	Mass of disk/shaft element [kg]	Polar mass moment of inertia, $\Theta_p$ [kgm <sup>2</sup> ]	Axial mass moment of inertia, $\Theta_a$ [kgm <sup>2</sup> ]
1	0.025	210E+9	0	m <sub>1</sub> = 0.015	0.0000001224	0.0000008581
2	0.025	210E+9	0			
3	0.065	210E+9	0			
4	0.065	210E+9	0	m <sub>2</sub> = 0.039	0.0000003096	0.0000021704
-	-	-	-	m <sub>3</sub> = 1.153	0.0025720000	0.0013560000
5	0.090	210E+9	30	m <sub>4</sub> = 0.054	0.0000004320	0.0000030285
6	0.090	210E+9	30			
-	-	-	-	m <sub>5</sub> = 1.153	0.0025720000	0.0013560000
7	0.065	210E+9	60	m <sub>6</sub> = 0.039	0.0000003096	0.0000021704
8	0.065	210E+9	60			
9	0.025	210E+9	60	m <sub>7</sub> = 0.015	0.0000001224	0.0000008581
10	0.025	210E+9	60			

### 3.RESULTS AND DISCUSSION

In this presented work, the natural frequencies and the dynamic responses of the rotor will be analyzed. In the experimental results, the natural frequencies of the rotor are obtained from the free vibrations of the rotor at rest excited by an impact force at disk 2 in z-direction. In the numerical results, the natural frequencies are obtained by solving the eigenvalues of the homogenous linear equation of the rotor in eq.1. Comparing the natural frequencies of the rotor as presented in table 3, the four lower natural frequencies of the rotor in the numerical result in the rotor model 1 are rather higher than the experimental result. Note that, for simplification in comparison of the natural frequencies, the third and the fourth natural frequencies both in the experimental result and the numerical result of the rotor model 1 are listed as the fifth and the sixth natural frequencies in table 3. In the numerical result of the rotor model 2, the six lower natural frequencies of the rotor are slightly lower than the natural frequencies of the rotor model 1, because the mass of shaft elements is taken into account and this mass contributes to reduce the natural frequencies. An alternative way in modeling of anisotropic rotor, whereas there is no change of the number of degrees of freedom of the rotor model and the number of discrete shaft elements: the mass of shaft is added in the mass of disk of the rotor, directly. The result of the first natural frequency of the modified rotor model 1 is only slightly higher than the first natural frequency of the rotor model 2. The second natural frequency of the modified rotor model 1 is only slightly decreased. However, the third and the fourth natural frequencies of the modified rotor model 1 (i.e. listed at the fifth and the sixth natural frequencies in table 3) tend to close to the experimental results.

Table 3: Comparison of natural frequencies

Natural frequency	Experimental [Hz]	Numerical (model 1) [Hz]	Numerical (model 2) [Hz]	Numerical (modified model 1) [Hz]
1	21	25.3	24.3	24.5
2	26	33.5	25.7	32.5
3	-	-	33.5	-
4	-	-	38.6	-
5	55	55.7	55.4	53.9
6	68	72.8	72.5	70.6

Furthermore, the dynamic responses of the rotor especially in the experimental results only the displacement of the disk 2 will be analyzed, because the responses of the disk 2 shows the better signal than the signal at disk 1. This may be caused by two possibilities. First, it may be caused by the coupling (see figure 1) which holds the free motion of the shaft end. Therefore, a bending moment occurs in the bearing which reduces the displacement near this bearing. For the disk 2, this effect is small because of the larger distance to the bearing. Second, it may be caused by a misalignment or bowing at the shaft center line. In the dynamic responses analyses, the signal in time domain is transformed into frequency domain by using Fast Fourier Transform (FFT) in the MATLAB software. At each rotating speed of the rotor from 1 Hz to 80 Hz with an incremental speed of 1 Hz, the  $\Omega$  and  $2\Omega$  components of the signal are separated. At each frequency of the  $\Omega$  and  $2\Omega$  signal components, the maximum amplitudes are recorded and presented as shown in figure 4. In this figure, the dynamic responses of the rotor model 2 cannot be reached, because the difference between the biggest and the smallest of mass components in the mass matrix is too high, therefore the time interval  $\Delta t$  in the numerical simulation should be very small. The problem occurs in a calculation accuracy and in a computational time.

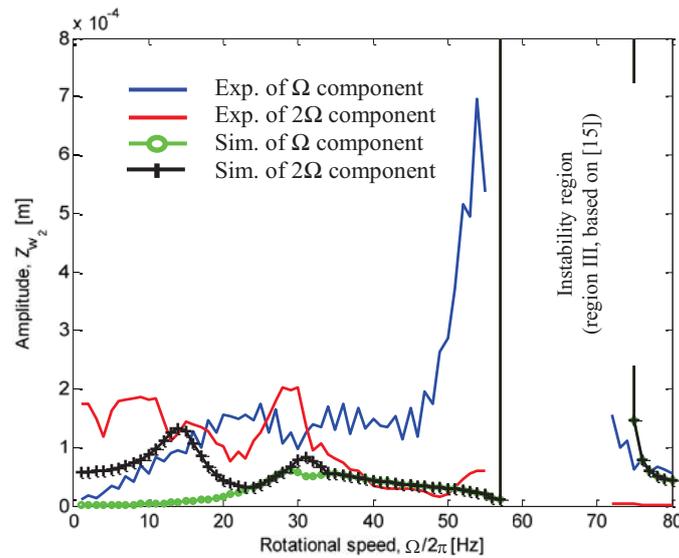


Figure 4: Comparison of the experimental and numerical simulation results (model 1) of the dynamic responses of the disk 2 ( $Z_{w2}$ )

The responses of the disk 2 in figure 4 tend to similar results which have three separated regions of instability as shown for the rotor cases in [15]. The first region of instability corresponds to the region between the first and the second natural frequency and the third instability region to the third and the fourth natural frequency with a shift to higher frequencies. However, the response amplitudes in the first region (18-27 Hz) as listed in table 4 and the second region (34-38 Hz) do not show unstable responses. It was verified experimentally in figure 4 that the rotor may be influenced by higher damping coefficient especially by the external dampers. The instability region of the experimental results occur only in the third region at frequencies 56-71 Hz, whereas in the numerical results of the rotor model 1 at frequencies 58-74 Hz and in the modified rotor model 1 at frequencies 55-72 Hz. Here, the third instability interval of the experimental result is narrower than the one of the numerical results.

Furthermore, the comparison of the regions with the relatively higher amplitudes or instability regions based on the  $\Omega$  component of the responses in the disk 2 is listed in table 4. The responses in the experimental results at rotational speeds around 18-27 Hz and around 34-38 Hz occur with the moderately higher amplitudes, whereas the moderately higher amplitudes in the numerical results occur at rotational speed around 27-28 Hz and 33-35 Hz in the rotor model 1 and 24-26 Hz and 33-35 Hz in the modified rotor model 1. Generally, the numerical results of the modified rotor model 1 tend to similar to the result of the rotor model 1.

Table 4: Comparison of the relatively higher amplitudes or the instability regions based on the  $\Omega$  component of the responses at disk 2

Region	Experimenta 1 [Hz]	Numerical (model 1) [Hz]	Numerical (model 2) [Hz]	Numerical (modified model 1) [Hz]
1	18-27 <sup>(*)</sup>	27-28 <sup>(*)</sup>	n.a.	24-26 <sup>(*)</sup>
2	34-38 <sup>(*)</sup>	33-35 <sup>(*)</sup>	n.a.	33-35 <sup>(*)</sup>
3	56-71	58-74	n.a.	55-72

<sup>(\*)</sup> the response amplitude in this region is moderately high only (not unstable)

Finally, the  $2\Omega$  component of the experimental results is compared to the numerical results. In the experimental results, the peaks of the  $2\Omega$  component occur at frequencies 15 Hz and 30 Hz, whereas in the numerical results at frequencies 14.6 Hz and 30.8 Hz. This comparison is listed in table 5. At lower rotational speeds (i.e. rotational speeds from  $\Omega=0$  to 12 Hz), the  $2\Omega$  components of the experimental result in figure 4 show the higher amplitudes compared to the numerical result. In the numerical result, the deflections of the rotor at lower rotational speeds are caused by the anisotropy of the shaft, whereas the greater deflections in the experimental results are caused not only by the anisotropy of the shaft but also by the misalignment or bowing in the shaft. Therefore, measured data up to 12 Hz were neglected in the following analysis.

Table 5: Comparison of the peaks of the  $2\Omega$  component of the responses at the disk 2

Peak	Experimenta 1 [Hz]	Numerical (model 1) [Hz]	Numerical (model 2) [Hz]	Numerical (modified model 1) [Hz]
1	15	14.6	n.a.	13.5
2	30	30.8	n.a.	30.0

#### 4. CONCLUSION

Based on the experimental and numerical simulation results, generally, the dynamic responses of the anisotropic rotor are dominated by  $\Omega$  and  $2\Omega$  components of the rotating disk speeds. Because of anisotropy of the rotor the instabilities occur in the wide range with the sharp boundary of the rotating disk speeds. Comparing the numerical and the experimental results, the natural frequencies of the numerical results of the first model is rather higher than the experimental results. The better results which closed to the experimental results are obtained in the second rotor model, where the mass of shaft is taken into account, therefore, they contribute to reduce the natural frequencies. However, the rotor model, in which the mass of element is distributed into mass of discrete shaft element, therefore the number of discrete shaft element and the degrees of freedom of the rotor system increase, thus the computational time will increase significantly. Besides, the numerical problem will occur in the simulation of the dynamic responses if the mass of disk and the mass of shaft is too different each other. A better alternative way in modeling of anisotropic rotor, where there is no change of the number of degrees of freedom of the rotor model and the number of discrete shaft elements: the mass of shaft is added in the mass of disk of the rotor, directly.

#### ACKNOWLEDGMENT

The author is grateful to the Indonesian National Higher Education which has funded this current research through the Research Unit of the Andalas University with "Fundamental Research Fund 2013"

#### REFERENCES

- [1] Kellenberger, *Biegeschwingungeneinerunrunden, rotierendenWelle in horizontalerLage*, Ingenieur-Archiv26, 1958, pp. 302-318.
- [2] E. H. Hull, *Shaft Whirling as Influenced by Stiffness Asymmetry*, ASME Journal of Engineering for Industry 83 (1961), pp. 219-226.
- [3] S. T. Ariaratnam, *The Vibration of Unsymmetrical Rotating Shafts*, Journal of Applied Mechanics, Transactions of ASME, Mar. 1965, pp. 157-162.
- [4] T. Yamamoto, H. Ota, K. Kono, *On the Unstable Vibrations of a Shaft with Unsymmetrical Stiffness Carrying an Unsymmetrical rotor*, Journal of Applied Mechanics, 35 (1968), pp. 313-321.
- [5] J. Michatz, *Das Biegeverhalten einer einfachbesetzten, unrunrundenrotierendenWelle unter Berücksichtigung äußerer und innerer Dämpfungseinflüsse*, Dissertation an der TU Berlin, 1970.
- [6] H. L. Wettergren, K.-O. Olsson, *Dynamic Instability of a Rotating Asymmetric Shaft with Internal Viscous Damping Supported in Anisotropic Bearings*, Journal of Sound and Vibration, 195 (1), pp. 75-84, 1996.
- [7] N. Bachschmid, P. Pennacchi, *Theoretical model results of rub in real rotating machinery*, Proceedings of the XII International Symposium on Dynamic Problems of Mechanics (DINAME 2007), Brazil, February 26-Mar 2, 2007.
- [8] J. Malta, *Pemetaan Kestabilan Turbin Gas Horizontal dengan Pendekatan Rotor Multi Disks*, Proceeding of SNTTM XI Yogyakarta, 2012, MT-042.
- [9] Chen, L.-W., Peng, W.-K., *Stability Analyses of a Timoshenko Shaft with Dissimilar Lateral Moments of Inertia*, Journal of Sound and Vibration, (1997) 207(1), pp. 33-46.
- [10] Onescu, F., Lakis, A.A., Ostiguy, G., *Investigation of the Stability and Steady State Response of Asymmetric Rotors using Finite Element Formulation*, Journal of Sound and Vibration (2001) 245 (2), pp. 303-328.
- [11] F. E. Boru, and H. Irretier, *Numerical and Experimental Dynamic Analysis of a Rotor with Non-Circular Shaft Mounted in Anisotropic Bearings*, SIRM 2009-8th International Conference on Vibrations in Rotating Machines, Vienna, Austria, 23-25 February 2009.
- [12] J. Malta, *Effect of different shaft orientation due to stability of anisotropic rotor*, Jurnal Teknik Mesin Indonesia Vol. 5 No. 2, October 2010, pp. 127-133.
- [13] *Accelerated Anisotropic Rotor through its Critical Speeds*, Proceeding SNTTM 9 Palembang, 13-15 October 2010.
- [14] R. Gasch, K. Knothe, *Strukturdynamik, Band 1: Diskrete Systeme*, Berlin Heidelberg: Springer-Verlag, 1987.
- [15] J. Malta, *Stability Investigation of Anisotropic Rotor with Different Shaft Orientation Supported by Anisotropic Bearings*, Proceeding of Seminar Nasional Tahunan Teknik Mesin (SNTTM ke-9) Palembang, 13-15 October 2010, p. MIII:23-30.

# Real-time Monitoring System for Dieless Bellows Forming using Machine Vision

Sugeng Supriadi<sup>a,b</sup>, Tsuyoshi Furushima<sup>b</sup> and Ken-ichi Manabe<sup>b</sup>

<sup>a</sup>Department of Mechanical Engineering, Universitas Indonesia, Depok 16424, Indonesia  
E-mail : sugeng@eng.ui.ac.id

<sup>b</sup>Department of Mechanical Engineering, Tokyo Metropolitan University, Tokyo 192-0397, Japan  
E-mail : furushima-tsuyoshi@tmu.ac.jp; manabe@tmu.ac.jp

## ABSTRACT

Dieless bellows forming using local heating technique is an advanced flexible forming technology to produce bellows from straight tube without the use of dies. The deformation is induced by applying continuous compression, and local heating. Advantages of these processes are the absence of dies, applicability for various materials, suitability for flexible forming process including low batch production, flexibility on workpiece sizes and output geometries. However, the implementation of these processes is still low owing to the low quality, reproducibility, and production speed. The limitation of these dieless forming processes using local heating is caused by the absence of dies required to form the desired profile. Therefore deformation depends on temperature, length of heating zone, processing speed, speed ratio of feeding to fabrication speeds. In order to enhance the product quality in these dieless forming with local heating, real-time monitoring are necessary to identify deformation progress. Machine vision based on image processing technique was selected to monitor deformation behavior on dieless bellows forming process. The present paper describes real-time monitoring using image processing approach to monitor dimensional profile and temperature distribution during the process. The results show that machine vision is effective and efficient to monitor dynamic deformation of dieless bellows forming process and able to identify abnormal process condition.

## Keywords

Dieless bellows forming, machine vision, real-time monitoring.

## 1. INTRODUCTION

Dieless bellows forming is novel process to produce metal bellows without die materials. This process is able to produce metal bellows with various geometry without changing the tools. However there is a technical challenge of increasing dimensional accuracy and reliability[1-3]. Since the process is conducted at high temperature, non-contact sensing technique is necessary. Laser micrometer was applied to monitor metal forming process at high temperature such as dieless drawing process[4]. However this technique is less effective since sensing position is not in deformation zone. When unstable deformation occurs, it is difficult to recognize the deformation immediately[5]. In other hand, temperature distribution as one of key point to control deformation behavior depends on selected processing condition[3, 6]. Therefore real time monitoring on dimension and temperature distribution is essential to achieve real-time control system. Machine vision based on image processing technique offers an alternative technique to monitor dimensional and thermal behavior on deformation zone of dieless drawing process simultaneously. Since machine vision can be used in limited space and wide covered area. This paper describes the utilization of machine vision technique to maintain dimensional bellows profile and temperature distribution.

## 2. DIELESS BELLOWS FORMING PROCESS

Dieless bellows forming is a heat assisted forming technique without using die material to make metal bellows from straight tube as shown in Figure 1. Bellows is series of convolution on the pipe. Formation of the local convolution on the heating area is produced by applying compression speed ( $v_1$ ) from back side faster than feeding speed ( $v_2$ ) on front side. Height of bellows convolution depends on compression speed ratio which is ratio of  $v_1 / v_2$ . Dieless bellows forming is very sensitive temperature disturbance. Therefore stable bellows convolution is difficult to obtain. Therefore real-time bellows formation is necessary to get early information of unstable bellows formation. In this work is presented utilization of machine vision technique to monitor deformation progress in dieless bellows forming process.

## 3. MACHINE VISION

Semi-dieless bellows forming has two main characteristics, a wide deformation zone and a complex deformation mechanism. Therefore the deformation process is difficult to observe using a narrow measuring scope. The semi-dieless bellows forming

apparatus has limited spaced for equipping a sensor, which must be flexibly attached in the semi-dieless bellows forming apparatus. A vision-based sensing system is a suitable sensing technique that deals with those measuring conditions for tool inspection and hot forging, [7-9]. Dworkin and Nye (2006) developed a machine vision system using an infrared filter to monitor a hot forging process. An infrared-pass filter is used to improve the visibility of the fluorescent workpiece through elevated temperature. The machine vision algorithm is the same as that used in our previous study to monitor dieless tube drawing process [10, 11]. The components of the vision-based monitoring are image acquisition, image processing, data processing, and measurement accuracy of machine vision.

#### 4. EXPERIMENTAL PROCEDURE

##### 4.1 Image acquisition

Since the initial deformation occurs under the heating coil and it is not directly visible, the camera must be tilted up to  $10^\circ$  from the perpendicular direction, as the optimum position considering the visibility and accuracy, to obtain the representative image in Figure 1. In this study, the image was captured without using an infrared-pass filter. A high contrast image of the workpiece was obtained by decreasing the exposure level on the camera.

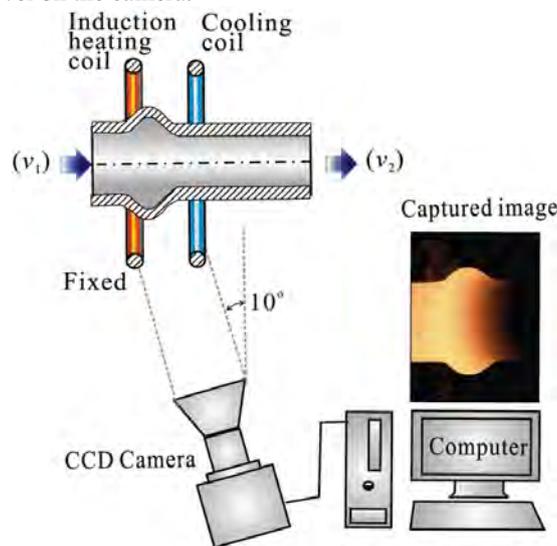


Figure 1: Camera positioning for monitoring the local deformation of the tube during semi-dieless bellows forming.

##### 4.2 Image processing

After images captured, image processing technique is applied to measure bellows height through convert to gray follow by edge detection. Bellows height is obtained by measuring outer diameter then multiply with pixel ratio to metric unit. It is obtained by comparing real part dimension.

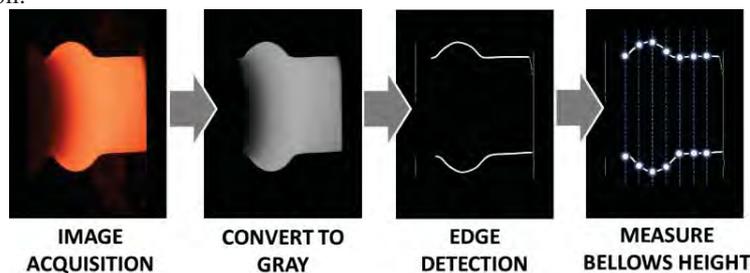


Figure 2 : Image processing to measure bellows height.

The image processing to measure the bellows height is conducted by edge detection of the workpiece outline. The convolution height is measured by calculating the distance between the workpiece edge outline, as shown in Figure3. The measuring region was set up as 16 sections, as shown in Figure 4. The measured output from image processing is the number of pixels. The desired measured value is in metric units. Therefore, a pixel ratio is used to convert the pixel number into metric. The pixel unit is obtained by comparing the image processing result and the actual dimension.

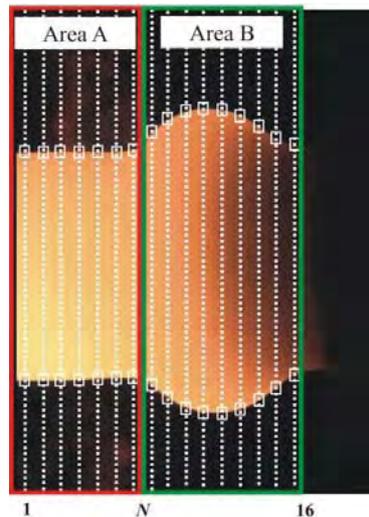


Figure3: Multi-sectional measurement in the deformation part for semi-dieless bellows forming process.

## 5. RESULT AND DISCUSSION

### 5.1 Measurement result using machine vision

Every section shows a different diameter, as shown in Figure 4. The measuring area is divided into two: areas A and B. The initiation of bellows convolution takes place in “area A” encompassing the 1<sup>st</sup> section up to section *N*. The convolution height increases to the maximum value in “area B”, which is from section *N* up to section 16. In semi-dieless bellows forming, after the first bellows is formed, the next convolution is initiated.

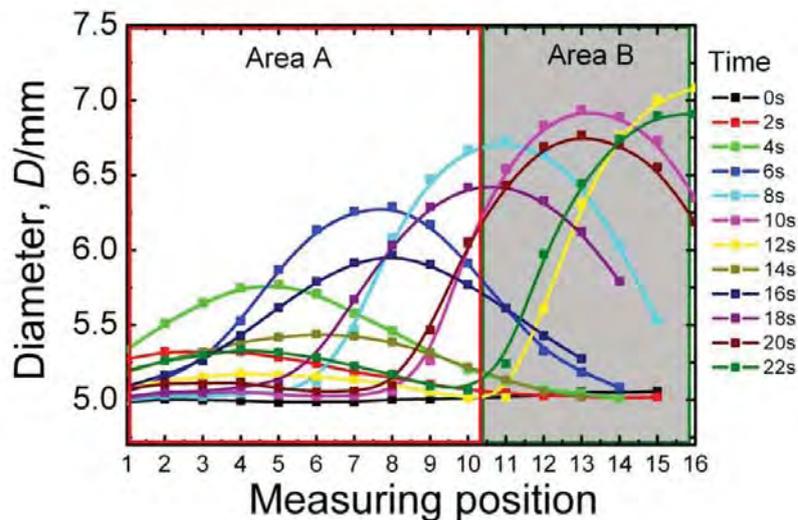


Figure 4: Deformation process in semi-dieless bellows forming at different measuring positions.

### 5.1 Data processing

In semi-dieless bellows forming, the important property for controlling the process is the bellows height. Since the maximum height of the bellows moves from one section to another section, an additional program is necessary to select the appropriate bellows height data. An additional data processing algorithm is necessary. Therefore, the measurement area is divided into two observation areas. Figure5 shows the algorithm used to manipulate measurement data from 16 sections to the deformation point during semi-dieless bellows forming. The monitoring of bellows height should enable us to monitor the current bellows deformation.

The first step is to find the maximum diameter  $D(t)$  among all the measurement sections. The position of the maximum diameter is

section  $M$ . After the first convolution reaches its maximum height, which is indicated by the derivative of  $D(t)$  being equal to or less than zero ( $dD/dt \leq 0$ ), the analysis shifts to the next convolution, which occurs in area A. Section  $N$  must be decided in order to determine area A. Section  $N$  has the minimum diameter from among section 4 to section  $M$ . After a boundary of area A is obtained (the  $N$  value), the next convolution height is the maximum diameter in area A. The process is repeated until the semi-dieless bellows forming process is finished. Figure 6 (a) shows the original measurement data in time series for 16 sections before the measurement value was selected and after using the algorithm to acquire bellows height data (Figure 6 (b)). The convolution height is the maximum value for every peak point. Therefore, the monitoring of every convolution can be conducted. The time period between measurement peaks indicates the pitch distance after multiplication with feeding speed ( $v_2$ ).

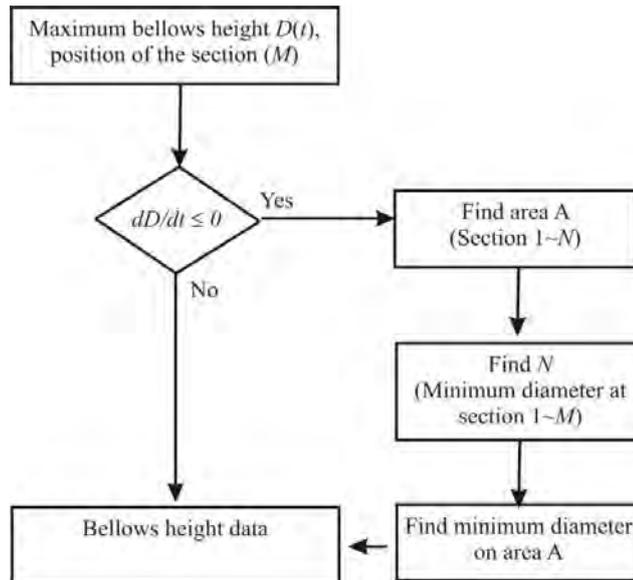


Figure5 Algorithm to determine the required bellows height from multi-sectional measurements.

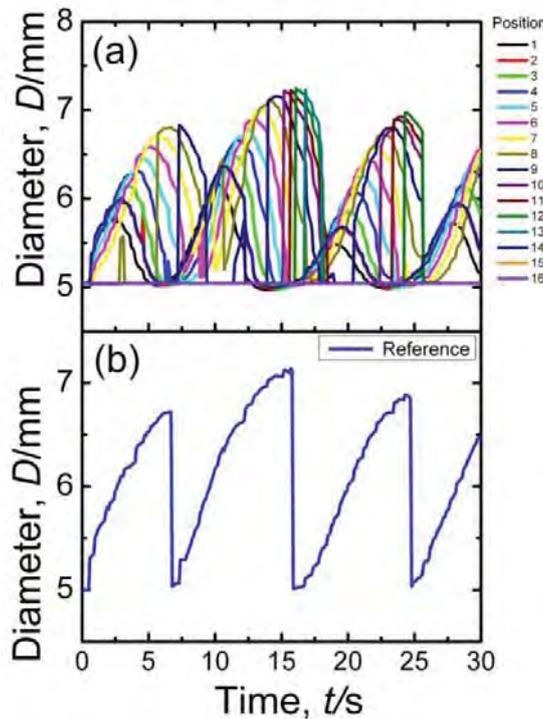


Figure 6: (a) Bellows profile measurement data sensed from 16 sections, (b) Profile height data in time series after data

processing

### 5.2 Measurement the accuracy of machine vision

The accuracy of the machine vision technique was evaluated by optical microscope measurement. The convolution height determined using the machine vision result shows a good agreement with the optical microscope result. Figure7 shows the accuracy of machine vision result for pitch. The average pitch value obtained from machine vision is smaller than that measured with the microscope. In machine vision, the pitch distance is calculated by multiplying the time interval between the peak of convolution and moving speed of the convolution. Measurement error of pitch from the machine vision might be caused by improper assumption of moving speed of the formed convolution. In this paper assume that the moving speed of the convolution is equal with feeding speed. In the actual condition, the formed convolution (deformation area) is a transitional speed area from compression speed into feeding speed. Therefore, the moving speed is higher than feeding speed.

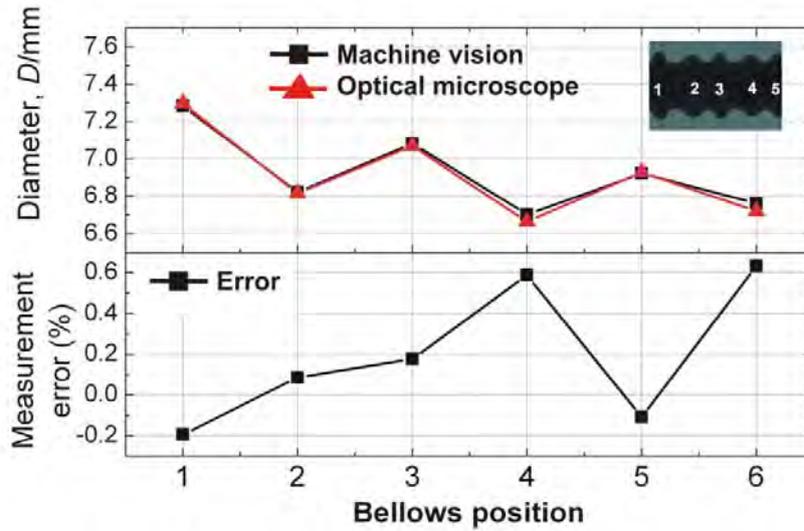


Figure7 :Measurement accuracy of bellows height obtained by machine vision.

### 5.3 Measurement abnormality of dieless bellows forming process

By analyzing bright intensity, machine vision can estimate temperature [10, 11]. In our previous work was verified this. When this technique is applied to monitor maximum bellows processing temperature, there are correlation between variation of maximum bellows forming temperature and variation of bellows height. As shown in Figure 8 history of maximum bellows forming process is vary depends on bellows formation progress. When convolution is produced temperature increased, while when temperature is decreased is new convolution is initiated. At low bellows forming temperature produce lower convolution height, while at high processing temperature shows high convolution height. By analyzing variation of temperature can be used to identify stability of bellows formation.

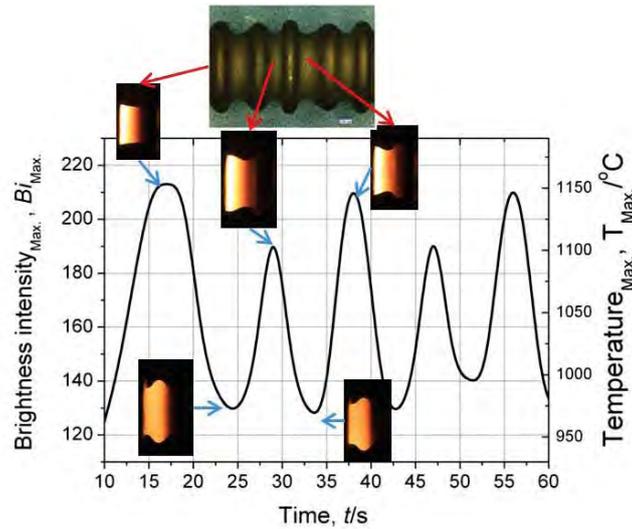


Figure 8: Unstable bellows height can be detected by variation of brightness intensity that correlate with temperature.

When unstable processing temperature of bellows occurs in radial direction, axymetric bellows shape will obtained. Table. 1 shows the example of balanced brightness intensity and unbalance brightness intensity between upper side and bottom side. When gap of upper and bottom side inceases aximetric bellows will occurs.

Table. 1 Comparison of Brightness profile to examine axymetricity.

Time	1) Balanced brightness intensity	2) Unbalanced brightness intensity	Difference brightness intensity $\Delta Bi = Bi_1 - Bi_2$
24 s			
36s			

## 6. CONCLUSIONS

In this paper described real-time monitoring system using vision based image processing to monitor deformation of bellows formation. That performs flexibility to monitor deformation in limited access in dieless bellows forming machine. The results of machine vision has been validated that shows good agreement with other measuring device. The proposed technique also able to monitor temperature different that promote unstable deformation and asymmetric bellows shape. Therefore unstable deformation can be easily detect to anticipate further product defect. Therefore vision-based monitoring system is effective and efficient to sense deformation progress for dieless bellows forming process.

## REFERENCES

- [1] S. Supriadi, N. Q. Hung, T. Furushima, and K. Manabe, "A Novel Dieless Bellows Forming Process Using Local Heating Technique," *Steel research international*, pp. 950-955, 2011.
- [2] T. Furushima, N. Q. Hung, and K. Manabe, "Fabrication of metal bellows by dieless compression technique," in *The Proceeding of the 61th Japanese Joint Conference for the Technology of Plasticity*, Yamagata, Japan, 2010, pp. 87-88.

- [3] Tsuyoshi FURUSHIMA, Nguyen Quang HUNG, Ken-ichi MANABE, and O. SASAKI, "Development of Semi-dieless Metal Bellows Forming Process," *Journal of the Japan Society for Technology of Plasticity*, vol. 53, pp. 251-255, 2012.
- [4] Y. Huh, B. K. Ha, and J. S. Kim, "Dieless drawing steel wires using a dielectric heating method and modeling the process dynamics," *Journal of Materials Processing Technology*, vol. 210, pp. 1702-1708, 2010.
- [5] S. Supriadi, T. Furushima, and K. Manabe, "Real-Time Process Control System of Dieless Tube Drawing with an Image Processing Approach," *Materials Transactions*, vol. 53, pp. 862-869, 2012.
- [6] S. Supriadi, N. Q. Hung, T. Furushima, and K. Manabe, "A Novel Dieless Bellows Forming Process Using Local Heating Technique," presented at the International Conference on Technology of Plasticity, Aachen, Germany, 2011.
- [7] S. Kurada and C. Bradley, "A review of machine vision sensors for tool condition monitoring," *Computers in Industry*, vol. 34, pp. 55-72, 1997.
- [8] S. Kurada and C. Bradley, "A machine vision system for tool wear assessment," *Tribology International*, vol. 30, pp. 295-304, 1997.
- [9] S. B. Dworkin and T. J. Nye, "Image processing for machine vision measurement of hot formed parts," *Journal of Materials Processing Technology*, vol. 174, pp. 1-6, 2006.
- [10] S. Supriadi, T. Furushima, and K. Manabe, "Real-Time process control system of dieless tube drawing with an image processing approach," *Materials Transactions*, vol. 53, pp. 862-869, 2012.
- [11] S. Supriadi, T. Furushima, and K. Manabe, "Real-time Process Control System of Dieless Tube Drawing with An Image Processing Approach," in *Proceeding of the 5th International Conference on Tube Hydroforming*, Noboribetsu, Hokaido, Japan, 2011, pp. 92-95.

## Numerical Modeling of Ship Composite-Based on Aluminum Casting as Alternative Materials for Ship Building

Tjahjanti P.H<sup>a</sup>, Manfaat.Dj<sup>b</sup>, Panunggal.E<sup>c</sup>, Darminto<sup>d</sup>, Nugroho W.H<sup>e</sup>

<sup>a</sup>Department of Mechanical Engineering, University of Muhammadiyah Sidoarjo (UMSIDA), Sidoarjo, Jawa timur, Indonesia  
E-mail : pran\_tasi@yahoo.com, prantasi@gmail.com

<sup>b,c</sup> Faculty of Marine Technology Engineering, Institute Technology of Sepuluh Nopember (ITS) Surabaya, Jawa Timur, Indonesia

<sup>d</sup> Department of Physics Sciences, Institute Technology of Sepuluh Nopember (ITS) Surabaya, Jawa Timur, Indonesia

<sup>e</sup>BPPT Lab. Hydrodynamics Indonesia UPT-BPPH Surabaya Jawa Timur, Indonesia  
E-mail : bowo02@yahoo.com

### ABSTRACT

The structure and construction of the ship is made of aluminum alloy, generally are of wrought aluminum alloys, when experiencing fatigue failure caused by a cracked vessel structure, is a serious problem. Reviewing of 'weakness' of wrought aluminum alloys for the ship, then in this study tries to provide material alternative for ship building is composite material based on aluminum casting AlSi10Mg (b) and reinforcing material silicon carbide (SiC), which has been in-treatment with the optimum composition 15%. Analysis of numerical computation with the help of ANSYS software version 2.00 to be made numerical modeling ship to ship aluminum EN AC-AlSi10Mg (b) and ship composite EN AC-AlSi10Mg (b)+SiC\*/ 15p whether the material can be applied to building ship for see the distribution of stress . The results of the stress distribution in both of model numerical of ship, its value does not exceed the stress permits ( $\sigma$  0.2) and have a factor of safety above the minimum allowable limit, so it is safe to use. The overall, in numerical modeling, the ship material aluminum and ship composite materials can be used as an alternative material for ship building, however is still needed comprehensive testing in the field.

### Keywords:

Aluminum casting ; ship building ; composite EN AC-43100(AlSi10Mg(b))+SiC\*/15p; ANSYS ver.12,0

This Paper is Published in Advanced Materials Research Journal

# Techno-Economic Review Of Hybrid / Electric Catamaran Fishing Vessel

Pramudya Imawan Santosa <sup>(1)</sup> and I Ketut Aria Pria Utama <sup>(2)</sup>

<sup>(1)</sup>PhD Student, Department of Naval Architecture and Shipbuilding Engineering, ITS, Surabaya

<sup>(2)</sup>Professor, Department of Naval Architecture and Shipbuilding Engineering, ITS, Surabaya

E-mail : mpic\_pramudya@yahoo.com, kutama@na.its.ac.id

## ABSTRACT

Fishing boat technology has grown up rapidly, both the fishing equipment and the boat itself. The weaknesses of monohull fishing boat, particularly in relation with ship stability, have been anticipated by the introduction of catamaran fishing vessel. In addition, the scarcity of fossil fuels hence causes the fishermen cannot afford to buy it, and many fishing boats are grounded, but now faces promising hopes by the introduction of hybrid/electric boat together with the use of conventional engine and its fuel.

The current paper describes engineering review and economic viability of the use of hybrid/electric catamaran fishing vessel. Comparative analysis with other published data is carried out in order to support the findings of the current research.

### Keywords:

*catamaran, fishing vessel, hybrid/electric, solar cell.*

## 1. INTRODUCTION

Catamaran type of vessel has been widely used since the last 30 years for many purposes: passenger carrier, oceanographic research vessel and sailing yacht [1]. The use of catamaran for fishing vessel was reported in [2]. A new layout arrangement on main deck was proposed and compared with the monohull type. It was discovered that the catamaran of the same displacement has wider deck area hence better deck arrangement may be applied. This consequently provides wider space to put fishing equipment on deck as well as to store the catching fishes.

That fishing vessel was developed with the use of conventional engine together with the use fossil fuel. It is found to be not economical in term of fuel spending and environmental issues. The money spent by fishermen to purchase fuel has increased significantly hence becomes un-affordable to the most of them. In other side, there is an increase on green-house gases (GHG) such as NO<sub>2</sub>, SO<sub>2</sub> and CO<sub>2</sub> to the atmosphere hence the concept is not environmentally friendly.

Many attempts to minimize the use of fuel and GHG effect have been carried out worldwide. The use of alternative energy to complement the fossil fuel and if possible, to replace the use of it is actively conducted around the globe. Some of the ideas include the use of sail, solar cells and wave power mechanism [3]. The combination of engine and sail, later known as sail assisted engine, has been applied in many places in Indonesia for many years especially by fishermen. It has been found to cut the use of fuel of about 15% as reported in [4]. The hybrid use of solar powered and wave power mechanism is another possible answer [3].

Recent analysis in [5] indicates the conflicting of energy against the economic consequences of the use of hybrid system. The use of hybrid system, in one hand, may reduce the cost of energy spending but in other hand, it causes the delay of cargoes delivery to customers hence become less attractive to them. Other issues to consider including the cost of installing the hybrid system, which is normally rather expensive and stability evaluation especially with the use of sails may cause some problems. The use of sails may increase the metacenter and hence affect the ship stability. Accordingly, this may cause the boat become less comfortable.

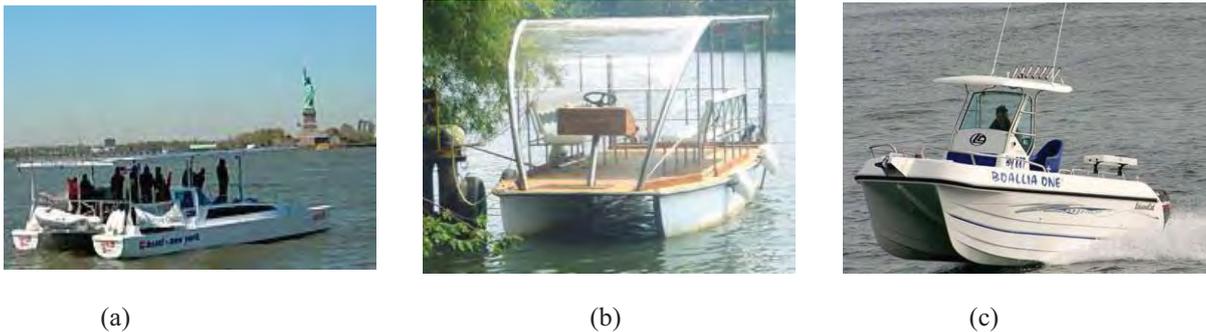
Furthermore, the emissions from ships produce GHG such as NO<sub>2</sub>, SO<sub>2</sub> and CO<sub>2</sub>. CO<sub>2</sub> emissions have a global climate impact and concentrated effort is being made worldwide towards their reduction. In order to monitor and quantify CO<sub>2</sub> emissions, the International Maritime Organization (IMO) introduces an Energy Efficiency Design Index (EEDI) [6], [7].

## 2. ENGINEERING REVIEW

### 2.1 Solar power boat

The idea of developing solar power boat coming from electric power boat, where the energy captured from sun-rays is stored into battery. The energy is then used to power the engine to move the boat into certain distance at certain speed. The first practical electric boat, powered by solar energy, was constructed in 1975 in England [9]. It was later followed by some countries, such as Switzerland, which has developed the biggest solar powered vessel so-far with length up to 31m and sailed around the world successfully. Planet-Solar, the Swiss solar catamaran has travelled a journey of about 60,000 kilometers across the ocean. With 537 m<sup>2</sup> of solar panels, the Planet-Solar has ever produced up to 600 kWh in good weather to cause the boat to go up to 300 km when the battery is charged up to 100%. Every thing on board is powered by the sun: the engine to computers through the water heating. In 2008, Japanese already launched the 200 m length “Auriga Leader” cargo ship solar power. The ship with displacement of about 60, 000 tonnes capable to carry about 6400 cars. The ship was produced by a joint venture of Nippon Yusen K K shipyard and Nippon Oil Corp [8].

Furthermore, Figures 1(a) to 1(c) portaits the development of adequately small solar power boat around the world.



**Figure 1: Examples development of solar power boat**

Figure 1 (a) shows a 14-meter boat (Sun 21 New York) which produces about 2,000 kWh of solar energy at constant speed of 5-6 knots (10-12 km/h) [9]. She enjoyed her first journey in the Rhine in October 2006. Figure 1(b) shows a 9-seat tourism boat developed in India and she can run at service speed about 6.5 knots [9]. Figure 1(c) shows a leisure boat of 6.88m length (Islander 6000) which is designed for fishermen along with walk-around decks and including two forward platforms for fly-fishing [10].

### 2.3 Emission factor

International Maritime Organization (IMO) adopted a new chapter to MARPOL annex VI in order to reduce GHG emission from international shipping by improving the energy efficiency for ships. The hull design, propulsion techniques and operational practices are expected technology that can be improved in order to increase the energy efficiency for ships. The Marine Environment Protection Committee (MEPC) approved the interim guidelines on the method of calculation of Energy Efficiency Design Index (EEDI) towards determining minimum energy efficiency level for new ships. It is mandatory to all merchant ships of 400 GT and above regardless the nationality of the owners [11]. However, it is considered in the near future to apply to other type of vessels using fossil fuels.

Furthermore, the EEDI formula provides a specific figure for an individual ship design, as proposed by IMO [6], [7], as given in Equation (1):

$$EEDI = \frac{P \times sfc \times C_F}{C \times V} \text{ gm CO}_2/\text{tonne mile} \quad (1)$$

Where  $P$  is power (kW),  $sfc$  is specific fuel consumption (gm/kW.hr),  $C_F$  is a CO<sub>2</sub> conversion (tonne CO<sub>2</sub>/tonne fuel),  $C$  is the capacity of the ship (DWT or GT) and  $V$  the speed (knots). As such, EEDI can be seen as a measure of a ship's CO<sub>2</sub> efficiency.

When considering the overall form of EEDI, it is clear that in order to reduce the index for a given ship at a given speed, a decrease in propulsive power must be achieved and/or improvements made in engine efficiency with a reduction in  $sfc$ . The EEDI formula can later be simplified to Equation (2):

$$EEDI = \text{CO}_2 \text{ emission} / \text{transport work} \quad (2)$$

The CO<sub>2</sub> emission represents total CO<sub>2</sub> emission from combustion of fuel at design stage, including propulsion and auxiliary engines, taking into account the carbon content of the fuels in question. If shaft generators or innovative mechanical or

electrical energy efficient technologies are incorporated on board a ship, these effects are deducted from the total CO<sub>2</sub> emission. If wind or solar energy is used to board a ship, the energy saved by such measures will also be deducted from the total CO<sub>2</sub> emissions, based on the actual efficiency of the system. The transport work is calculated by multiplying the ship's capacity as designed (DWT for cargo ships and GT for passenger vessels) with the ship's design speed measured at the maximum design load condition and at 75% of the rated installed shaft power. Speed is the most essential factor in the formula and may be reduced to achieve the required index.

### 3. ECONOMIC REVIEW

Solar power boats obtain their energy from the sun. Using electric motors and storage batteries charged by solar panels and photovoltaic cells, solar power boats can significantly reduce the use of fossil fuels. Solar boats are uniquely suited to transform light energy (from the sun) to movement. Environmentally friendly solar energy is an energy efficient way to power commercial oceangoing vessels and leisure boats [9]. This later found to be very worthwhile if installed into fishing vessels.

The high cost of fossil fuels hence causes the fishermen unable to buy it, can be overcome by the introduction of solar power boat. The high cost of solar panel can be anticipated by the combination use of conventional diesel engine and the solar panels. In this case, the size of engine may be reduced and hence the fuel consumption. The high cost of solar panels is purely a crucial problem at the beginning (for the fishermen), but they will spend less money to buy fuels in the future as long as they maintain the solar panels properly [13].

### 4. EXAMPLE OF APPLICATION AND DISCUSSION

#### 4.1. The practical electric boat

A small and practical solar powered catamaran was developed and reported in [12]. The principle particulars of the boat are: L<sub>BP</sub> = 9.765 m, B = 3.5 m, T = 0.9 m and block coefficient (C<sub>B</sub>) = 0.68. The resistance calculation was made based on Insel and Molland approach [14]; the complete formulation is given in Equations (3 and 4). The service speed of the boat is 6.25 knots (Fr = 0.33) hence its total resistance is 0.95 kN.

The most widely used estimation of catamaran resistance is the method proposed by Insel and Molland [14]. In this case, catamaran hull consists of 2 isolated demihulls and creates wave and viscous resistance interference and formulated as follows:

$$C_T = (1 + \phi k) \sigma C_F + \tau C_W \quad (3)$$

Where:

C<sub>T</sub> is total resistance coefficient,

C<sub>F</sub> is frictional resistance coefficient and obtained from ITTC-1957 correlation line,

C<sub>W</sub> is wave resistance coefficient of isolated demihull,

(1+k) is form factor value of isolated demihull,

ϕ is used to estimate the change of pressure around demihull,

σ represents additional velocity between demihulls and calculated from the summation of local frictional resistance around wetted surface area.

In fact, the factors of ϕ and σ are difficult to measure hence for the practical purposes, the two factors can be combined to form viscous resistance interference factor β where (1 + ϕ k)σ = (1 + β k) hence:

$$C_T = (1 + \beta k) C_F + \tau C_W \quad (4)$$

Where for monohull or demihull at isolation the value of β=1 and τ=1.

Furthermore, the effective power of the boat is calculated using Equation (5) and giving the effective power (PE) about 3.04 kW. However, since the boat is a catamaran and using two engines and propellers hence the capacity of each engine is 1.52 kW. The thrust power is calculated using Equation (5) and giving thrust power (T) of about 3.053 kW.

$$P_E = R_T V \quad (5)$$

Furthermore, Ref [12] concluded that the boat required 10 solar panels in which each panel can produce energy about 100 WP (watt-peak). The charged battery can power the boat, solely supported by 10 solar panels, for about 5 hours.

#### 4.2. Possible Cost Saving

The Indian boat (Sun 21) as shown in Figure 1 (b) is a 45.9-foot-long specially built solar powered boat known as a catamaran [9]. It is installed 48 silicon photovoltaic cells on its canopy like roof, which can collect energy from sunlight and transmit it to a device in one of her cabins. The device transmits the energy to the 3,600 lbs of storage batteries placed below the deck. The 11-ton solar boat was powered on the energy needed to light 10 100-watt light bulbs. The typical speed was 3.5 knots and together with two engines so that the boat can go up to 107 nautical miles a day in good weather. Her fuel consumption is about 17 Liter/hour (MCR), hence, ignoring the cost of the system, the solar boat can save 17 liter/hour x 24 hours x IDR 4,500 that is IDR 1,836,000 per day.

Meanwhile, other work conducted in Indonesia and reported in [13], the cost to built a solar boat of 4.30 m LOA, 3.80 m LWL, 2.50 m breadth moulded (B), 0.30 m draught (T) and 1.39 ton displacement was approximately IDR 105 millions. In term of investment value, the cost of the boat is somehow more expensive than the same boat powered by conventional engine. The boat can save about IDR 1.4 million for 20 operational days. This is, indeed a very small saving of money, but the operational cost could be cheaper in long term since the boat does not need fuel and the battery (if well maintained) can be used up to about 10 years.

Furthermore, refers to the work report in [9] and [11], the use of solar cells can reduce energy index (EEDI) of those two boats. Further details of the calculation is still being carried out at ITS.

## 5. CONCLUSION

The current work clearly portrays the study into the development of solar powered boat in order to reduce the use of fossil fuels. It has been found (through case example) that the use of solar panel in combination with the operation of electric engine was to be very useful.

Economic review indicates the potency of cost saving if the solar power is applied to small boat such as fishing vessels. In term of energy index, the system can reduce the emission of green houses gases. There is shown a good promise that can lead to significant savings in fuel consumption and hence reduce emission of greenhouse gases. However, in reacting to the increase pressure from the environmental viewpoints and with the possibility of future introduction of emissions trading schemes, reduction in power and emissions might be achieved with design changes and fuel saving devices but this may not be the best economic solution.

## REFERENCES

- [1] Murdijanto, Utama, I K A P and Jamaluddin, A, An investigation into the resistance/powering and seakeeping characteristics of river catamaran and trimaran, Makara Seri Teknologi, Vol 15, No. 1, April 2011.
- [2] Setyawan, D, Utama, I K A P, Murdijanto, Sugiarto, A and Jamaluddin, A, Development of catamaran fishing vessel, IPTEK – the journal for technology and science, Vol. 21, No. 4, November 2010.
- [3] Santosa P. I. and Utama I. K. A. P., Preliminary study into the development of hybrid catamaran fishing vessel, MARTEC Conference., Kuala Terengganu, Malaysia, 20-22 October 2012.
- [4] WINDTECH'85, International symposium on windship technology, University of Southampton UK, 1985.
- [5] Utama, I K A P and Molland, A F, The powering of future ships taking into consideration economic viability and environmental issues, International Conference on Ship and Offshore Technology (ICSOT), 7-8 November 2012, Ambon, Indonesia.
- [6] IMO. Guidelines on the method of calculation of the Attained Energy Efficiency Design Index (EEDI) for new ship. Resolution of the Marine Protection Environment Committee, MPEC212(63), 2012.
- [7] IMO. Guidelines on Survey and Certification of the Energy Efficiency Design Index (EEDI). Resolution of the Marine Protection Environment Committee, MPEC214(63), 2012.
- [8] www. "Auriga Leader" cargo ship solar power japanesse, 2008
- [9] <http://www.dasolar.com/solar-energy/solar-powered-boats>
- [10] <http://www.nauticexpo.com/prod/aussiecat/power-catamarans-out-board-center-console-boats-twin-engine-20734-47262.html>
- [11] IMO (2000). Marine Environmental Protection Committee. 44th session available at: <http://www.imo.org/meeting/44.html>.
- [12] Nasirudin, A., An innovation of hybrid ship (wind and solar power) to transport cargo in Indonesian waters vessel (in Indonesia), <http://digilib.its.ac.id>, 2009.

- [13] Daniel, D and Chandra, H, The Evaluation of Solar Power on Sea Trial Results of Catamaran Boat, *Jurnal Kelautan Nasional* (in Indonesian), 2011.
- [14] Insel, M dan Molland, A F (1991), *An Investigation into the Resistance Components of High Speed Displacement Catamarans*, Meeting of the Royal Institution of Naval Architects.

## Determining Risk Accidents based on Shiphandling Difficulty Model for Ferry: A validation approach

Antoni Arif Priadi<sup>a,b</sup>, Tri Tjahjono<sup>a</sup>, Abdellatif Benabdelhafid<sup>b</sup>, Sunaryo<sup>c</sup>

<sup>a</sup>Department of Civil Engineering, University of Indonesia  
Depok 16424 Indonesia  
E-mail : antoni.bmmc@gmail.com, tri.tjahjono@ui.ac.id,

<sup>b</sup>Laboratoire de Mathématiques Appliquées, University of Le Havre  
Le Havre 76600 France  
E-mail : antoni-arif.priadi@etu.univ-lehavre.fr, abdellatif.benabdelhafid@univ-lehavre.fr

<sup>c</sup>Department of Mechanical Engineering, University of Indonesia  
Depok 16424 Indonesia  
E-mail: naryo@ui.ac.id

### ABSTRACT

The risk assessment commonly is performed by assessing the risk of accident from the point of probability of historical accident. Since sometimes it is quite difficult to get the historical data, the instrument to assess safety risk for ferry is developed through AHP and fuzzy approach. The instrument is based on the shiphandling difficulty level for ferry and later it is named with SHDMF. This paper presents how the SHDMF could be validated through experiment in shiphandling simulator. The shiphandling simulator NAVI TRAINER 5000 Transas is used. The experiment is performed by using 13 groups on ferry passenger with 7 scenarios which constitute of berthing, unberthing and crossing activities at Madura Strait, Indonesia. The result is compared to the SHDMF calculation.

### Keywords

*Shiphandling simulator, risk assessment, AHP and fuzzy approach*

## 1. INTRODUCTION

The risk assessment is an activity to assess level of risk concerned from one activity. Risk assessment approach generally uses historical data as an input to predict the outcome of process. Yet, this historical data sometimes is quite difficult to be acquired. Therefore, the development of analytic model could be an alternative approach to be used as an instrument of risk assessment. The analytic model validation needs to be performed in relation with real world. The types of validation consist of two types which are internal validation and external validation. The internal validation relates to the model validation itself and it could be performed according to its approach. Meanwhile, the external validation is performed based on the design of model itself. It may use real experiment, simulated experiment or even by case study. In this paper, to validate the AHP Fuzzy shiphandling difficulty model for ferry (SHDMF), shiphandling simulator experiment is carried out. The shiphandling simulator experiment is conducted by placing some experienced officers through some scenarios and the results are compared to the SHDMF. This experiment will be used as a justification step whether such simulator experiment approach could be employed for validating SHDMF. The description of SHDMF, shiphandling simulator and the result of experiments are described in this paper.

## 2. REFERENCES REVIEW

In this section, shiphandling difficulty model for ferry (SHDMF) and simulator overview are presented. The SHDMF reference review is based on the previous research which was conducted by the writers. In this paper, we do not discuss in detail about SHDMF construction such as AHP formulation and fuzzy member development, because this paper is a continuation of previous research and it focuses on the part of external validation.

### 2.1 Shiphandling difficulty model for ferry (SHDMF)

Shiphandling difficulty model (SHDMF) for ferry is developed through analytic hierarchy process (AHP) and fuzzy logic approach [1]. The first approach is performed to determine hierarchy among factors which consider as complex and inconstant toward shiphandling operation. The output of AHP is used to formulate fuzzy logic. The end output of this model is the level of shiphandling difficulty which further is used as a tool of making decision in risk accident assessment. The layout of SHDM is illustrated in figure 1.

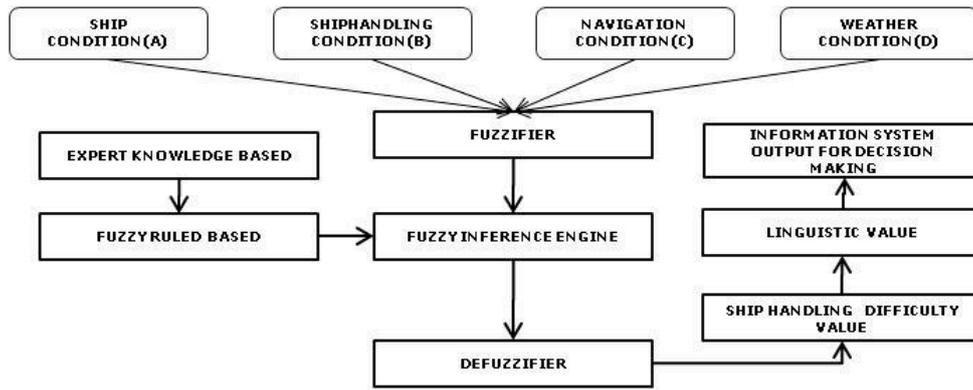


Figure 1 SHDMF overview

There are four variables which are processed into fuzzifier such as ship condition (A), Shiphandling facility condition (B), Navigation condition (C) and Weather condition (D). Each variable consists of sub variables which was arranged and formed in accordance with AHP. The ship condition (A) consists of tonnage (A1), ship draft (A2), ship type (A3), ship age (A4), bridge location (A5) and ship trim (A6). The shiphandling facility condition (B) covers main engine type (B1), propeller number (B2), the type of propeller (B3), ship rudder type (B4) and side thruster (B5). Then navigation condition (C) considers sub variables such as ship speed (C1), the depth of water (C2), ship position (C3), navigation status (C4) and traffic situation (C5). The last variable, weather condition (D) consists of wave (D1), wind (D2), current (D3), visibility (D4), swell (D5) and day/time situation (D6).

The fuzzy Mamdani Min- Max method is selected as methodology approach. In this method, the rule composition is developed based on the method of minimum. The fuzzy crisp solution is generated by taking the maximum value of the rule, then it is used to modify fuzzy area and it is applied to the output area with union (And) operation. If the entire preposition has been evaluated then the output will consist of fuzzy crisp which reflects the contribution of each preposition. It can be written as:

$$\mu_{fs}(x) = \text{Max}(\mu_{fs}(x), \mu_{fc}(x)) \quad (1)$$

Where:

$\mu_{fs}(x)$ =value of membership fuzzy solution until rule-x

$\mu_{fc}(x)$ =value of membership fuzzy consequence until rule-x

Based on the algorithm (1), for the purpose of this research, the algorithm is modified to accommodate 4 inputs and 1 consequence. The operator MIN is used for finding the consequence for each rule toward the inputs and the operator MAX is used for finding the aggregation among the consequences rules. The algorithm can be presented as:

$$\mu_{SHD}(z) = \max^i [\min[\mu_{WS}(i), \mu_{WF}(i), \mu_{WN}(i), \mu_{WW}(i)]] \quad (2)$$

Where,

$\mu_{WS}(i)$  : membership degree of ship condition for rule i.

$\mu_{WF}(i)$  : membership degree of shiphandling facility condition for rule i.

$\mu_{WN}(i)$  : membership degree of navigation condition for rule i.

$\mu_{WW}(i)$  : membership degree of weather condition for rule i.

min : operator for consequence

max<sup>i</sup> : operator for aggregation

$\mu_{SHD}(z)$  : membership degree of shiphandling difficulty/fuzzy solution.

Finally, formulation of the implication of fuzzy solution as a crisp value based on the Centroid method could be written as:

$$SHD(z) = \frac{\int_z \mu_{SHD}(z) \cdot z \, dz}{\int_z \mu_{SHD}(z) \, dz} \quad (3)$$

Where, SHD (z) : crisp value of shiphandling difficulty

$\mu_{SHD}(z)$  : membership degree of shiphandling difficulty.

## 2.2 Simulator Overview

This sub section present references study of simulator but this is not an exhaustive list of review study. The references studies use a simulator on road transport and maritime transport as a keyword to start with. The advantage of using simulator in some research can be explained that simulator provides interactivity process, record function and multiple measurements [2]. The interactivity process is quite important to see the behavior of respondent as well as the behavior of simulator. Therefore, the behavior aspects become the main purpose of using simulator. The behavior characteristic in detail can be analyzed such in waterway design [3]. Further, the availability record function will make a simple task for reviewing precisely. The most important, multiple measurements at same time could be performed at simulator. The measurement of respondent by simulator can be conducted in the term of internal measurement such as respondent property and external measurement such as speed and time [4]. Other purpose of using simulator is to perform hazard measurement related activities. For instance, simulators had been used for hazard anticipation [5, 6], risky situation as well as control strategic and decision making [7], dangerous territory and attention demand [8] as the considerations of safe and controllable environment become a main issue.

However, among the advantages of shiphhandling simulator, some disadvantages need to be notice. Generally, simulator does not present all visual cues but it provides necessary visual cues for designed scenario. Moreover, simulator may not represent visual complexity of real world because it may cause high cost of simulator and it may not necessarily to be shown. Respondents need to try simulator as they may need to familiarize and to adapt before they may feel fine to use it [9]. Here, the adaptation process is quite important to get the better result of experiment as it may be performed through practice session based on time, distance or scenario [6, 9].

The fidelity of simulator is the most important consideration before a simulator is used for a designed research. The term fidelity refers to the appearance and functionality simulator as it is experienced by expert which may consist of familiar pilot with designed scenario [3]. The appearance of simulator may be justified on screen to eye distance, the field of view, color and texture, resolution and update rate. The functionality of simulator may be verified by bridge control equipment and instrument display. Therefore, the mock up of bridge as similar as real ship will enhance fidelity of simulator.

The method of using simulator generally discusses on profile and number of respondents, the design of experiment, the use of apparatus and procedure. The profile and number of respondents will much depend on the purpose of simulator experiment. For instance, three pilots had been used to evaluate the ship collision risk monitoring system [10]. The most important is the expertise level of respondent which may be based on license level and experience. The design of experiment can be prepared based on the purpose of research, therefore different research objective may need different design. The design of experiments may be formed in form of scenarios. The use of apparatus depends also on the objective of research. The apparatus may consist of equipment inside simulator and it may also necessary to use the different type of simulator. The procedure of experiment will ensure the validity and reliability process of research.

## 3. PROCEDURE

The procedure of experiment consists of several steps such as the assignment of respondent, the creation of scenario, the familiarization of shiphhandling simulator, actual experiment and result analysis. The respondent of simulator was selected based on the level of experience and competency. The scenario is developed at Madura Strait in Indonesia between ferry port of Ujung and ferry port of Kamal. Before the experiment is performed, the familiarization of using simulator was conducted based on the scenario which will be used. The familiarization consists of two parts. The first part, the explanation of bridge equipment and scenario overview are given. Secondly, they try all equipment and scenario until the end of scenario for twice. Then, the actual experiment is conducted and at the end the result is analyzed.

Respondents are divided into 13 groups which each of group consists of two or three members. One member of each group is assigned as a master and the rest are acted as an officer on duty or as a wheel man. Each group will be examined through same scenario and bridge. For collecting data purpose, they are provided with questionnaire paper. Through radio communication, they are asked to fill up questionnaire after the completion of each scenario.

Scenario is arranged according to the input of SHDMF, so comparison result as a benchmark can be obtained. The scenarios consider variables as developed in the SHDMF. They consist of ship condition, shiphhandling facility condition, navigation condition and weather condition. The experiment uses a shiphhandling simulator TRANSAS NAVI Trainer 5000. This simulator has capability for performing shiphhandling and navigation activity as well as for recording parameter during experiment. The experiment is performed on ferry passenger with 974 gross tonnages. The ferry has length 58,6 meter , engine power 2x637 kW. Some restrictions of inputs are given such as the age of ship, the type of rudder which is not mentioned in the simulator. The example of extracted scenario is illustrated in Table 1.

Table 1 extracted form of scenario

A	SHIP CONDITION	VALUE	B	SHIP HD. FAC. COND.	VALUE
1	Ship Tonnage/DWT	974 t	1	Main Engine Type	Diesel
2	Ship Draft	2,4 m	2	Propeller number	2
3	Ship Type	Full super structure	3	Propeller type	Fixed
4	Age of Ship	Less than 10 years	4	Number of Rudder	2
5	Bridge Location	Forward	5	Rudder type	Simple/unbalanced
6	Ship Trim	By stern	6	Side thruster	Yes
C	NAVIGATION COND	VALUE	D	WEATHER COND	VALUE
1	Ship speed	Max 13 knots	1	Wave	000/ 0 meter
2	Water depth	Min 4 m	2	Wind	000/ 0 knots
3	Communication	Yes	3	Current	000/ 0 knots
4	Ship position	Various	4	Visibility	6 nm
5	Navigation status	Underway	5	Swell	000/ 0 meter
6	Traffic situation	Various	6	Day/Night	Day

Shiphandling difficulty experiment (SIMEXP) is conducted through seven scenarios. The scenario 1 until scenario 5 examines the shiphandling difficulty in approaching jetty during berthing and unberthing activities. The scenario 6 and 7 examine the shiphandling difficulty during crossing the strait. Each scenario is modified on some input parameters, particularly on the weather condition. The scenario is commenced from condition without any disturbance on the weather and at the end, the 2 meter wave, 2 meter swell, 2 knots of sea current and 20 knots of wind speed are given. Therefore, it is assumed that the difficulty level of shiphandling will increase gradually. The lay out screenshot of scenario as a sample is illustrated in figure 2.

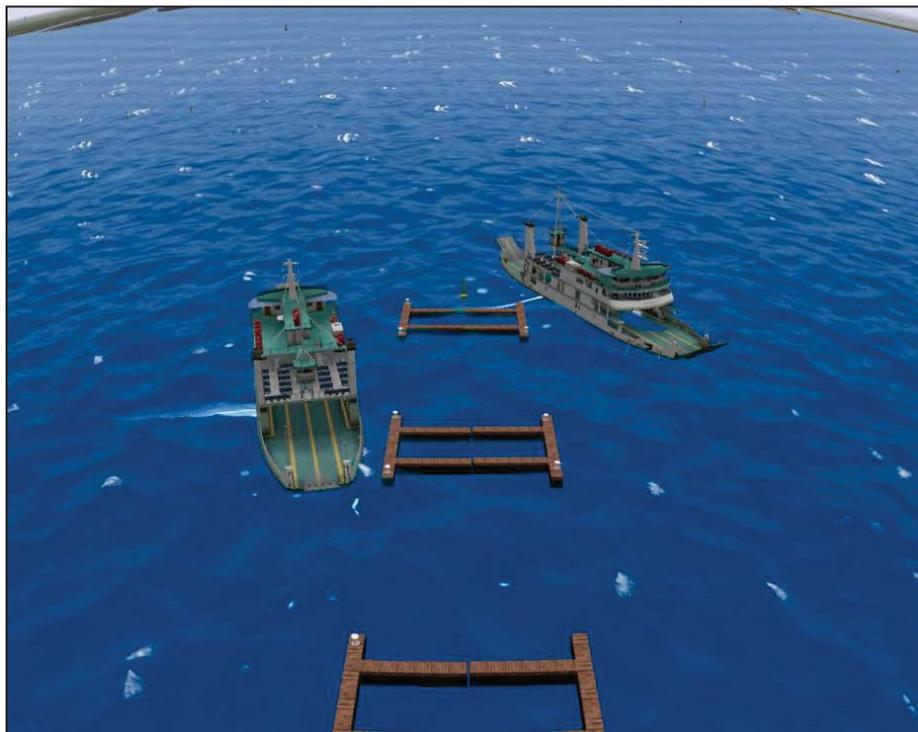


Figure 2 layout sample of scenario

The result of SIMEXP in the form of average score for all groups is converted into linguistic scale. Then the linguistic scale for SIMEXP is compared with the linguistic scale for SHDMF in term of linguistic difficulty for further analysis. The linguistic scale table is presented in table 2.

Table 2 Linguistic scale for SHDMF

SHDMF LINGUISTIC LEVEL	SCORE	DIFFICULTY RANK	SHDMF SCORE	ACCEPTANCE CRITERIA
Extremely Safe	125	NEGLIGENCE	100	ACCEPTABLE
Fairly Safe	200			
Somewhat safe	275			
Neither Safe/Dangerous	350	MARGINAL	250	
Somewhat dangerous	430	CRITICAL	400	
Fairly dangerous	480	CATASTROPIC	440	UNACCEPTABLE
Extremely dangerous			500	

#### 4. RESULT AND DISCUSSION

The measurement of this experiment consists of two measurements which are internal and external measurements. The Internal measurement relates to the respondent profile. The respondent profile describes several parameters such as age, competency certificate and sea experience. Among 13 groups, the mean of respondent age is 34 years old with standard deviation of 6 years old. In average, they have 10 years sea experience with 5 years standard deviation. Regarding certificate competency, 6 groups hold class 3 certificate and 7 groups hold class 4 certificate. The decision about which class of certificate competency used for this experiment is based on the field observation, most officers in charge of navigational watch and some master of ferry at some ferry routes in Indonesia hold class 4 certificate. Therefore, justification of respondent with the minimum of class 4 certificate is taken.

Based on the Gross tonnage of ship, individually as a member of group, 9 respondents on ship with  $GT < 500$ , 10 respondents with  $500 \leq GT < 3000$ , 13 respondents with  $3000 \leq GT < 10000$ , and 4 respondents with  $GT \geq 10000$ . They had experience on ship length as 5 respondents on ship with  $7m \leq LOA < 24m$ , 14 respondents with  $24m \leq LOA < 100m$ , 9 respondents with  $100 \leq LOA < 200m$  and 9 respondents with  $LOA \geq 200m$ . Most respondents had experience on more than 2 meter of ship draft. Regarding bridge location, 12 respondents had experience on forward bridge, 4 respondents on mid bridge and 19 respondents on aft bridge. Most of respondent had experience on main engine with more than 750 HP. Moreover, they are also asked for their experience on ship rudder, ship propeller, bow thruster and others related questions.

Meanwhile, the external measurement relates to performance measurement which is accomplished by subjective measurement through shiphandling difficulty questionnaire for each scenario. The external measurement is decided by each group after having discussion with their member to state their subjective level of shiphandling difficulty.

The result of simulator experiment (SIMEXP) is analyzed through 5 steps. The first step, the average score of shiphandling difficulty for each scenario is accounted. The average score consisted of 13 groups of experiments. For instance, for the unberthing scenario 1, the average score is 11, 54 while the average score for the unberthing scenario 2 is 21,79 (see table 3 ). The second step is the translation of average score into linguistic level. The linguistic level is created in the previous section. For instance, the mentioned average score for the unberthing scenario 1 is "fairly safe". The detail table of linguistic level can be consulted again in the table 2.

The third step is placing the input data used in the SIMEXP into shiphandling difficulty model for ferry (SHDMF). Then, the result in the form of score is averaged. The fourth step is similar with the second step which the translation of SHDMF score into linguistic level is executed. The last step, step 5, comparison both linguistic level of SIMEXP and SHDMF is conducted. The comparison is grouped into unberthing scenario, berthing scenario and crossing strait scenario. Table 3 shows the result of comparison between SIMEXP and SHDMF for unberthing scenario. It is shown that the SIMEXP linguistic level for scenario 1, 2 and 3 have a one level lower than SHDMF linguistic level, whereas for scenario 4 and 5 is on the same linguistic level.

Table 3 comparison result for unberthing scenario

Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
<b>SIMEXP Score</b>	11,54	21,79	25,64	53,85	51,28
<b>SIMEXP Linguistic</b>	Fairly Safe	Fairly Safe	Somewhat Safe	Neither Safe/Danger	Neither Safe/Danger
<b>SHDMF Score</b>	25,82	41,09	44,46	45,47	45,78
<b>SHDMF Linguistic</b>	Somewhat Safe	Somewhat Safe	Neither Safe/Danger	Neither Safe/Danger	Neither Safe/Danger

For the berthing scenario, same analogy is assigned. The result of comparison between SIMEXP and SHDMF is presented in table 4. We may see also that that linguistic level of SIMEXP for scenario 1,2 and 3 have one level lower than SHDMF linguistic level.

Table 4 comparison result for berthing scenario

Scenario	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
<b>SIMEXP Score</b>	12,82	24,36	26,92	55,13	56,41
<b>SIMEXP Linguistic</b>	Fairly Safe	Somewhat Safe	Somewhat Safe	Neither Safe/Danger	Neither Safe/Danger
<b>SHDMF Score</b>	25,82	41,09	44,46	45,47	45,78
<b>SHDMF Linguistic</b>	Somewhat Safe	Somewhat Safe	Neither Safe/Danger	Neither Safe/Danger	Neither Safe/Danger

For the crossing scenario, same analogy is assigned. The result of comparison between SIMEXP and SHDMF is presented in table 5. We may see that there is no different linguistic between SIMEXP and SHDMF.

Table 5 comparison result for crossing strait scenario

Scenario	Scenario 6A	Scenario 6B	Scenario 7A	Scenario 7B
<b>SIMEXP Score</b>	19,23	23,08	33,33	34,62
<b>SIMEXP Linguistic</b>	Fairly Safe	Fairly Safe	Somewhat Safe	Somewhat Safe
<b>SHDMF Score</b>	25,94	39,01	43,16	43,36
<b>SHDMF Linguistic</b>	Somewhat Safe	Somewhat Safe	Somewhat Safe	Somewhat Safe

Based on the comparison result, we may see that SIMEXP has lower linguistic level in certain scenario than SHDMF. It may be also stated that SHDMF for all cases has one linguistic level higher than SIMEXP. As a conclusion, the SHDMF in all cases of experiment has one linguistic level higher than SIMEXP. It could be argued that SHDMF could be used for higher standard of safety assessment related to the shiphandling difficulty level. Meanwhile, the result of experiment is based on the subjective judgment by questionnaire. It is necessary in the future, the result of SIMEXP could be justified through objective analysis therefore the experiment will give more precisely result. Finally, the simulator experiment (SIMEXP) approach is an alternative approach which could be used to justify the external validation of SHDMF.

## REFERENCES

- [1] A.A. Priadi, T. Tjahjono, and A. Benabdelhafid, "Assessing Safety of Ferry Routes by Shiphandling Model through AHP and Fuzzy Approach," in *Intelligent Information Management*, vol. 4, pp. 277-283, 2012.
- [2] G. Underwood, D. Crundall, and P. Chapman, "Driving simulator validation with hazard perception", in *Transportation Research Part F*, vol. 14, pp. 435-446, 2011.
- [3] W. C. Webster (ed), "shiphandling simulation: application to waterway design by Committee on assessment of shiphandling simulation", The national academic press, 1992, ISBN: 0-300-59802-8.
- [4] A. Sundstrom, "Self-assessment of driving skill – A review from a measurement perspective", *Transportation Research Part F*, vol. 11, pp. 1-9, 2008.
- [5] E. Chan, A. Pradhan, A. Pollatsek, M. A. Knodler, and D. L. Fisher, "Are driving simulators effective tools for evaluating novice drivers' hazard anticipation, speed management, and attention maintenance skills?", *Transportation Research Part F*, vol. 13, pp. 343-353, 2010.
- [6] M. G. Lenné, J. A. Groeger, and T. J. Triggs, "Contemporary use of simulation in traffic psychology research: Bringing home the Bacon?", *Transportation Research Part F*, vol. 14, pp. 431-434, 2011.

- [7] H. Farah, E. Yechiam, S. Bekhor, T. Toledo, and A. Polus, "Association of risk proneness in overtaking maneuvers with impaired decision making", *Transportation Research Part F*, vol. 11, pp. 313–323, 2008.
- [8] A. Stinchcombe, and S. Gagnon, "Driving in dangerous territory: complexity and road-characteristics influence attention demand", *Transportation Research Part F*, vol. 13, pp. 388–396, 2010.
- [9] S. Sahami, and T. Sayed, "How drivers adapt to drive in driving simulator, and what is the impact of practice scenario on the research?", *Transportation Research Part F*, vol. 16, pp. 41–52, 2013.
- [10] N. Son, I. Y. Gong, C. S. Pyo, C. S. Lee, C. H. Oh, and M. H. Lee, "On the Validation of Collision Risk Monitoring System through Shiphandling Simulator Experiments and Field Tests", *Proceeding of Asian conference on maritime system and safety research (ACMSSR)*, 2012.

# Selecting Mono- and Multi-Hull Passenger Vessels for Moluccas Waters: Resistance/Powering and Seakeeping Evaluation

Richard Benny Luhulima <sup>(1)</sup> and I Ketut Aria Pria Utama <sup>(2)</sup>

<sup>(1)</sup>PhD Student, Department of Naval Architecture and Shipbuilding Engineering, ITS, Surabaya

<sup>(2)</sup>Professor, Department of Naval Architecture and Shipbuilding Engineering, ITS, Surabaya  
E-mail : richardluhulima@yahoo.com, kutama@na.its.ac.id

## ABSTRACT

The use of multi-hull vessels, particularly of catamaran type, is very popular since the last 3 decades. It has been widely used as passenger and cargo carriers, oceanographic research vessels and fast patrol boats. The reasons behind this success are attributed to better transverse stability; wider deck space area and possible lower drag hence lower power of engine produced by the multi-hull vessels.

The paper explains the investigation of resistance/powering and seakeeping of mono- and multi-hull vessels which is operated within archipelagic waters such as Moluccas islands. Studies are conducted on medium size of passenger vessels in order to identify and illustrate potential levels of savings in propulsive power at the design stage. Performance of ships at sea (seakeeping) evaluation is included since typical of Moluccas waters consist of narrow straits or restricted waters and open sea waters which is completely two different situations in term of sea conditions.

## Keywords

*resistance, powering, mono-hull, multi-hull, seakeeping.*

## 1. INTRODUCTION

The need for sea transportation sea system according to geography, weather, climate and waves condition become a crucial problem particularly to archipelagic countries such as Indonesia and the Philippines. The need for various types of ship has increased in the last thirty years, where many ship types been developed to satisfy the engineering and economic criteria. Among other, multihull concept (such as catamaran and trimaran) has received considerable attention due to their stability characteristics and freedom in arranging deck layouts. The multihulls have been built as passenger vessel, sporting craft, oceanographic research vessel and fishing vessel [1].

There are plenty work conducted world-wide in order to explore the benefits of multihull ships. [2] developed a preliminary design method to provide accurate solution of catamaran passenger vessel. Meanwhile, trimaran hull form or vessel with three hulls has received considerable attention because it can provide even bigger deck area and shallower-draft [3, 4]. The form of trimaran, at the beginning, is popularly used as warships because of its high quality of stability [5].

The calculation of power required by the catamarans and trimaran needs an investigation into the resistance characteristics entirely in order to obtain the most by ship design [6]. The resistance of catamaran and trimaran can provide complex phenomena to ship designers particularly with the appearance of interaction between the demihull of catamaran or between the main-hull and side-hull of trimaran. Therefore, it has been a basic need to obtain the breakdown and understanding of correct ship resistance components in order to obtain accurate calculation based on scaling transformation from model to the real ship.

Furthermore, during its voyage on the water, a ship experiences 6 degree of freedom (DOF) of movement [3] Among others, three DOF (heave, pitch, roll) relates to ship performance at sea (seakeeping) and this connects to the comfortability of the vessel. Seakeeping characteristics can be estimated or calculated using tank test or tested in an MOB, numerically using computational fluid dynamics (CFD) approach, and using commercial design softwares such as Maxsurf [7].

## 2. MODEL DESCRIPTION AND TEST SET-UP

The models (mono, catamaran and trimaran) were produced according to a scale of 1:9. Their principal dimensions and mass properties are shown in Table 1. The model was statically and dynamically balanced to adjust the position of centre of gravity and radii of gyration as specified. Figure 1 to 3 showed the setting of monohull, catamaran and trimaran in the towing tank, respectively.

A series of model tests was conducted at the towing tank of Indonesian Hydrodynamics Laboratory (IHL) [7]. In this model tests, the resistance tests were carried out where the model was towed by the carriage. The model was connected to the load cell transducer at a point located amidships and vertically at 0.45T above base line, allowing the model to move freely in the vertical plane.

Table 1. Principal data of monohull, catamaran and trimaran

Dimension	Mono	Catamaran		Trimaran	
		Twin	Demi	Main	Side
LWL (m)	13.8	14.5	14.5	14.5	12.0
B (m)	2.88	7.66	1.86	2.00	1.15
D (m)	0.65	0.65	0.65	0.72	0.52
H(m)	1.30	1.30	1.30	1.44	1.24
Cb	0.50	0.38	0.382	0.384	0.39
DISP (tons)	11.8	11.8	5.90	6.96	2.42
TOTAL DISP (tons)	11.8	11.8		11.8	



Figure 1: Monohull model

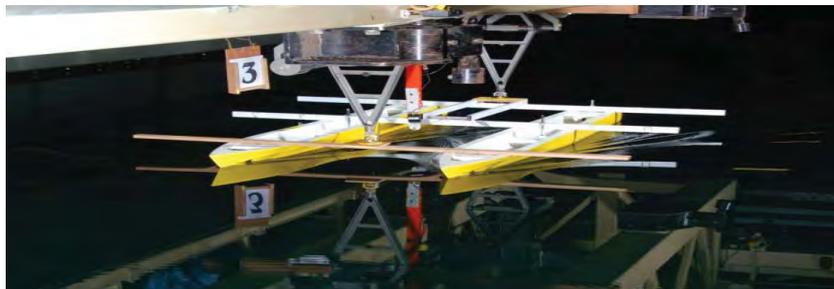


Figure 2: Catamaran model



Figure 3: Trimaran model

### 3. EXPERIMENTAL AND NUMERICAL RESULTS

The wider space area for activities on main deck is the main concern for the commercial sea transportation now. The space area on main deck for catamaran is mostly related to the separation length ratio ( $S/L$ ). Therefore, this ratio need to be investigated and discussed into the resistance performance to estimate the ship power and seakeeping qualities.

### 3.1. Resistance/ Powering

The most widely used estimation of catamaran resistance is the method proposed by [8]. In this case, catamaran hull consists of 2 isolated demihulls and creates wave and viscous resistance interference and formulated as follows:

$$C_T = (1 + \phi k) \sigma C_F + \tau C_W \tag{1}$$

Where:

$C_T$  is total resistance coefficient,

$C_F$  is frictional resistance coefficient and obtained from ITTC-1957 correlation line,

$C_W$  is wave resistance coefficient of isolated demihull,

$(1+k)$  is form factor value of isolated demihull,

$\phi$  is used to estimate the change of pressure around demihull,

$\sigma$  represents additional velocity between demihulls and calculated from the summation of local frictional resistance around wetted surface area.

In fact, the factors of  $\phi$  and  $\sigma$  are difficult to measure hence for the practical purposes, the two factors can be combined to form viscous resistance interference factor  $\beta$  where  $(1 + \phi k) \sigma = (1 + \beta k)$  hence:

$$C_T = (1 + \beta k) C_F + \tau C_W \tag{2}$$

Where for monohull or demihull at isolation the value of  $\beta=1$  and  $\tau=1$ .

Empirical formulation to estimate the total resistance of trimaran, however, is so far not known and depends highly on the experimental results [9]. This is attributed to the minimum publications of trimaran resistance Yet, there is no standard design or model test for trimaran. Results of the experimental work were tabulated in Table 2, which described the correlation of resistance against speeds of ship.

Furthermore, the results from Maxsurf were shown in Table 2. Despite the software does not take resistance interaction between the hulls, the numerical study was taken at  $S/L=0.3$  when there is presumably no significant interaction between demihulls [4, 8]

Table 2. Results of monohull, catamaran and trimaran from Maxsurf

Monohull				Catamaran				Trimaran			
Speed (knot)	Fr	Resist (kN)	Power (PE)	Speed (knots)	Fr	Resist (kN)	Power (PE)	Speed (knots)	Fr	Resist (kN)	Power (PE)
5,706	0,252	1,988	10,625	5,787	0,249	1,455	8,091	5,732	0,247	1,736	9,637
6,089	0,269	2,242	12,958	6,218	0,268	1,686	10,204	6,364	0,274	2,131	13,230
6,693	0,295	2,642	16,635	6,676	0,287	1,932	12,454	6,666	0,287	2,320	14,950
7,259	0,320	3,016	20,075	7,051	0,304	2,132	14,293	7,153	0,308	2,624	17,717
7,660	0,338	3,281	22,518	7,559	0,326	2,405	16,789	7,658	0,330	2,940	20,591
8,130	0,359	3,592	25,379	8,032	0,346	2,658	19,107	8,085	0,348	3,206	23,018
8,420	0,372	3,784	27,143	8,384	0,361	2,847	20,834	8,561	0,369	3,504	25,729
8,941	0,395	4,129	30,315	8,817	0,380	3,080	22,963	8,829	0,380	3,672	27,252
9,283	0,410	4,355	32,393	9,233	0,398	3,302	25,001	9,284	0,400	3,956	29,841

Table 3. Results of monohull, catamaran and trimaran from Experiment

Monohull				Catamaran				Trimaran			
Speed (knot)	Fr	Resist (kN)	Power (PE)	Speed (knots)	Fr	Resist (kN)	Power (PE)	Speed (knots)	Fr	Resist (kN)	Power (PE)
5.706	0.252	1.070	6.105	5.787	0.249	1.658	9.594	5.732	0.247	1.826	10.466
6.089	0.269	1.739	10.588	6.218	0.268	1.851	11.509	6.364	0.274	2.428	15.451
6.693	0.295	2.236	14.965	6.676	0.287	2.238	14.940	6.666	0.287	2.700	18.004
7.259	0.320	2.883	20.927	7.051	0.304	2.677	18.878	7.153	0.308	3.489	24.956
7.660	0.338	3.713	28.441	7.559	0.326	3.567	26.963	7.658	0.330	4.229	32.385
8.130	0.359	4.995	40.609	8.032	0.346	3.953	31.750	8.085	0.348	4.804	38.840
8.420	0.372	6.064	51.058	8.384	0.361	4.345	36.428	8.561	0.369	5.400	46.229
8.941	0.395	7.260	64.911	8.817	0.380	4.790	42.233	8.829	0.380	5.851	51.658
9.283	0.410	7.667	71.172	9.233	0.398	5.591	51.621	9.284	0.400	6.813	63.251

### 3.2. Seakeeping

The requested random wave condition was adjusted prior to the actual model. This condition was done by measuring wave height at the neutral position of the model. The wave elevation was measured by means of a resistance wire type wave probe. The irregular waves were adjusted such that the spectral density distribution compares with the required theoretical energy distribution

When there is a linear relation between wave elevation and motions, accelerations or forces, this relation can be presented in the frequency domain with response functions or Response Amplitude Operators (RAOs). These RAOs give the ratio between the input wave amplitude and the output signal for each wave frequency and can be calculated using the spectral densities of the calibrated wave and the output signals according to :

$$H_u = \frac{u_a(\omega_e)}{\zeta_a(\omega_e)} = \sqrt{\frac{S_{uu}(\omega_e)}{S_{\zeta\zeta}(\omega_e)}} \quad (3)$$

In which:

- $H_u$  = response function of a signal u
- $U_a(\omega_e)$  = amplitude of frequency  $\omega_e$  of signal u
- $\zeta_a(\omega_e)$  = amplitude of frequency  $\omega_e$  of wave elevation  $\zeta$
- $S_{uu}(\omega_e)$  = spectral density of signal u
- $S_{\zeta\zeta}(\omega_e)$  = spectral density of wave elevation  $\zeta$

Beaufort provides data on wave height where the sea state 3 wave height between 0.6 m – 1 m high and sea state 5 waves between 2 m - 3 m, seakeeping analysis with Maxsurf Program for both sea conditions

Table 4. Sea state 3 Wave height 0.6 m Monohull Heading 90 deg and 180 deg

Monohull 90 deg					Monohull 180 deg				
Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO	Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO
2,34	2,34	1,007	1,548	0,389	5,61	2,65	0,025	0	0,021
2,52	2,52	1,071	1,693	0,308	5,97	2,76	0,016	0	0,014
2,7	2,7	1,136	1,88	0,239	6,32	2,87	0,014	0	0,007
2,88	2,88	1,177	2,13	0,196	6,68	2,97	0,014	0	0,002
3,06	3,06	1,175	2,474	0,17	7,04	3,07	0,014	0	0,002
3,23	3,23	1,118	2,969	0,149	9,15	3,63	0,006	0	0,001
3,41	3,41	1,016	3,715	0,125	11,26	4,12	0,003	0	0,001
3,59	3,59	0,894	4,853	0,099	13,37	4,58	0,001	0	0
3,77	3,77	0,782	6,269	0,069	15,48	5	0	0	0

Table 5. Sea state 3 Wave height 0.6 m catamaran Heading 90 deg and 180 deg

Catamaran 90 deg					Catamaran 180 deg				
Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO	Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO
2,34	2,34	0,515	1,21	0,216	9,51	3,41	0,02	0	0,002
2,52	2,52	0,565	1,251	0,104	10,14	3,54	0,01	0	0,005
2,7	2,7	0,571	1,299	0,053	10,76	3,67	0,002	0	0,005
2,88	2,88	0,518	1,354	0,055	11,38	3,8	0,011	0	0,003
3,06	3,06	0,45	1,418	0,044	12	3,92	0,013	0	0,001
3,24	3,24	0,402	1,492	0,032	15,6	4,58	0,004	0	0,001
3,41	3,41	0,34	1,579	0,041	19,2	5,17	0,008	0	0,001
3,59	3,59	0,241	1,683	0,042	22,8	5,71	0,011	0	0,001
3,77	3,77	0,149	1,806	79,5	26,4	6,2	0,038	0	0,002

Table 6. Sea state 3 Wave height 0.6 m trimaran Heading 90 deg and 180 deg

Trimaran Heading 90 deg					Trimaran Heading 180 deg				
Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO	Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO
2,34	2,34	0,485	1,038	0,299	8,49	3,46	0,026	0	0,003
2,52	2,52	0,499	1,044	0,165	9,03	3,6	0,023	0	0,003
2,7	2,7	0,523	1,051	0,06	9,57	3,73	0,013	0	0,006
2,88	2,88	0,51	1,059	0,032	10,11	3,86	0,004	0	0,006
3,06	3,06	0,464	1,067	0,046	10,64	3,98	0,011	0	0,004
3,24	3,24	0,425	1,075	0,034	13,84	4,67	0,007	0	0,001
3,41	3,41	0,403	1,084	0,021	17,03	5,29	0,002	0	0,002
3,59	3,59	0,357	1,094	0,033	20,22	5,85	0,020	0	0,002
3,77	3,77	0,265	1,105	0,038	23,41	6,37	0,067	0	0,003

Table 7. Sea state 5 Wave height 2.0 m monohull Heading 90 deg and 180 deg

Monohull heading 90 deg					Monohull 180 deg				
Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO	Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO
2,34	2,34	0,897	5,461	0,416	5,45	2,41	0,037	0	0,029
2,52	2,52	0,972	3,16	0,338	5,8	2,5	0,027	0	0,022
2,7	2,7	1,063	2,048	0,27	6,14	2,6	0,016	0	0,018
2,88	2,88	1,142	1,471	0,223	6,49	2,69	0,008	0	0,013
3,06	3,06	1,179	1,127	0,193	6,84	2,78	0,007	0	0,009
3,24	3,24	1,156	0,902	0,17	8,9	3,27	0,006	0	0,004
3,41	3,41	1,077	0,744	0,145	10,95	3,71	0,005	0	0,001
3,59	3,59	0,964	0,628	0,116	13	4,12	0,003	0	0
3,77	3,77	0,842	0,54	0,081	15,06	4,49	0,001	0	0

Table 8. Sea state 5 Wave height 2.0 m catamaran Heading 90 deg and 180 deg

Catamaran 90 deg					Catamaran 180 deg				
Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO	Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO
2,34	2,34	0,515	1,21	0,216	9,51	3,41	0,02	0	0,002
2,52	2,52	0,565	1,251	0,104	10,14	3,54	0,01	0	0,005
2,7	2,7	0,571	1,299	0,053	10,76	3,67	0,002	0	0,005
2,88	2,88	0,518	1,354	0,055	11,38	3,8	0,011	0	0,003
3,06	3,06	0,45	1,418	0,044	12	3,92	0,013	0	0,001
3,24	3,24	0,402	1,492	0,032	15,6	4,58	0,004	0	0,001
3,41	3,41	0,34	1,579	0,041	19,2	5,17	0,008	0	0,001
3,59	3,59	0,241	1,683	0,042	22,8	5,71	0,011	0	0,001
3,77	3,77	0,149	1,806	0,027	26,4	6,2	0,038	0	0,002

Table 9. Sea state 5 Wave height 2.0 m trimaran Heading 90 deg and 180 deg

Trimaran Heading 90 deg					Trimaran Heading 180 deg				
Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO	Encounter Freq (Rad/sec)	Wave Freq (rad/sec)	Heave RAO	Roll RAO	Pitch RAO
2,34	2,34	0,479	1,167	0,306	8,27	3,13	0,016	0	0,018
2,52	2,52	0,488	1,199	0,181	8,8	3,25	0,011	0	0,013
2,7	2,7	0,524	1,235	0,08	9,34	3,37	0,018	0	0,007
2,88	2,88	0,524	1,276	0,039	9,87	3,49	0,021	0	0,002
3,06	3,06	0,483	1,322	0,044	10,4	3,6	0,018	0	0,002
3,24	3,24	0,442	1,375	0,033	13,52	4,21	0,011	0	0,001
3,41	3,41	0,417	1,436	0,025	16,64	4,76	0,004	0	0,001
3,59	3,59	0,373	1,506	0,037	19,76	5,26	0,002	0	0,001
3,77	3,77	0,281	1,587	0,04	22,88	5,72	0,004	0	0,002

#### 4. DISCUSSION

Experimental results shown in Table 3 and the Maxsurf results in Table 2 described the relation between speed and resistance at various configurations. However, Maxsurf shows a little increase compared to the experimental result and this also occurs at catamaran and trimaran configurations. This is attributed to the exclusion of resistance interference and wave breaking phenomenon by Maxsurf. The last term occurs at higher speed or Froude numbers and further discussion about this can be found in Hogben and Standing [10,11]. Similar phenomena are also shown by catamaran with clearance  $S/L=0.3$  (see Figure 2) and trimaran with clearance  $S/L=0.3$  (see Figure 8) configurations. The catamaran form (Figure 2) shows lower resistance and the trimaran mode (Figure 3) indicates even lower resistance than the monohull mode of similar displacement. The reason for this, despite similar displacement, is because the catamaran and trimaran modes have slenderer hull-form than the monohull one. Thus, this has caused the resistance interaction and hence total resistance to decrease. By the use of Maxsurf, however, there is no indication of resistance decrease since the software or code does not take both resistance interaction and wave breaking phenomenon into consideration.

Among the catamaran and trimaran modes, it is clear that the total resistance decreases as the separation to length (S/L) ratio increases and this is caused by the decrease of resistance interaction following the increase of S/L ratios. This is in a good agreement with Utama [8, 12].

#### Curve Response Amplitude Operator (RAO) influence on Wave Encountered

Figure 4: Sea state 3 Wave height 0.6 m conditions of monohull heading 90 deg and 180 deg

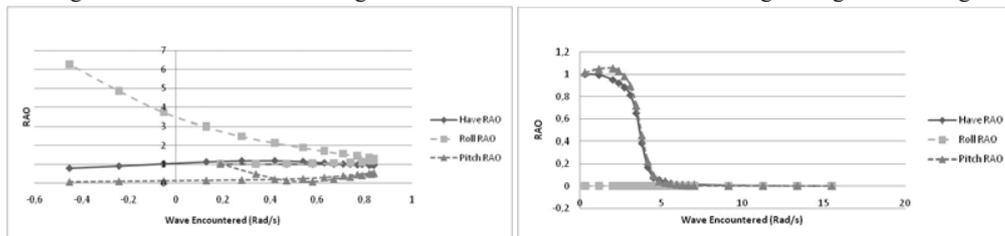


Figure 5: Sea state 3 Wave height 0.6 m conditions of catamaran heading 90 deg and 180 deg

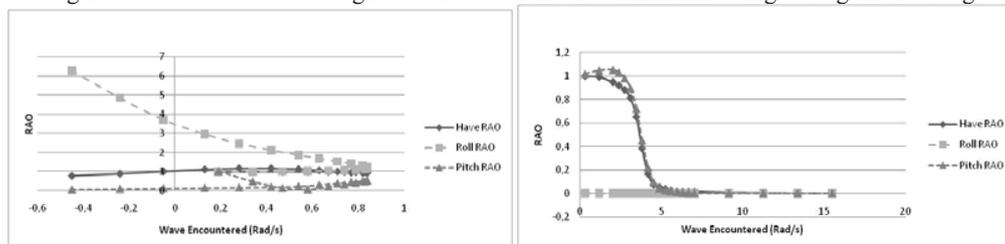


Figure 6: Sea state 3 Wave height 0.6 m conditions of trimaran heading 90 deg and 180 deg

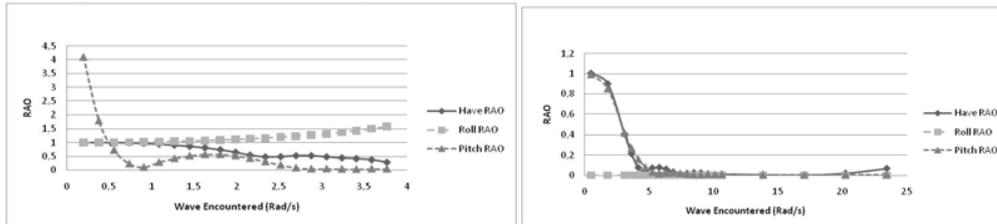


Figure 7: Sea state 5 Wave height 2.0 m conditions of monohull heading 90 deg and 180 deg

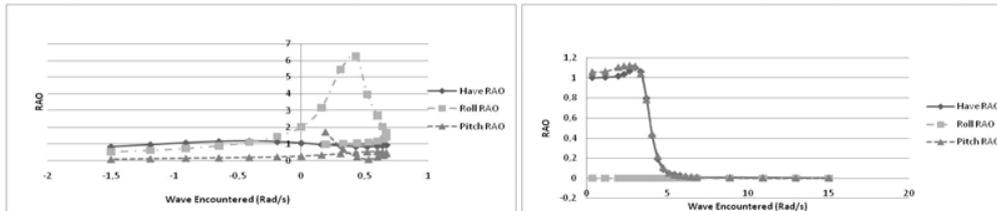


Figure 8: Sea state 5 Wave height 2.0 m conditions of catamaran heading 90 deg and 180 deg

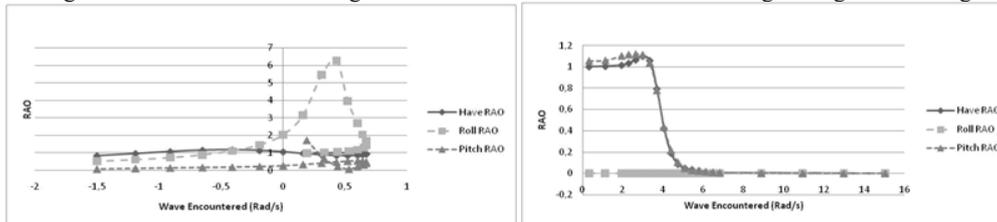
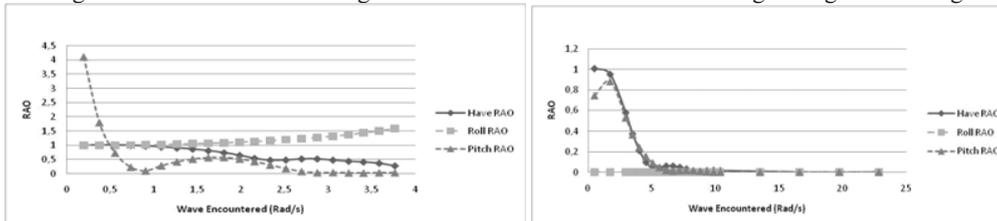


Figure 9: Sea state 5 Wave height 2.0 m conditions of trimaran heading 90 deg and 180 deg



In addition, among the multihulls, the catamaran mode demonstrates slightly smaller heave and pitch responses compared to the trimaran. Conversely, the trimaran showed smaller roll response to the catamaran. This is because of the number of hulls, in which trimaran has more hulls and hence the total ship breadth. This further cause better or lower roll response, but higher heave and pitch responses, and this corresponds well with [ 8].

## 5. CONCLUSION

View of the experimental and numerical model analyses undertaken in research work, the following conclusion can be drawn:

The catamaran and trimaran configurations provide lower total resistance than monohull one with equal displacement. The main and most significant factor is the geometry of ship hull and arrangement of ship wetted surface area.

The trimaran mode demonstrates higher resistance or power effective at lower separation ratio ( $S/L=0.2$  and  $0.3$ ). This is because the main hull of trimaran is bluff enough to cause higher flow interaction between the hulls hence causes higher resistance and power effective. In addition, the trimaran possesses three hulls, whilst the catamaran does have only two hence resistance and resistance interaction of the trimaran are consequently higher than those of the catamaran. However, at  $S/L=0.4$  the interaction decreases significantly hence total resistance and power effective become much smaller.

The multihull modes show almost similar motion characteristics as compared to the monohull. This is an indication (up to sea state 3), that catamaran and trimaran are as comfortable as the monohull. Furthermore, the effect of wave direction on ship motion is clear. Heave and pitch motions of both multihulls are more excessive under following sea condition, whilst roll motion is more extreme under quartering and beam sea conditions.

## REFERENCES

- [1] MURDIJANTO, UTAMA, I K A P and JAMALUDDIN, A, An Investigation into the Resistance/Powering and Seakeeping Characteristics of River Catamaran and Trimaran, *Makara Seri Teknologi*, Vol. 15, No. 1, 2011.
- [2] Pal, P K and Doctors, L J (1995), "Optimal Design of High-Speed River Catamarans", *Proc. FAST Sea Transportation*, Travermunde, Germany
- [3] Rawson, K J and Tupper, E C (1994), *Basic Ship Theory*, Vol. 2, Longman Scientific and Technical, Oxford, UK.
- [4] Utama, I K A P (1999), "An Investigation into the Viscous Resistance of Catamaran Form", *PhD Thesis*, Department of Ship Science, the University of Southampton, UK.
- [5] Hebblewhite, K., Sohoo, P.K. and Doctors, L. J. (2008), "A Case Study: Theoretical and Experimental Analysis of Motion Characteristics of a Trimaran Hull Form", *Journal of Ships and Offshore Structures*, 2:2, 149 – 156.
- [6] Utama, I K A P, Murdjanto dan Santosa, I G M (2007), "Kapal Reset yang Ekonomis dengan Lambung Katamaran", *Proc. Seminar Nasional Teori dan Aplikasi Teknologi Kelautan (SENTA 2007)*, Surabaya, 24 Nopember
- [7] Utama, I K A P, Murdijanto, Sulisetyono, A and Jamaludin, A (2009), "Pengembangan Moda Kapal Berbadan Banyak untuk Transportasi Penyeberangan dan Sungai yang Aman, Nyaman dan Efisien", *Final Report, Applied Incentive Research*, KNRT
- [8] Insel, M and Molland, A F (1992), "An Investigation into the Resistance Components of High Speed Displacement Catamarans", *Transactions of the Royal Institution of Naval Architects (RINA)*, Vol. 134.
- [9] Doctors, L J, Renilson, M R, Parker, G and Hornsby, N (1991), "Waves and Wave Resistance of a High-Speed River Catamaran", *Proc. Fourth International Conference on Fast Sea Transportation (FAST 1991)*, Trondheim, Norway
- [10] Hogben, N and Standing, R G (1975), "Wave Pattern Resistance from Routine Model Tests", *Transactions of the Royal Institution of Naval Architects*, Vol. 126.
- [11] Molland, A.F. (2008), *A Guide to Ship Design, Construction and Operation*, The Maritime Engineering Reference Book, Butterworth-Heinemann, Elsevier
- [12] Utama, I K A P (2006), "Analisis Eksperimental Hambatan Kapal Katamaran pada Berbagai Jarak Demihull", *Jurnal Penelitian Engineering*, Vol. 12, No. 1.

## Vane-Turbine as an Energy Conversion in the Propeller Slipstream of Single Screw Ship

S Leksono<sup>a</sup>, IKAP Utama<sup>a</sup>, MA Djoni<sup>b</sup>, WD Aryawan<sup>a</sup>

<sup>a</sup>Department of Naval Architecture and Shipbuilding Engineering, ITS, Surabaya, Indonesia

<sup>b</sup>Department of Mechanical Engineering, ITS, Surabaya, Indonesia

### ABSTRACT

The screw propeller of a ship generates thrust to make it moving. As a propeller rotates, it draws fluid into itself from the surrounding area (slipstream). The propeller produces two types of flow behind it, accelerated flow and circulating flow. Some of the energy from the ship engine is lost in the accelerated flow behind ship as a jet wash. The kinetic energy losses in the slipstream propeller will be captured by a Turbine and then called the propeller-turbine system. This composed of screw propeller of a vessel (called the main propeller) and a vane turbine that is the area of vanes located inside the wake of the main propeller. It recovers the energy generated by the main propeller pushing water back out (which would be otherwise wasted behind the main propeller) and hopefully enhancing the efficiency of the main propeller.

The influence of vane turbine on the performance breakdown of single screw ships were analyzed by using 5 (five) ships. Ship powering was calculated by using DESPC (DESP Code 10) software and the performance of vane turbine by applying actuator disc theory for calculating thrust and power generated. Although the vane turbine affected speed loss of the ship, the power efficiency gained to be found always positive. Vane turbine is suitable as an energy saving device of the single screw ship.

### Keywords

*propeller-turbine, energy-slipstream, speed loss, efficiency-gained*

This Paper is Published in Advanced Materials Research Journal

# The Role Of Multi -Yard Ship Construction Method in Integrated Shipbuilding Cluster

Sunaryo

Naval Architecture Study Program, Faculty of Engineering  
University of Indonesia, Depok 16424  
E-mail : naryo@@eng.ui.ac.id

## ABSTRACT

Shipbuilding market is booming in Indonesia due to dramatic increase of national merchant shipping fleet since the implementation of cabotage principle in 2005. In order to fulfill the demand of shipping market and to renew the old fleet it is predicted that at least one million GT new buildings are on demand every year. Unfortunately the capacity of the national shipbuilding industry is not sufficient to cater the growing market due to its low productivity, high building cost, and slow delivery time. Integrated shipbuilding cluster has just been introduced to the Indonesian shipbuilding industry in attempt to increase their capacity and productivity. In conjunction with this research is being carried out to apply Multi-yard ship construction method to the shipyards involved in the clusters as complementary to the integrated shipbuilding cluster with the objective to increase the productivity and quality of the shipyards and to reduce the delivery time of ships being built so that the existing market could be grasped. Three shipyards in Jakarta are chosen for the research and the ship being built is investigated as pilot project. Beside all the committed industries in the cluster i.e. core industry, pulling industry, supporting industry, supplying industry and supporting services, the shipyards are assigned to build certain parts of ships in accordance to their individual characteristics, then the ship parts or blocks are joined together in one of the collaborating shipyards. Ship structural components are defined and the processing tasks are distributed to the shipyards in accordance to their typical expertise, the coordination and production processes including the man-hours needed are simulated using available production soft-wares. Since the shipyards are located in the same area transporting of the ship blocks will not be any problem, each individual yard will only concentrate to build certain parts of the ships so that their learning process will be shortened, and the construction process of the ships can be carried out simultaneously by the collaborating shipyards, thus the ships can be built faster and hence will increase the productivity of the shipyards involved. Good coordination among the shipyards and application of same ship production standards are the key components for the successful implementation of the method. It is assumed that 30% of shipyards productivity could be achieved

### Keywords:

*Shipbuilding cluster, multi-yard, ship construction, productivity.*

## 1. INTRODUCTION

### 1.1. Background

Since the implementation of Cabotage principle in 2005 and the establishment of Shipping Law No. 17/2008 the national shipbuilding market has increased dramatically due to obligation of using national flagged ships for local shipping, even though part of the demand is fulfilled by importing used ships from aboard, but the used ships need to be renewed in less than 5 years because many of them are considered very old. According to INSA (Indonesian National Shipowners Association) it is predicted that at least 1 million GT of ships are on demand every year [1]. Unfortunately this market booming could not be catered by national shipbuilding industry due to lack of building capacity, low productivity, high building cost, and slow delivery time. In attempt to increase the building capacity of the national shipbuilding industry and to improve its productivity shipbuilding industry cluster has been introduced in Surabaya in 2006 known as KIKAS (Klaster Industri Perkapalan Surabaya), in Jakarta in 2007 known as KIKAJA (Klaster Industri Perkapalan Jakarta) [2], and recently in 2012 has just been proposed in Lampung Province [3].

### 1.2. Shipbuilding Industry Cluster

Industrial cluster is defined as a group of inter-related industries that drive wealth creation in a region, primarily through export of goods and services. It represents the entire value chain of a broadly defined industry from suppliers to end products, including supporting services and specialized infrastructure. Cluster industries are geographically concentrated and inter-connected by the flow of goods and services [4].

In the case of shipbuilding cluster there are 4 industries that inter-related with shipbuilding industry as the core, they are: pulling industry, supplying industry, supporting industry, and supporting services [5], which can be illustrated as follows:

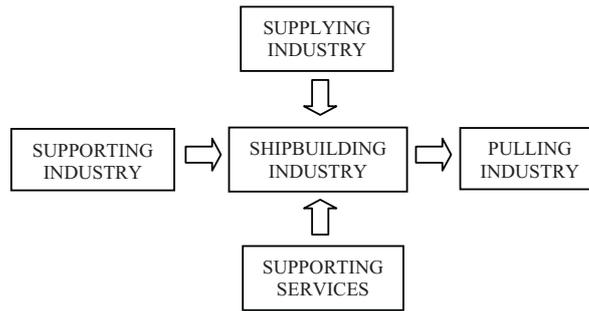


Figure 1: Shipbuilding Industry Cluster

Shipbuilding industry is the core of the cluster that will create wealth in the region with all its prospective opportunities, shipping industry is the pulling industry that provide market for the shipbuilding industry, supporting industry is the industry that produces main materials and components for shipbuilding that need further fabrication or work by the shipyards such as steel plates and sections and other hull materials, fabrication industry, and consumables industries such as water, gas and electricity etc., supplying industry is those that supply all kind of machineries and equipment for the ship that only need to be installed or applied by the shipyards including paint, chains, zinc anodes etc., and supporting services are institutions that provide services both directly and indirectly to the shipbuilding industry such as classification societies, design and surveying firms, educational institutions, financial institutions etc. All the inter-related industries should commit themselves to foster the development of the shipbuilding cluster.

### 1.3. Multi-yard Ship Construction Method

Multi-yard ship construction method is a ship production approach for building a ship by more than one shipyard [6]. The shipyards in the group should be complementing each other with their particular facilities, shipbuilding experience, and capacity. Each shipyard is assigned to build certain blocks of the ship in accordance with their respective specialty, upon their completion the blocks are transported to one of the group's building dock to be erected and joined to each other to form a complete ship. By implementing this method the ship can be built much faster than if it is built by a single shipyard; smaller shipyards still have opportunity to build ships larger than their capacity; the shipyards can take advantage out of their differences; competition is changed into collaboration, and every yard gets benefit from it. On the other hand some requirements are needed to be considered such as: the location of the collaborating shipyards has to be in the neighbouring area; the approach is more suitable for ship series project; good coordination system is needed; every shipyard in the group must implement the same production standards, and high commitment from the collaborating yards.

### 1.4. Objectives of the Research

The objective of the research is to explore the role of multi-yard ship construction method in assisting to achieve the successful implementation of shipbuilding industry cluster.

## 2. THE ROLE OF MULTI-YARD SHIP CONSTRUCTION

### 2.1. Why Multi-yard Ship Construction

Refer to the definition of shipbuilding industry cluster where a number of shipyards and other inter-related industries exist in a certain region and the industries commit to support each other to drive wealth creation in the region it is very appropriate to implement Muti-yard Ship Construction method to the industries in the cluster to the shipyards in particular. The neighboring shipyards will complement each other instead of unhealthy competition; less obstacles in coordination and transportation of ship's components; related industries to the shipyards will benefit from continuous jobs and orders created by series of ships built in the collaborating yards; and hence the efficiency and productivity of the cluster will increase too.

### 2.2. Stages of Implementation

To implement the method to shipbuilding industry cluster the "plan-do-check-act cycle" principle introduced by W Edwards Deming in quality management [7] are proposed in the form of the following stages:

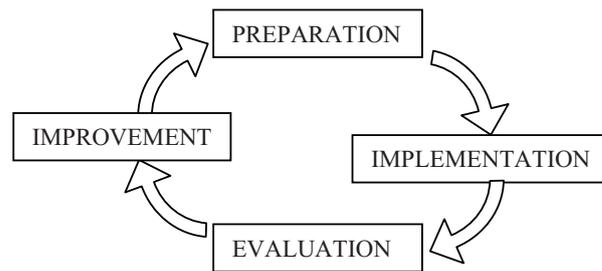


Figure 2 Implementation Stages

### 2.2.1. Preparation stage

In the preparation stage the activities started with introduction of the method to the involving shipyards and industries to ensure their understanding of and commitment to the system, then followed by identification of individual yard's specialty and capability as the basis for the assignment of construction tasks, the ship structural design is then broken-down into blocks and smaller parts design followed by ship parts definition, which will be used to calculate the work content and to arrange the work processing schedule.

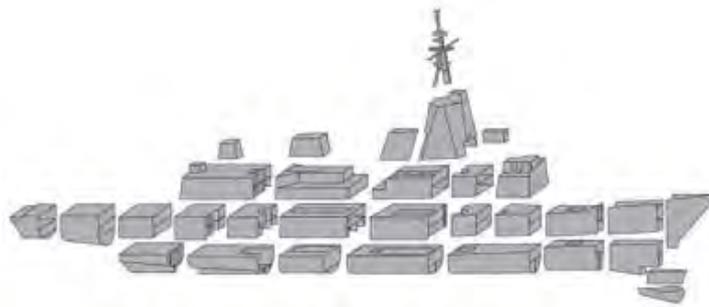


Figure 3 Ship Blocks Break-down Structure

### 2.2.2. Implementation stage

Upon completion of the preparation stage the method is ready to be implemented. Raw materials such as plates and sections and ship equipment are procured by the coordinating yard on behalf of the "consortium". It is suggested that the materials are not directly sent to individual yard but to one of the supporting industry to be fabricated into ship parts. These ship parts are then distributed to each individual yard to be assembled into panels, modules and blocks in accordance to the tasks assigned to them. In carrying out the tasks each yard is given production drawings and work instruction, and the time schedule on when the blocks and modules should be completed and shipped to the block joining yard. The blocks and modules are shipped using barge towed by tugboats, at the joining yard they are lifted to the buffer area to wait for their turn to be erected to the building dock to be joined to the other blocks. Blocks joining schedule and production schedule are arranged based on the work content and standard man-hour applied in the collaborating yards. When the blocks and modules have been joined on the building dock the rest of the activities are as applied in the ordinary shipbuilding process.

### 2.2.3. Evaluation stage

Every work being undertaken in the collaborating yards should be monitored and its results should be recorded along the implementation of the system so that future analysis and evaluation could be carried out well at certain agreed milestones in order to continuously improve the benefit of the method. To accomplish it regular coordination meeting should be carried out in various levels according to the needs, so that every target and achievement could be analyzed and lessons learn could be drawn.

### 2.2.4. Improvement stage

Data recorded from the production processes are used for analyzing and evaluating the achievements of the method, and lessons learn from the evaluation are used as input and recommendations for the following implementation of the system so that continuous improvement could be applied.

### 2.3. Tasks Assignment

Capability and specialty of each collaborating yard should be identified before the production tasks could be assigned to them in order to have complementary between the yards. Refer to Product Work Breakdown Structure (PWBS) [8] of the ship being built work contents of each block of the ship could be identified and matched to the specialty and capability of the collaborating yards. Based on these findings the tasks are then assigned to each individual yard.

Combined with man-hour standards applied in the consortium the work contents are also used for arranging the production schedule including blocks erection schedule. Using backward calculation based on the blocks erection schedule the starting time of each construction work in each individual yard could be decided. It is assumed that if everything is going in accordance to the planning the ship could be completed on time.

#### **2.4. The Coordination**

Coordination is the key element of the Multi-yard Ship Construction method. Complementary between the collaborating yards, good efficiency and productivity can only be achieved through good coordination therefore how the system would be coordinated should be decided in advance among the inter-related industries. The coordination should cover at least the following subjects:

##### **2.4.1. Product Work Breakdown Structure and ship-part definitions**

The task would include the breakdown of construction design into blocks and modules, and defining of every ship-part including its details and work instructions as basis for defining the work contents and construction schedules.

##### **2.4.2. Role of individual shipyard**

Based on the product work breakdown structure and ship-part definitions the role of individual yard are appointed in accordance with its capability and specialty so that the collaborating yards could complement each other in achieving the objective of the system.

##### **2.4.3. Application of standards**

Consistency in using the standards will minimize unnecessary reworks and confusions during the construction process therefore application of same standards is very important in determining the successful implementation of multi-yard ship construction method. The standards applied in multi-yard ship construction method would include: measurement standard, parts definition standard, production standard, man-hour standard etc.

##### **2.4.4. Scheduling**

Schedule is part of the planning therefore it should be realistically arranged based on past experience and agreed standards. The schedule is arranged based on product work breakdown structure and parts definition combined with agreed man-hour standard which can be divided into blocks joining schedule and production schedule. The two schedules are dependent on each other and should be agreed by all collaborating yards.

### **3. BENEFITS OF MULTI-YARD SHIP CONSTRUCTION TO SHIPBUILDING CLUSTER**

The implementation of multi-yard ship construction is in line with the concept of shipbuilding industry cluster because it fosters the complementary and collaboration of the neighboring yards and other related industries. Each individual yard does not have to invest for all kind of production facilities and machineries as in the ordinary yard but only facilities and machineries needed for the tasks assigned to it so that will optimize the investment cost, for example the fabrication of plates and sections is not carried out by the shipyards but by one of the supporting industry therefore fabrication machineries are not needed in the shipyards. Each individual yard only constructs the blocks or modules assigned to it so that many works could be carried out simultaneously, and if the ships are built in series the learning process could be accomplished much faster and hence the ships could be built faster too and in good quality.

### **4. THE PILOT PROJECT**

The pilot project was undertaken on the proposed shipbuilding industry cluster in Tanggamus Regency, Lampung. There are four shipyards existed in this cluster which consist of: 1 large repair and new building yard with capacity up to 150,000 DWT; 1 middle size repair and new building yard with capacity up to 50,000 DWT; and 2 small size repair and new building yards with capacity up to 15,000 DWT, and other related industries such as fabrication firms, ship equipment manufacturers, steel mill, classification societies etc. [9].

For the purpose of this pilot project and for familiarization of multi-yard ship construction method the ship to be built is an aluminum catamaran 59.50 m search and rescue boat with the following main particulars:

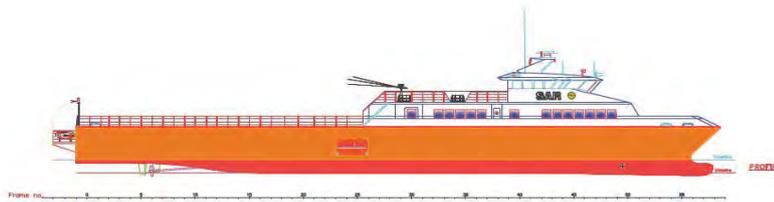


Figure 4 Aluminum Catamaran 59.50 m SAR Boat

▪ Length Over All (Loa)	59.50 m
▪ Length Waterline (LWL)	55.60 m
▪ Breadth (B max)	16.00 m
▪ Height (H amidships)	4.50 m
▪ Design Draft	1.50 m
▪ Maximum Speed	28 knots
▪ Displacement	320 tons
▪ Crews	25 persons
▪ Fuel Tank Capacity	42.5 tons
▪ Fresh Water Tank Capacity	10 tons
▪ Main Engine (High Duty)	2 x min 1342Kw (1800HP)
▪ Generator	2 x min 150 kVA

The ship was broken-down into seven main blocks with their estimated individual assembly time as follows: 1 Navigation Bridge (24 days), 1 accommodation block (72 days), 1 main deck with helipad (18 days), 2 engine room blocks (30 days each), 2 forward below deck blocks (18 days each). It was assumed that the procurement of materials and equipment was well planned and they all arrived in accordance with the schedule. Fabrication of the ship parts was assigned to a fabrication shop in the cluster, and the parts arrived in the yards on schedule.

Since the ship is relatively small therefore only three shipyards were involved in the pilot project i.e. two small yards and one middle size yard. The tasks assignments to the yards are as follows: Small yard I was assigned to build engine room blocks, Small yard II was assigned to build forward below deck blocks and navigation bridge, the Middle size yard would build accommodation block and main deck. The construction sequences were simulated including the blocks joining processes and on block outfitting works. It was assumed that the fabrication of ship parts was started one week before the first assembly work was commenced in the yard, time needed for transporting each block to the slipway is one day, and joining process were between two to three days. It was concluded that the construction work of the ship would accomplish in 83 days, and the ship was ready for launching.

Using the conventional method the ship would be ready for launching in about six months, thus the proposed method would save about 50% of the time for construction. The results would be more significant if a series of ships were built.

## 5. CONCLUSION

Multi-yard ship construction method is properly suit in shipbuilding industry cluster because the collaborating yards are located in the same area so that coordination and transport of ship parts from fabrication shop to the yards and blocks from constructing yards to building dock effectively. The overall production processes could be achieved faster compared to the conventional method, which means the productivity of the shipyards is increased.

## ACKNOWLEDGMENT

Special thanks are addressed to National Search and Rescue Agency for allowing its boat for the simulation of the project, and IPERINDO (Association of Indonesia's shipbuilding and offshore industry) for providing information on shipbuilding practices.

## REFERENCES

- [1] S N HIDAYAT, "5,000 Ships need routine repair every year" (*Indonesian*), Kontan Newspaper, 2011.
- [2] DIRECTORATE OF MARITIME INDUSTRY AND TECHNOLOGY, "Development Application Concept of Shipbuilding Industry Cluster" (*Indonesian*), Ministry of Industry Republic of Indonesia, 2006.
- [3] BAPPEDA, 'Lampung Province's Strategic Development Planning' (*Indonesian*), Lampung Province Government, 2011.

- [4] SAN DIEGO REGIONAL TECHNOLOGY ALLIANCE, “What Are Industrial Cluster”, *San Diego Association of Governments*, 1995.
- [5] DIRECTORATE OF MARITIME INDUSTRY AND TECHNOLOGY, “Development Application Concept of Shipbuilding Industry Cluster” (*Indonesian*), Ministry of Industry Republic of Indonesia, 2006.
- [6] Sunaryo, “Lecture Note on Ship Production Management”, p 16-11, unpublished, 2010.
- [7] Plan-Do-Check-Act (PDCA) - Project Management Tools, MindTools.com, 2012.
- [8] T W Seubert, “Modular Shipbuilding and Its relevance to Construction to Nuclear power Plant”, Massachusetts Institute of Technology, 1988.
- [9] Sunaryo, “Study On The Possibility Of Establishing Shipbuilding Cluster In Lampung Province Sumatra Indonesia”, International Conference on Ships and Offshore Technology, 2012.

# Combustion Analysis of Proto X-2 Bioenergy Micro Gas Turbine with Diesel – Bioethanol Blends

Ahmad Indra Siswantara<sup>a</sup>, Steven Darmawan<sup>a,b</sup>, Okwaldu Purba<sup>a,c</sup>

<sup>a</sup> Mechanical Engineering Dept., University of Indonesia, Depok 16424  
E-mail : a\_indra@eng.ui.ac.id

<sup>b</sup> Mechanical Engineering Dept., University of Tarumanagara  
Jl. Letjen S.Parmar No.1, Jakarta 11440  
E-mail : stevend024@yahoo.com

<sup>c</sup> PT. Pembangkitan Jawa Bali, Unit Pembangkitan Muara Karang  
Muara Karang, Jakarta 11384, Indonesia  
Email: aldo.prb@gmail.com

## ABSTRACT

Research and development of biofuel and bioenergy prime mover has been active recently. Micro gas turbine (MGT) is one of prime mover and has been projected as a prospective prime mover; technically, dimension, cost, environmentally, and has a high tolerance to many kind of fuels. The aim of this research is to analyze the performance of Proto X-2 Bioenergy Micro Gas Turbine that has been developed which consist of one stage radial compressor and turbine, and a combustion system. The Proto X-2 then tested with biofuel; Diesel-bioethanol blended. The fuel blends were varied to 100% Diesel (D100), 2.5% bioethanol (DBE2.5), 5% bioethanol (DBE5), 7.5% bioethanol (DBE7.5), and 10% bioethanol (DBE10). The nozzle was 0.75 GPH with 45 degree spray angle. CFD simulation is also done with CFDSOF<sup>®</sup> and the results are utilized to verify the experimental data. The analysis then focused on combustion temperature since it's dominant effect on the system performance. DBE2.5 yield the optimum result with 1000 rpm increasing the shaft speed, 2.2% in pressure ratio, 2°C lower TIT, and increased AFR compared to D100. Combustion temperature contours was only slightly difference to experimental data with maximum deviation 7.4%. Optimal biofuel use on the Proto X-2 can increase it's performance and more suitable to use in Zero Energy Building.

### Keywords

micro gas turbine, biofuel, combustion characteristics, CFD

## 1. INTRODUCTION

Research and development of biofuel and bioenergy prime mover has been active in recent years. Micro gas turbine (MGT) is one of prime mover has been projected as a prospective; technically, dimension, cost, environmentally with power up to 200kW [1]. High power to weight ratio and wide range of application; as a power source for electricity and other application. This characteristic has lead to development of Proto X-2 Bioenergi Micro Gas Turbine which has been developed in past few years. It's high exhaust gas temperature also can be used for other application; such as a hot inlet gas for shell & tube heat exchanger [2-5]. High tolerance to many kind of fuel also another advantage of gas turbine system, from gas to liquid; LPG, CH<sub>4</sub> domestic oil, alcohol family (methanol, ethanol) and include biofuel, such as biogas, sunflower oil [6-8]. Furthermore, the global issue about decreasing fossil fuel, environment, and political views has stimulate the research and development of renewable fuel and it's application [9,10]. This condition also lead the development of biofuel and bioenergy power system, including in Indonesia. Ministry of Energy and Mineral Resources (KESDM) has supporting the development of new and renewable fuel in Indonesia and planning that new and re-newable energy could be at least 25% part of national energy use in 2025. This policy also known as "VISI 25/25" [11]. Main strategy of "VISI 25/25" are stated as below:

- Development of sustainable energy village (Desa Mandiri Energi – DME)
- Bioenergy application for industrial sector
- Bioenergy application for other sector; power source and domestic application

Renewable energy resource is undoubtedly available in Indonesia, such as biogas, jatropha oil, bioethanol, etc. Bioethanol is one of available biofuel which has been used widely, especially to blend with Diesel fuel. Among others biofuel, fuel-grade bioethanol has several advantages and the most compatible for fossil fuel; biodegradable, low toxicity, renewable properties (from biomass or plant), can be directly blend to diesel fuel, thus can reduce the use of fossil fuel, and it's high oxygen concentration in bioethanol will make the combustion leaner, increase the combustion performance and give lower emission compared to diesel fuel [10], [12,13]. Recent research of prototype Proto X-2 MGT discover availability with the use of biofuels; Diesel fuel (fossil fuel), bioethanol (biofuel), and jatropha oil (biofuel) [14-16]. Aside of it's advantages compare to

diesel fuel, bioethanol as fuel also has circumstances; which are the mixture homogeneity with Diesel fuel is doubtful and alcohol contained need special pump rather than ordinary fuel pump.

This research aim is to analyze the combustion performance of Proto X-2 MGT with the use of Diesel-bioethanol blends. The blends were varied into several fraction to 100% Diesel (D100), 2.5% bioethanol (DBE2.5), 5% bioethanol (DBE5), 7.5% bioethanol (DBE7.5), and 10% bioethanol (DBE10). This blendsfuel then directly injected to combustion system of Proto X-2 Bioenergy Micro gas Turbine and ignited. Among its components, combustion system is one of the three main component on micro gas turbine which can be represent the performance of the system, beside compressor and turbine. The combustion system consist of swirl unit a incorporating spray nozzle and a combustion chamber. Swirler use to give a better mixture fuel-air which a turbulent flow [7]. Combustion process took place in three zone; primary, secondary, and tertiary zone, where the fuel entered the combustion chamber via nozzle at primary zone and enter the turbine with high temperature, which also known as TIT (Turbine Inlet Temperature). Overall system performance oftenly represented by this characteristic parameter since the TIT is affected by the fuel flow rate, air flow rate, and pressure ratio. This combustion chamber and modeled with CFD method to predict the combustion process since the Diesel-bioethanol blended gave a different combustion characteristic. Both of this experimental and CFD simulation (CFDSOF) result will be used to develop the prototype. Optimal biofuel application on the Proto X-2 and sustainable research in bioenergy can increase it's performance and make it suitable to use in Zero Energy Building, as shown in research road-map in figure 1.



Figure 1: Research road map

## 2. EXPERIMENTAL SET-UP

The research methodology consist of two parts: (a) Experiment on Proto X-2 Bioenergy micro gas turbine and (b) CFD simulation.

### 2.1 Experiment

Experiment done to prototype of Proto X-2 Bioenergy Micro Gas Turbine and use two kind of fuel; Diesel fuel and Diesel-bioethanol blends. The fuel blends was varied to 100% Diesel (D100), 2.5% bioethanol (DBE2.5), 5% bioethanol (DBE5), 7.5% bioethanol (DBE7.5), and 10% bioethanol (DBE10). Ethanol is a oxygenate fuel and consist of up to 35% oxygen [10], where the bioethanol used in this research is E-75. The experimental set-up of prototype is shown on figure 2 below and resulting parameter and characteristics parameter [2]: (a) shaft speed, (b) compressor pressure ratio, (c) Turbine inlet temperature, (d) fuel flow rate, (e) Air flow rate. (f) AFR. The Proto X-2 Bioenergy Micro gas Turbine consist of single stage compressor and turbine, and the combustion system. The compressor and turbine were radial type and the combustion system consist of swirl unit a incorporating spray nozzle and a combustion chamber [17], as seen on figure 3. The nozzle use was liquid fuel nozzle, capacity of 0.75 GPH and 45° spray angle. The combustion chamber consist of flame swirler and

combustion liner. The ignited flame was run through the primary, secondary, and the tertiary zone of the combustion chamber. Fuel pressure was 20 bar. The fuel leave the nozzle and entered the burner swirler so that the swirling flame can occurred. The experimental data shown in figure 6-figure 10.

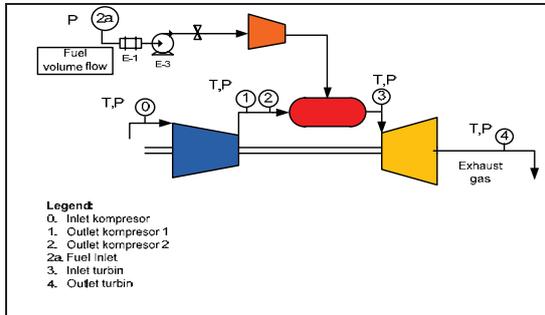


Figure 2: Experimental set-up

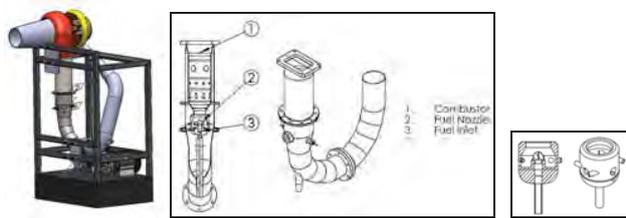


Figure 3:  
 (a) Combustion chamber design, (b) flame swirler,  
 (c) Proto X-2 geometry model

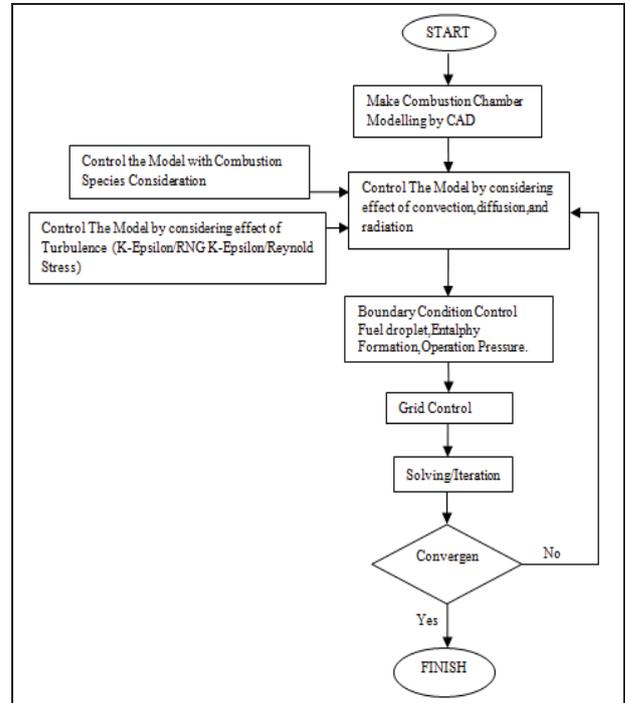


Figure 4: CFD simulation flow chart

## 2.2 CFD Simulation

CFD simulation done to D100, DBE2.5, DBE5, DBE7.5 with CFDSOF<sup>®</sup> software. The result thus compared with CFD simulation result of combustion chamber from experimental data. The model was simplified into 2D, the grid was 300 x 30, 250 mm in length, 25 mm in width as shown in figure 4. The Model Control using the *k-ε* model of turbulence and combustion air velocity entered the chamber was assumed 1m/s and consist of 21% oxygen. The result of CFD simulation shown in figure 10-figure 14.

## 3. RESULT AND DISCUSSION

### 3.1. Experimental Data

Figure 5-figure 9 showed the experimental data of Proto X-2 bioenergy MGT. The parameters were shaft speed (N), pressure ratio, AFR, and turbine inlet temperature (TIT). DBE2.5 yield the optimum result. The shaft speed was increased from 35864 rpm (D100) to 36921 rpm in figure 5. DBE5 has increased the shaft speed on high fuel flow rate, while others not. The similiar result also yield in pressure ratio, DBE2.5 increased the pressure ratio of 2.2% compared to D100 on average while other fraction tend to decrease the pressure ratio. Oxygenate of ethanol [9,10] at DBE2.5 has the possibility resulting a leaner combustion and more complete combustion, while higher water contained in others blends tends to act as cooling agent rather than react with fuel. As the speed increased, the TIT increased due to higher combustion energy at higher fuel flow rate. From figure 6, turbine inlet temperature (TIT) by fuel flow rate reuslting from DBE2.5 was slightly lower to D100 but with higher shaft speed and higher pressure ratio. DBE2.5 yield from maximum tested fuel flow rate with TIT of 515°C at 0.893 g/s compared to D100 which yield 517°C at 0.924 g/s. AFR tend to decreased as the fuel flow rate increased. This phenomenon occur in all varied fuel fraction which means the increasing shaft speed not yet provide enough air flow rate. DBE2.5 yield highest AFR at 124 of 0.65 g/s fuel flow rate compared to D100 with AFR of 119 at fuel flow rate of 0.68 g/s. At maximum tested fuel flow rate, AFR of DBE2.5 was 93 compared to D100 with AFR of 91.8. Those phenomenon clearly presentated on figure 9 (a) that DBE2.5 yield shaft speed higher than other bioethanol fraction, although 280 rpm lower than D100. But compared with average fuel flow rate on figure 9 (b) which DBE 2.5 yield 2.6% lower than D100 and other characteristic

parameter, this value is acceptable. Blends homogeneity has to be a factor to concern on since this two kind of fuel has different characteristics. To avoid unmixedness between Diesel fuel-bioethanol, Arifin Nur et.al [10] have added *Sorbitan Methyl Ester* (SPAN 80) as surfactant to increase the chemical bonds stability. Unmixedness fuel blends was occur at higher bioethanol fraction also will decrease the fuel pump performance for long-term use.

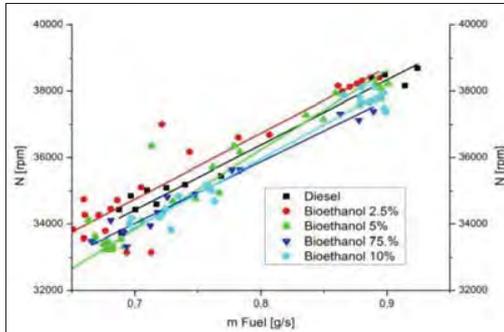


Figure 5: Shaft speed – Fuel flow rate

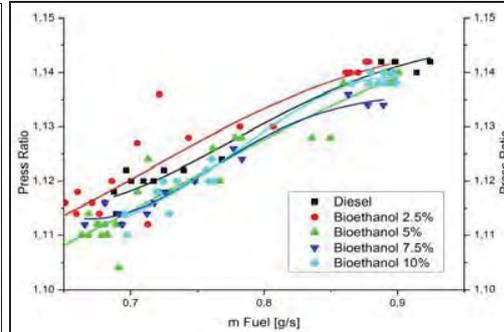


Figure 6: Pressure ratio –fuel flow rate

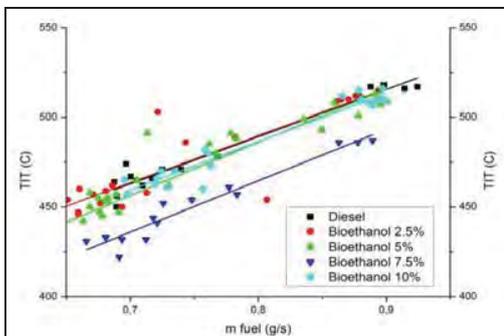


Figure 7: TIT – ful flow rate

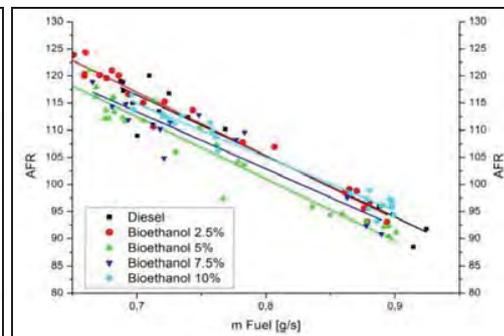


Figure 8: AFR – fuel flow rate

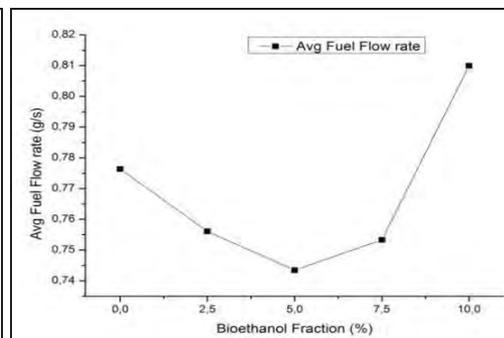
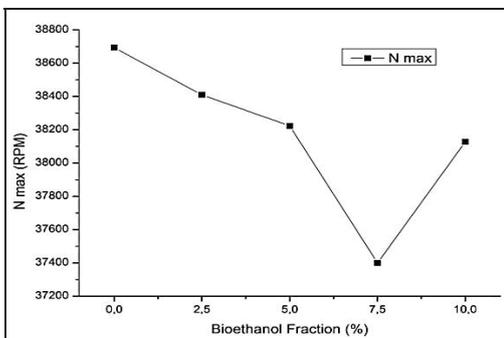


Figure 9: Shaft speed (a) and fuel flow rate (b).

### 3.2. CFD Simulation Result

The result of CFD simulation on Proto X-2 combustion temperature shown on figure 10-figure 14 with the use of Diesel-bioethanol blended fuel. On figure 10, temperature contour of prototype combustor running on 100 % Diesel Fuel (D100). Maximum combustion temperature achieved at 909,2 K (636,05 °C) occur at the center of the flame, line with fuel droplet out of the nozzle. With inlet fuel flow rate for CFD simulation 0.7 g/s, the combustion gas left the combustion chamber and entered the turbine at 550°C while experimental data on D100 is 517°C or 6.38% lower. Combustion temperature contour of DBE2.5 showed on figure 11. The CFD simulation showed that the combustion temperature at combustion chamber outlet is 537°C while the experimental data is 515°C, or 4.27%. The maximum combustion temperature occurred at flame centre line, 631°C. As seen on figure 13, the combustion outlet temperature of DBE5 is 540°C, while experimental data showed 509°C, or 6% difference. The maximum flame temperature was 625°C. Combustion temperature contour of DBE7.5 shown on figure 13. The CFD simulation showed that the combustion temperature at combustion chamber outlet is 523°C while the experimental data was 487°C, or 7.39% lower. The maximum combustion temperature occurred at flame centre line, 627°C. Combustion

temperature contour of DBE7.5 shown on figure 14. The CFD simulation showed that the combustion temperature at combustion chamber outlet was 519°C while the experimental data is 509°C, or 1.9% lower. The maximum combustion temperature occurred at flame centre line, 614°C. CFD simulation to MGT combustion chamber shows that the combustion chamber outlet temperature tend to lower at higher bioethanol fraction in Diesel-bioethanol blends. As the distance flame to flame tube became smaller, the temperature decreased. Leaner combustion occurred with secondary air from secondary air holes and the sirler which provide good mixing between fuel and oxydator and leaner combustion so the combustion was more complete and may reduce the NO<sub>x</sub> production [18,19]. Similiar trends also showed by experimental data, except on DBE10. This phenomenon may caused by homogeneity of fuel blends at high bioethanol fraction or poor mixing that could induce combustion instabilities [19]. In Diesel-bioethanol blends, the bioethanol tend to form coagulant and the temperature tend to increase as on D100. The difference location in measurement point was suspected to caused the temperature difference between experimental data and CFD simulation.

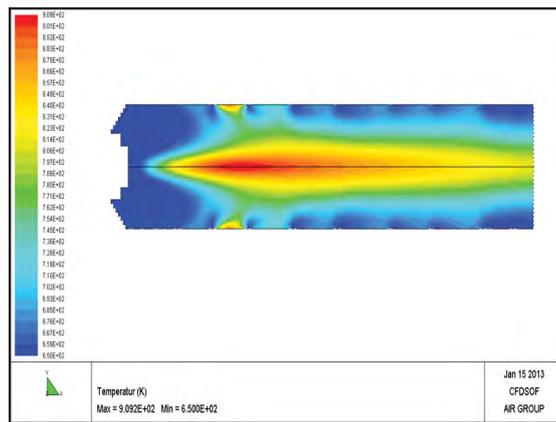


Figure 10: Temperatur contour of D100 combustion

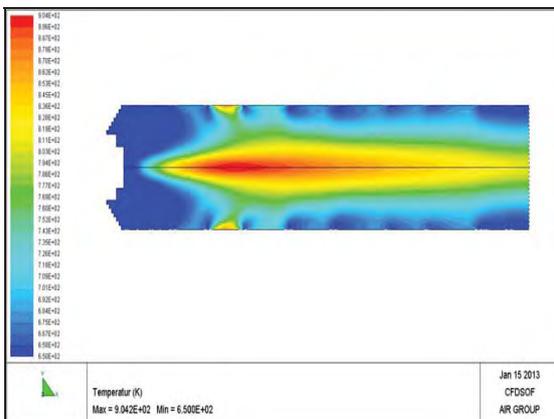


Figure 11: Temperatur contour for DBE2.5

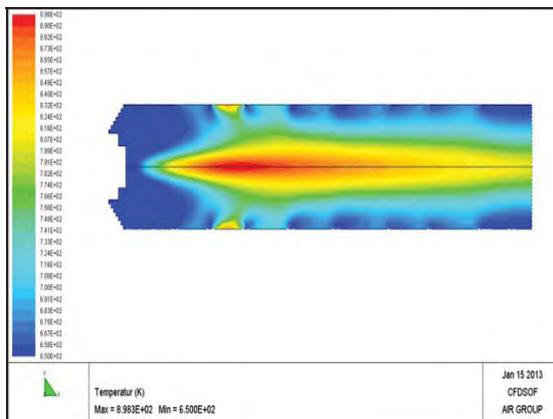


Figure 12: Temperatur contour for DBE5

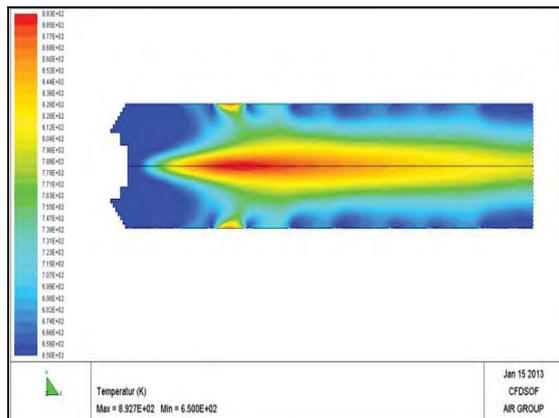


Figure 13: Temperature contour for DBE 7.5

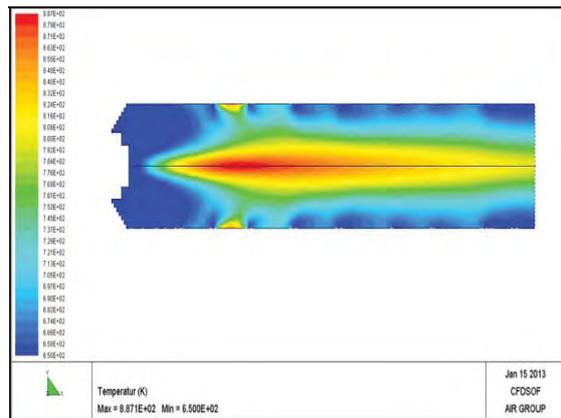


Figure 14: Temperature Contour for DBE 10

#### 4. Conclusion

The optimum combustion characteristic of Proto X-2 Bioenergy Micro gas Turbine is achieved by using 2.5% bioethanol in Diesel-bioethanol blends (DBE2.5) in overall. DBE2.5 increased the shaft speed from 35864 rpm (D100) to 36921 rpm. The compressor pressure ratio increased by 2.2% while other blend decreased the pressure ratio. With lower fuel flow rate, DBE2.5 decreased the TIT to 515°C. The result of CFD simulation was slightly difference to the experimental data which the TIT tends to lower at higher bioethanol fraction. Overall, CFD simulation resulting 7.38% lower (maximum) than experimental data.

#### ACKNOWLEDGMENT

The authors would like to thanks DRPM Universitas Indonesia for funding this research through Hibah Riset Awal UI scheme program – 2012.

#### REFERENCES

- [1] Hiroshi Saito et al., "Micro Gas Turbines, Risk and Markets," in *IMA Conference*, Stockholm, 2003.
- [2] Jong Joon Lee, Jae Eun Yoon, Tong Seop Kim, and Jeong L. Sohn, "Performance Test and Component Characteristic Evaluation of a Micro Gas Turbines," *Journal of Mechanical Science and Technology*, vol. 21, no. 1, pp. 141-152, 2007.
- [3] Anthony Giampaolo, *Gas Turbine Handbook: Principles and Practices*, 3rd ed. Liburn, U.K.: The Fairmont Press, 2006.
- [4] Candra Damis Widyawati, "Analisis Desain dan Redesain Alat Penukar Kalor Tipe Shell and Tube Dengan CFD," Depok, 2012.
- [5] Hadid Fadillah, "Analisis Reboiler Tipe Shell and Tube Untuk Sistem Destilasi Bioetanol Yang Terintegrasi Dengan Turbin Gas Mikro Bioenergi Proto X-2," Depok, 2012.
- [6] Iskender Gokalp and Etienne Lebas, "Alternative fuels for industrial gas turbines (AFTUR)," *Applied Thermal Engineering*, vol. 24, pp. 1655-1663, 2004.
- [7] W. Meier, X.R. Duan, and P. Weigand, "Reaction zone structure and mixing characteristics of partially premixed swirling CH<sub>4</sub>/air flames in a gas turbine model combustor," *Proceedings of the Combustion institute*, vol. 30, pp. 835-842, 2005.
- [8] D. Chiamonti M. Prussi, G. Riccio, F. Martelli, and L. Pari, "Straight vegetable oil use in Micro-Gas Turbines: System adaptation and testing," *Applied Energy*, vol. 89, pp. 287-295, 2012.
- [9] Zehra Habib, Ramkumar Partasarathy, and Subramanyam Gollahalli, "Performance and emission characteristics of biofuel in a small-scale gas turbine engine," *Applied Energy*, vol. 87, pp. 1701-1709, 2010.
- [10] Arifin Nur, Yanuandri Putrasari, and Iman Kartolaksomo Reksowardojo, "The effect of ethanol-diesel blends on the performance of a direct injection diesel engine," *Mechantronics, Electrical Power, and Vehicular Technology*, vol. 03, pp. 49-56, 2012.
- [11] Kementrian Energi dan Sumber Daya Mineral, "Sarasehan Energi Baru Terbarukan Untuk Mewujudkan Visi Energi 25/25," *Siaran Pers KESDM No. 57/Humas KESDM/2010*, 2 November 2010.
- [12] Seung Hyun Yoon, Jin Woo Hwang, and Chang Sik Lee, "Effect of Injection Strategy on the Combustion and Exhaust Emission Characteristics of a Biodiesel-Ethanol Blend in a DI Diesel Engine," *Journal of Engineering for Gas Turbines and Power*, vol. 132, pp. 094503 1 - 094503 3, September 2010.

- [13] Abrar Riza and Steven Darmawan, "Karakteristik pembakaran dengan udara berlebih pada motor bakar penyalaan busi," in *The National Conference on Hotel Engineering (KNEP)*, Denpasar, 2011, pp. 91-102.
- [14] Djuang Marhendra, "Analisis unjuk kerja turbin gas mikro bioenergi proto X-2 dengan bahan bakar solar," Universitas Indonesia, Depok, Skripsi 2013.
- [15] Abdul Azis, "Analisis unjuk kerja turbin gas mikro bioenergi proto X-2 dengan bahan bakar solar-bioetanol," Universitas Indonesia, Depok, Skripsi 2013.
- [16] Eka Prasetya, "Analisis unjuk kerja turbin gas mikro bioenergi proto X-2 dengan bahan bakar solar-minyak jarak," Universitas Indonesia, Depok, Skripsi 2013.
- [17] TQ-International, "Manual book GT85-2 Two Shaft Gas Turbine," Nottingham, 1982.
- [18] Guoqiang Li and Ephraim J. Gutmark, "Effect of exhaust nozzle geometry on combustor flow field and combustion characteristics," *Proceedings of the Combustion Institute*, vol. 30, pp. 2893-2901, 2005.
- [19] Seonghyeon Seo and Seong-Young Lee, "Effect of unmixedness on combustion instabilities in a lean-premixed gas turbine combustion," *Flow Turbulence Combustion*, vol. 85, pp. 95-112, 2010.

# Effect of Downdraught Mass Flow Rate Generated and The Uniformity of The Velocity and Temperature Profiles Downstream of The Multi-Array Nozzles

Sarjito<sup>a</sup>, Denis Marchant<sup>b</sup>

<sup>a</sup> Mechanical Engineering Department, Faculty of Engineering  
Muhammadiyah University of Surakarta, Jl. A. Yani Tromol Pos 1 Pabelan Kartasura 57102  
E-mail : sarjito@ums.ac.id

<sup>b</sup> Mechanical Engineering Department, Faculty of Science Engineering and Computing, Kingston University,  
Friars Avenue, Roehampton Vale London SW15 3DW, UK  
e-mail : d.marchant@kingston.ac.uk

## ABSTRACT

The aims of the research work described in this paper is a part were to use computational fluid dynamics (CFD) to investigate the effect of downdraught mass flow rate generated and the uniformity of the velocity and temperature profiles downstream of the multi-array nozzles. This involved a study to define the optimum number, and the most effective arrangement of spray nozzles in a multi-nozzle array. Two basic arrangements of the nozzles were investigated; one in which a constant radius of 0.75 metres was maintained for the nozzle pitch circle as nozzles were added, and another, in which a constant separation distance or spacing of 0.75 metres was maintained between all nozzles. A second simulation was set up using the configuration with constant spacing, with a single central nozzle added. A final simulation was carried out to determine if further optimization of the nozzle configuration could be obtained by altering the constant nozzle spacing in the range 0.35 to 0.85 metres. Based on these simulations, that constant spacing provided much more even cooling with fewer nozzles than the configurations with constant radius. The arrangement with 11 nozzles gave the best overall performance with nozzle spacing to 0.65 metres.

### Keywords:

*CFD, Downdraught mass flow rate, Multi-array nozzles configuration, cooling power*

## 1. INTRODUCTION

The passive downdraught evaporative cooling system might be fully-equipped with a wetted pad mode or water spray mode using atomizer [1], but excess water is still remain a not easy problem to manage. In a multi-nozzle array of identical nozzles at the same driving pressure, the spray water mass flow will be directly proportional to the number of nozzles used. However, the number of nozzles and their relative positions will affect thermal energy and momentum transfer due to the increasing interference between the individual spray cones when additional nozzles are added. It was expected that eventually, the inclusion of additional nozzles would offer no advantage, and that an optimum configuration could be identified.

A possible alternative approach which might offer some advantages would be to add additional nozzles while keeping the total spray water mass flow constant. While this approach would be possible theoretically, the subdivision of the constant total spray water flow each time an additional nozzle was added, would require the use of different nozzles of progressively smaller orifice diameter at each stage, and might also require a change in the driving pressure. Also, the droplet size distribution generated by the nozzles would change at each stage. This alternative approach was not investigated and further investigation in this paper used the same mass flow rate in each stage.

Modelling and testing of a CFD model of a single spray nozzle in a vertical cylinder in the interest of verification of appropriate software has been carried out [2]. The model, which simulated both the water mist evaporation process and the thermal energy and momentum transfer between the droplets and the surrounding air, was developed with the objective of validating the basic spray modelling methodology used in the present work by reproducing the results for a single spray nozzle model produced by Gant at the UK Health and Safety Laboratory, (HSL), Buxton [3]. The result of the simulation then be compared with the experimental data of single spray model carried out by St. George and Bucklin [4], resulting good agreement though velocity at the centre downstream to the nozzles slightly lower. Further development work on the model to incorporate two commercially-available nozzles, (BETE PJ32 and TF6) [5], and calculations to ensure that the results were theoretically and physically sensible are also described [2]. Results from recent experiments [6], which were carried out specifically to check the validity of the droplet evaporation model in CFX were also as a motivation in this work.

## 2. MODELLING OF MULTI-NOZZLE ARRAY OF IDENTICAL NOZZLES

The flow domain for these studies was created with overall length and diameter as a vertical cylinder at  $D = 4$  metres and  $L_0 = 3$  metres respectively.

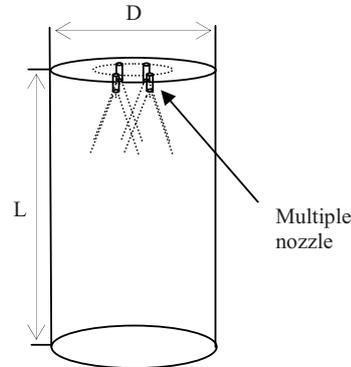


Figure 1: Flow Domain dimensions for multiple nozzle simulations

The evaporation modelling and droplet size distribution were set up with a single downward-facing nozzle at the centre of the upper circular face. The nozzle was modelled as a cylinder of diameter  $d_0 = 0.00625$  metres and length 0.05 metres, as shown on top in Figure 1. Within CFX [7] in the present work, a droplet diameter distribution was specified as a series of mass and number fractions in discrete diameter bands. This approach was adopted corresponding to the TF6 nozzles used with a water droplet mass flow rate of 0.096 kg/s and a spray velocity of 21.57 m/s, for a water temperature of 10°C, and a CFX input data set use 1500 representative particles to represent the droplet population, and was created from information based on mass and number fraction data sets summed to unity exactly, that at least one representative particle was present in each diameter band, and data was given in references [8] at a driving pressure of 3.33 bar:

Droplet diameter bands ( $\mu\text{m}$ )

27, 55, 82, 106, 121, 136, 152, 171, 193, 230, 256, 282, 307, 339, 381, 425

Mass fraction per band

0.0029,0.0100,0.0217,0.0387,0.0550,0.0745,0.0963,0.1136,0.1195,0.1119,0.0959,0.0800,0.0652,0.0502,0.0371,0.0273

Number fraction per band

0.3438,0.1379,0.0915,0.0758,0.0727,0.0686,0.0641,0.0529,0.0389,0.0214,0.0133,0.0083,0.0053,0.0030,0.0016,0.0008

In setting up the flow physics a reference temperature of 25°C, a reference pressure of 1 atmosphere, and a reference air density of 1.2 kg/m<sup>3</sup> were used. The boundary condition on both the upper and the lower circular faces of the flow domain was set as an opening, which permitted both inflow and outflow from the flow domain, and a free-slip adiabatic wall condition was specified at the cylinder surface. Buoyancy effects were modelled using the standard density difference model within CFX combined with an acceleration of -9.81 m/s<sup>2</sup> in the Y direction.

Within the flow domain, a variable composition gas mixture of air and water vapour was set up, with the water droplet being set up as a dispersed liquid phase. Drag forces on the liquid droplet were modelled by the Schiller Naumann equation. This drag model is based on the assumptions that the fluid droplets within the spray were sufficiently small to be considered spherical and that the volume fraction of the droplets was small. These assumptions were considered to be reasonable. Interphase thermal energy transfer was modelled using the Ranz Marshall (Nusselt number based) correlation, (ANSYS CFX 13-Solver theory guide 2010) [7]. Droplet evaporation was modelled using the standard evaporation model within CFX, in which the saturated vapour pressure is correlated as a function of temperature through the Antoine equation:

$$p_{sat} = \exp\left(A - \frac{B}{T + C}\right) \quad (\text{bar}) \quad (1)$$

where  $T$  is the temperature in kelvin and the constants  $A$ ,  $B$  and  $C$  are 5.11564ln(10), 1687.54ln(10) and -42.92 respectively.

For turbulence modelling, both the shear stress transport (SST) and k-epsilon models were used with automatic wall functions. In both cases, the inlet turbulence intensity level was set to 5%. However, only k-epsilon turbulence model were discussed.

At the spray inlet, the droplet injection region was specified using the standard cone injection method within CFX. Since the Lagrangian model does not accurately simulate primary droplet break-up, the injection centre was placed 0.01 metres below the nozzle outlet plane. The cone angle  $\theta$  was specified as 90° with full cone injection. Using a larger number of droplets gave a smoother distribution of results, but also increased the computing time and memory needed.

### 3. INVESTIGATION OF MULTIPLE NOZZLE CONFIGURATIONS

Two basic arrangements of the nozzles were investigated; a configuration, (Figure 2(a)), in which a constant radius,  $r = 0.75$  metres was maintained for the nozzle pitch circle as nozzles were added, and a configuration, (Figure 2(b)), in which a constant separation distance  $d = 0.75$  metres was maintained between all nozzles.

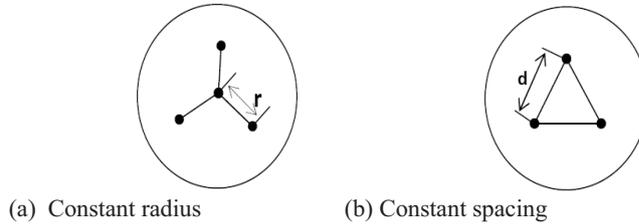


Figure 2: Basic nozzle arrangements

A range of constant radius configurations using from 3 to 20 nozzles was simulated. The configurations with 4, 11 and 18 nozzles are shown in Figure 3.

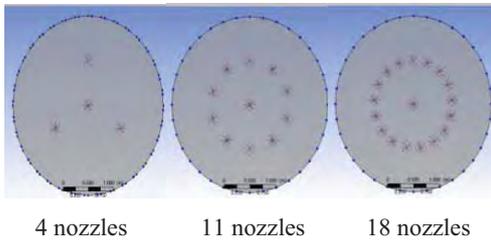


Figure 3: Constant radius configurations

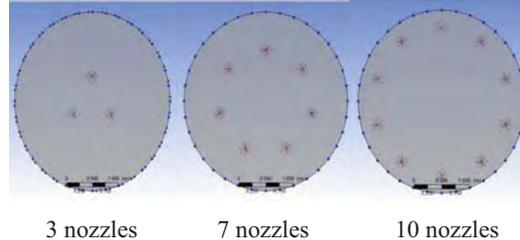


Figure 4: Configurations with constant spacing

A range of configurations with constant spacing using from 3 to 12 nozzles was simulated, also. The configurations with 3, 7 and 10 nozzles are shown in Figure 4.

The surface and volume meshes were created using minimum and maximum face spacings of 0.002 metres and 0.02 metres, with an angular resolution of  $30^\circ$ , and a body spacing of 0.02 metres. These settings produced approximately 1,455,000 tetrahedral elements for the simulations using 3 nozzles, and 3,655,000 tetrahedral elements for the simulation using 20 nozzles. The inlet boundary condition at the upper circular face was specified as an opening with an incoming air temperature of  $30^\circ\text{C}$  and 0% relative humidity. The boundary condition at the lower circular face was specified as an outlet at atmospheric pressure. A free-slip adiabatic wall condition was set on the cylinder surface. Steady-state simulations were carried out using a physical time scale control 0.05s with a residual target of  $1e-6$  and using the k-epsilon turbulence model with the inlet turbulence level set to 5%.

The variations in average outlet temperature and in total mass flow rate for all configurations are shown in Figure 5

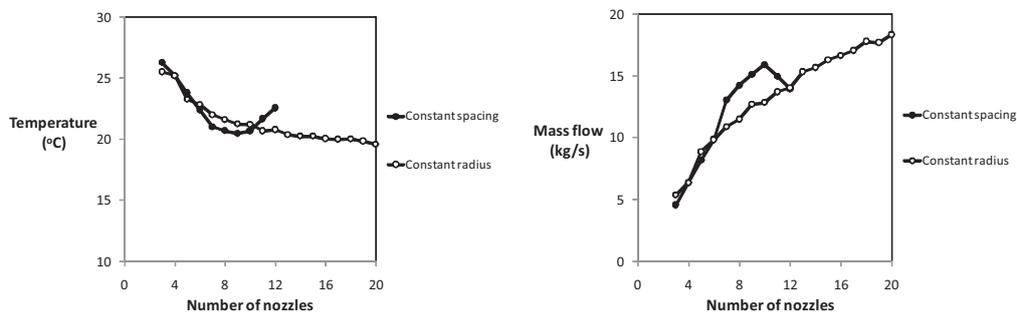


Figure 5: Variation in outlet temperature and mass flow with nozzle configuration

It can be seen from Figure 5 that the constant radius configuration produced the lowest overall temperature and the highest mass flow rate, but used more nozzles to produce these effects than the configuration with constant spacing. In particular, for numbers of nozzles between 6 and 11 the configuration with constant spacing was more effective at both reducing the average outlet temperature and entraining the air flow. The best cooling performance was obtained with 9 nozzles and the highest entrainment rate with 10 nozzles.

Based on these results a second series of simulations was set up using the configuration with constant spacing to investigate the effect of adding a central nozzle for the 8 to 12 nozzles including central nozzle.

#### 4. CONSTANT SPACING CONFIGURATION WITH CENTRAL NOZZLE

A second series of simulations was set up using the configuration with constant spacing, with a single central nozzle added. The configurations investigated used 8 to 12 nozzles. In all cases a constant nozzle spacing of  $d = 0.75$  metres was maintained. Contour plots showing the outlet temperature distributions range of 283.1 - 303.1 K obtained are shown in Figure 6.

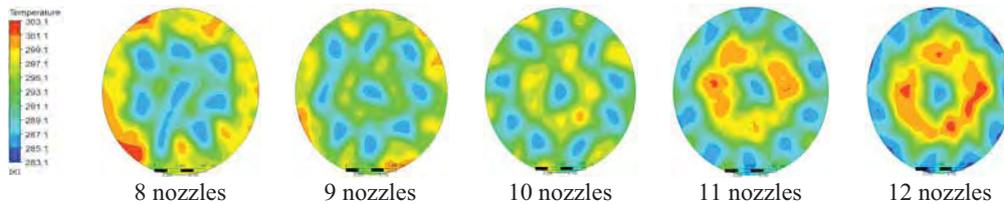


Figure 6- Outlet temperature distributions, configurations with constant spacing and a single central nozzle

By comparing the image for the case with 11 nozzles in Figure 6 with the result for the case with 10 nozzles without central nozzle, a significant improvement in cooling in the central region was observed. The variations in average outlet temperature and in total mass flow rate obtained for all configurations are shown in Figure 7 together with the previous results shown in Figures 5 for comparison.

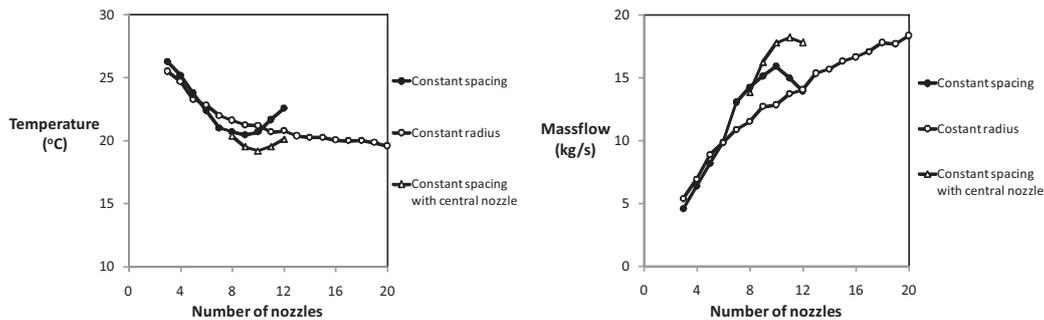


Figure 7: Variation in average outlet temperature and mass flow, (showing additional configurations with constant spacing and single central nozzle)

It can be seen from Figure 7 that the configurations with the additional central nozzle produced both lower average outlet temperatures and higher entrained mass flow rate in all cases. The best cooling performance was obtained with 10 nozzles and the highest entrainment rate with 11 nozzles.

Based on these results a third series of simulations was carried out to investigate if further optimization of the nozzle configuration could be obtained by altering the constant nozzle spacing. The configuration selected for these further studies was the 11-nozzle configuration. This configuration was selected because it produced the highest entrainment rate.

#### 5. OPTIMIZATION OF NOZZLE SEPARATION

These simulations were carried out for constant nozzle spacings  $d$  ranging from 0.35 to 0.85 metres in 0.1 metres steps. The simulations were carried out using an incoming air temperature of 30°C and 0% relative humidity and spray water temperature of 10°C.

The variations in average outlet temperature and mass flow rate with nozzle spacing are shown in Figure 8.

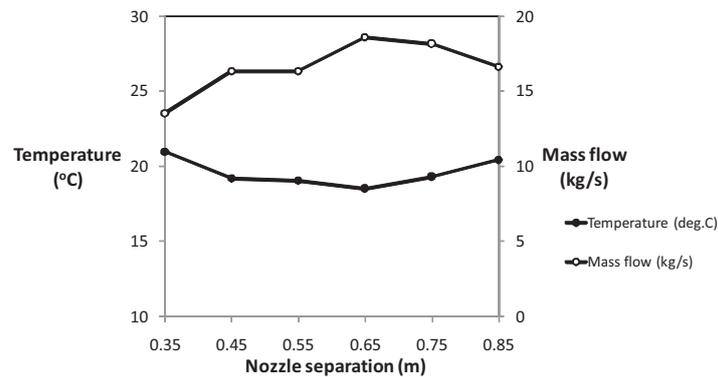


Figure 8: Variation in average outlet temperature and mass flow with nozzle spacing for 11-nozzle configuration with central nozzle

It can be seen from Figure 8 that the configuration with the 0.65 metres nozzle spacing produced both the lowest average outlet temperature and the highest entrained mass flow rate. Based on these results this nozzle spacing of 0.65 was selected for use in all future studies.

## 6. COOLING POWER FOR OPTIMUM NOZZLE CONFIGURATION

For evaporative cooling the sensible cooling power can be estimated from the induced mass flow rate and temperature reduction of the air flow. This calculation was carried out for the optimum arrangement of 11 nozzles and the result is discussed in a separately study. Certainly, it is possible when more detailed simulations using the optimum nozzle arrangement conducted and discussed.

## 7. CONCLUSIONS

CFD simulations were carried out to define the optimum number, and the most effective arrangement of spray nozzles in a multi-nozzle array. Two basic arrangements of the nozzles were investigated; one in which a constant radius of 0.75 metres was maintained for the nozzle pitch circle as nozzles were added, and another, in which a constant separation distance or spacing of 0.75 metres was maintained between all nozzles. Based on these simulations it was concluded that the configurations with constant spacing provided much more even cooling with fewer nozzles than the configurations with constant radius.

A second series of simulations was set up using the configuration with constant spacing, with a single central nozzle added. It was concluded that this arrangement produced both lower average outlet temperatures and higher entrained mass flow rates in all cases and that the arrangement with 11 nozzles gave the best overall performance.

A final series of simulation was carried out to determine if further optimization of the nozzle configuration could be obtained by altering the constant nozzle spacing in the range 0.35 to 0.85 metres. It was concluded that a further improvement in performance could be achieved by setting the nozzle spacing to 0.65 metres and this configuration would be selected for use in all future studies.

## ACKNOWLEDGMENT

My first thank must go to Dr George Simpson at Kingston University London (ex) for helpful discussion in preparing the work. Also, I would like to thank to Dr Yufeng Yao for his support and good collaboration. The support obtained from Muhammadiyah University of Surakarta is also gratefully acknowledged.

## REFERENCES

- [1] Pearlmutter, D., Erell, Y. (2008), "A novel multi-stage down-draft evaporative cool tower for space cooling. Part 2: Preliminary experiments with a water spraying system," *Solar Energy*, (82), pp. 430-440.
- [2] Sarjito (2012), "An investigation of the design and performance of a multi-stage downdraught evaporative cooler", Unpublished thesis, Kingston University, London, UK (1996) 53-88.
- [3] Gant, S. E. (2006) 'CFD Modelling of Water Spray Barriers', HSL (79), Harpur Hill, Buxton Derbyshire, SK17 9JN. UK.
- [4] St. George, M. and Buchlin, J. M. (1994) 'Detailed single spray experimental measurements and one-dimensional modelling', *Int. J. Multiphase flow*, (20), pp.979-992.
- [5] BETE TF6 nozzles, data sheet (2007), available information on <http://www.beteuk.com>

- [6] Lim, E. W. C. et al. (2008) 'Experimental and computational studies of liquid aerosol evaporation', *Aerosol Science*, (39), pp. 618 – 634.
- [7] ANSYS 12.1 and 13.0 CFX-Solver Manager User's Guide, (2010).
- [8] Tambur, Y. and Gueta, S., "Optimizing the design and operation of the sprays in the tower", Unpublished report, Faculty of Aerospace engineering, Technion-Israel Institute of Technology, Appendix B., Israel. (2006), (Private communication).

# Improving Cooling Performance by Modification of Spray Nozzle on 10 kW Absorption Chiller Model

Hariyotejo Pujowidodo<sup>a</sup>, Bhakti Nuryadin<sup>b</sup> and Himawan Sutriyanto<sup>c</sup>

*The Centre for Thermodynamics Engine Propulsion Puspiptek Serpong Banten Indonesia 15314*

*<sup>a</sup> [h\\_pujowidodo@yahoo.co.id](mailto:h_pujowidodo@yahoo.co.id), <sup>b</sup> [adin\\_mail@yahoo.com](mailto:adin_mail@yahoo.com), <sup>c</sup> [him2002s@yahoo.com](mailto:him2002s@yahoo.com)*

## ABSTRACT

Absorption Chiller is a refrigeration system for generating chilled water that makes use thermal energy (heat) to evaporate water refrigerant from LiBr Solution in a heat exchanger called generator. The water vapor is then condensed and the condensate is sent to evaporator as refrigerant. There is a component named absorber that has the functions of absorbing exhaust water vapor from evaporator and transferring the absorbed water to separation process in generator. The cooling performance of evaporator is determined by evaporation water temperature which depends on the absorption process performance. In this paper, the study of spray nozzle modification on 10 kW Chiller model to improve the cooling performance would be presented. The results give that evaporation temperature could reach until 4 degree Celcius and COP at instantaneous load is better than previous type of absorbent spray droplets.

## Keywords

*Absorption chiller, refrigerant, evaporation, absorption, cooling performance*

## 1. INTRODUCTION

Absorption chiller is a refrigeration system for generating chilled water by utilizing a heat source and an absorption process of the refrigerant by a particular solution. Although this type of chiller has lower coefficient of performance but it provides advantages over vapor compression system by reducing electrical energy consumption and using environmentally friendly refrigerants. It is therefore important for the absorption chiller to be developed to assist the national program of energy security and environmental sustainability.

Basically, the process of absorption refrigeration cycle is similar to that of vapor compression system. The most common absorption chiller systems are water-lithium bromide and ammonia-water, with water and ammonia respectively the refrigerant for each system. In the absorption refrigeration cycle, the compression step is accomplished by the use of absorber, pump, and generator. Exhaust vapor from evaporator is absorbed by LiBr solution in absorber. The diluted solution is then pumped from lower pressure chamber (absorber) to higher pressure chamber (generator). The water is then partly separated from LiBr solution by applying heat in the generator. The heat source can be derived from steam, hot water or the residual heat of combustion with low temperatures ranging from 80 °C. Refrigerant vapor from generator is then cooled in condenser to provide condensate of liquid refrigerant which can be re-circulated to the evaporator.

Thermodynamic cycle of the absorption refrigeration process is shown through pressure, temperature and concentration diagram, known as Duhring Plot [3]. In the diagram, there is a crystallization line or saturation line, which should be considered in the design process so that concentration does not exceed the saturated condition. Working temperature and concentration determine the operating pressure of refrigerant evaporation (desorption) in the generator and condensation in the condenser. To increase overall system efficiency, the heat of hot strong LiBr solution from generator is transferred to cold weak solution from absorber in a heat exchanger. Thus the heating load of the generator and cooling load of the absorber can be reduced simultaneously.

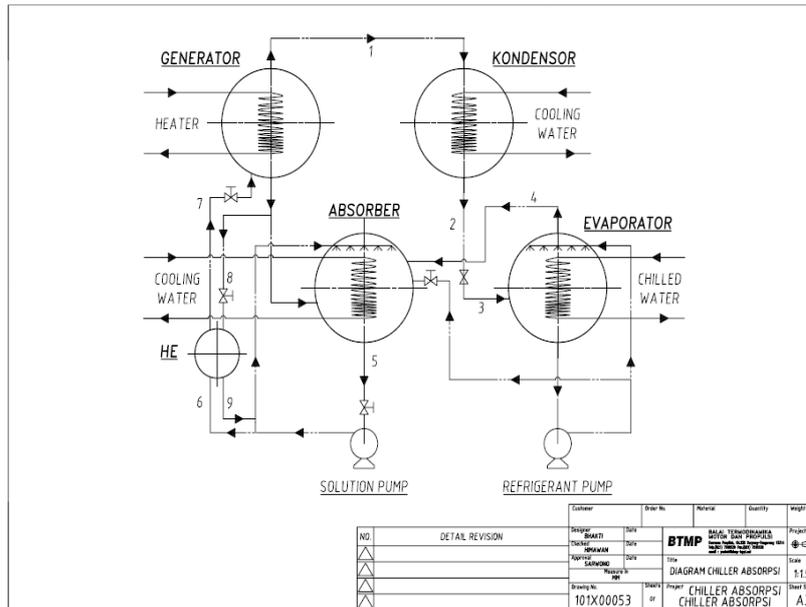


Figure 1. Basic Process of Single Effect Absorption Chiller 10 kW Model [Sutriyanto H.et.al, 2010]

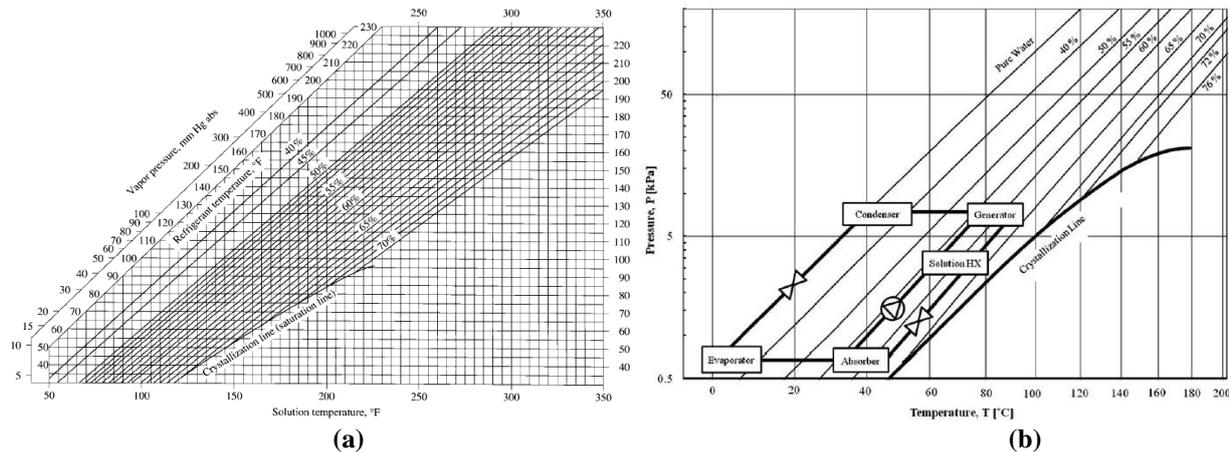


Figure 2. Duhring Plot Diagram for Lithium Bromide Solution (LiBr)

(a) PTX Solution Properties Diagram [Wang SK.,2000]

(b) Thermodynamics Cycle[Wang X. et.al, 2009]

Based on the validation studies on 10 kW absorption chiller model in BTMP [1,2], it has been concluded that modification on the model is required to improve the absorption process in absorber and refrigerant distribution in evaporator. Heat and mass transfer between refrigerant and absorbent occurs through direct contact mechanism on the droplet surface circulated [2]. Furthermore, in this study, chiller performance will be assessed by modifying the spray nozzle that can provide extensive contacts in the absorber and better refrigerant distribution in the evaporator.

## 2. METHODOLOGY

### 2.1. Overview Design and Validation Test [1,2]

Absorption chiller 10 kW cooling capacity system model has modular design consisting of 4 main equipments i.e. generator, condenser, evaporator, and absorber. The unit model is equipped with supporting facilities for testing which include heating fluid supply simulator, cooling water supply and dummy cooling load.

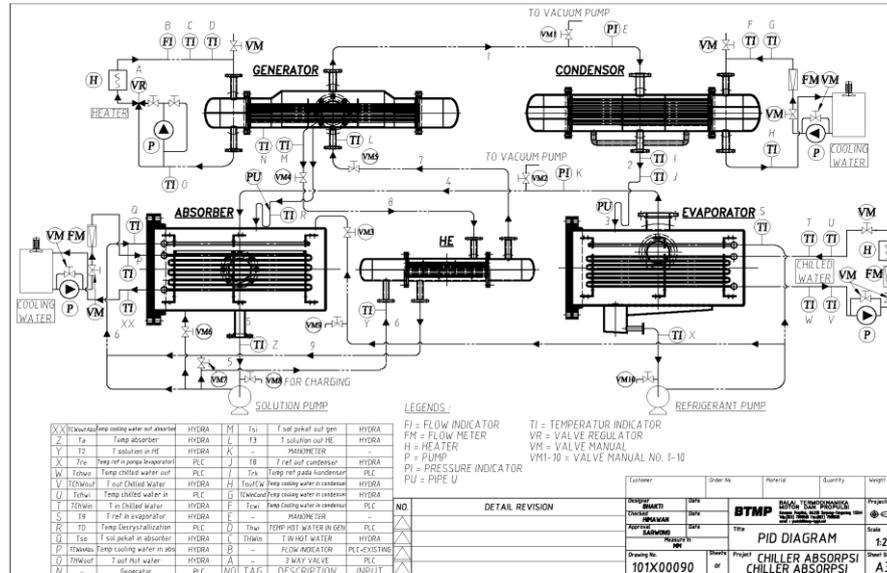


Figure 3. Process Diagram Chiller Absorption Model 10 kW [Sutriyanto H.et.al, 2010]

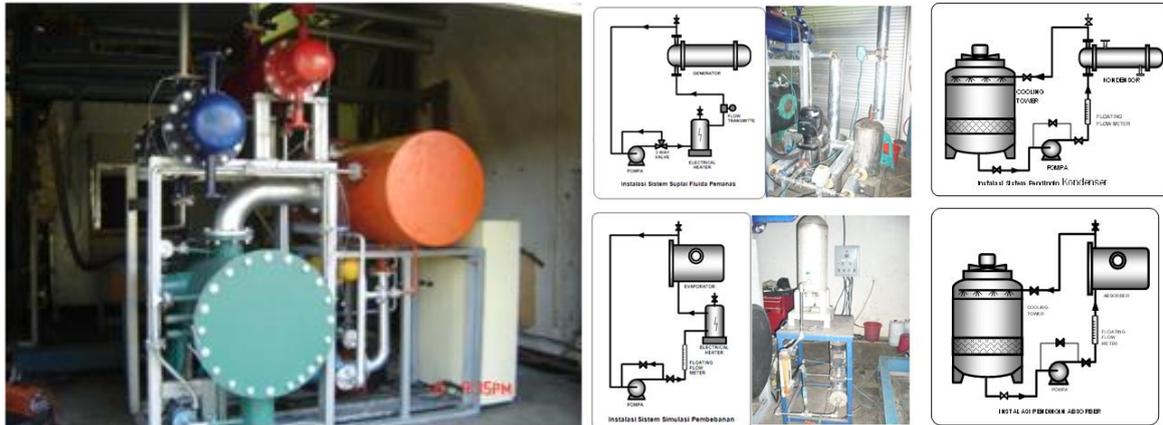


Figure 4. Unit and Supporting Facilities of Chiller Absorption Model 10 kW  
 (a) Model Unit (b) Utility Facilities for Heat Source, Cooling Water & Dummy Load

## 2.2. Modification Spray Nozzle at Absorber and Evaporator

The process of heat and mass transfer in the absorber occurs through direct contact mechanism between refrigerant vapor and LiBr solution droplets. Dimensions and distribution of droplets largely determine the effectiveness of the absorption process of the vapor to the liquid phase. Thus to optimize the process, the chiller model was modified with a spray nozzle system that has the ability to produce smaller particle size and more widely spread.

The previous design of the evaporator had poor distribution of refrigerant spray on the tube bundle. The use of spray nozzle provide better distribution, however smaller particle size can cause a problem of refrigerant spraying droplet evaporation. The vapor will add the absorption load that must be handled by the absorber.

## 2.3. Cooling Performance Evaluation

The effect of the nozzle spray modification will be studied by conducting test run on absorption chiller model. The test results will be compared to that of previous spray system. The parameters to be validated are temperature chilled water out evaporator before and after the modification at the same cooling loads.

## 3. RESULT & DISCUSSION

### 3.1. Study Design and Results Validation [1,2]

Absorption Chiller 10 kW Model is a single effect type of small-scale absorption chiller which has modular component configuration and requires a solution of lithium bromide-water (LiBr) with a concentration of 51-55% (mass fraction). Operating pressures for generator is around 7.721 kPa (related to saturated water temperature at 39.9 °C), while in the

evaporator pressure evaporation at 0.872 kPa (related to saturated liquid water temperature at 5 °C). The 10 kW cooling capacity is planned to be able to cool the incoming water temperature from 12 °C to 8 °C.

The test run on model before modification results in performance of lowest achieved chilled water temperature of 11.49 °C averaged without cooling load while the average evaporation temperature is reached only by 7 °C. Based on that results and visual observation in connection with spray setting during test run, the validation study has concluded that the model needs modification to reduce droplet dimension of LiBr-solution sprays in absorber and to improve refrigerant spray pattern in evaporator.

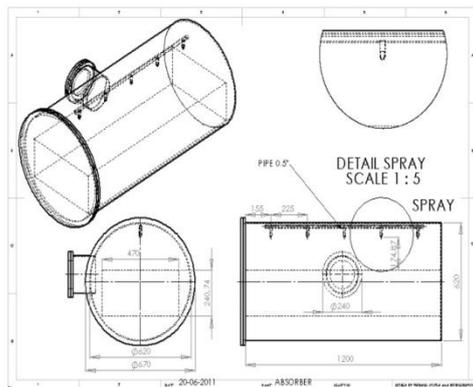
### 3.2. Modification and Functional Test Spray Nozzle

Heat and mass transfer processes in absorber occur on the surface of the LiBr-solution droplets. When the droplets in contact with refrigerant vapor, then the solution will absorb the water vapor to make the absorbent diluted. Although the vapor temperature is lower than droplets temperature, the heat brought by the vapor makes dilute solution temperature will increase. Therefore for continuous operation, the heat must be removed from the absorber by cooling system.

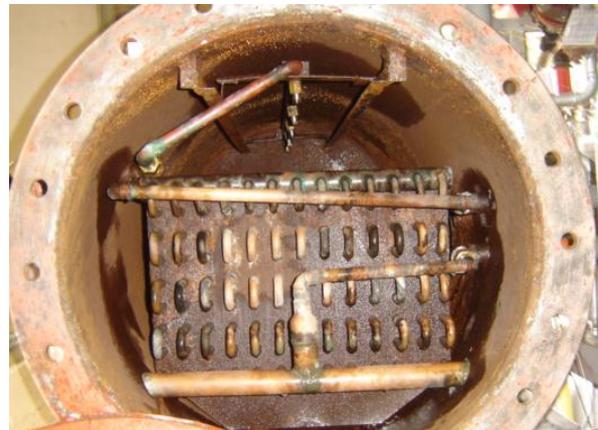
The transfer processes between vapor and absorbent droplets are affected by several parameters including LiBr concentration in the droplets, droplets temperature, and contact surface area between the two phases. The higher LiBr concentration the stronger the absorption power is. However, the concentration must be controlled so that it does not exceed its saturation point. Since the process is exothermic then the lower droplet temperature is better. However, the cooling water temperature will limit this parameter. The transfer processes occur on the droplets surface. The larger the area, the probability of the absorption process will increase. Since, total contact surface area depends on the average droplet diameter for a particular flowrate, the increasing contact surface area can be achieved by application of spraying nozzle that can give smaller droplets diameter.

The problem of previous configuration of the evaporator is that the distribution of spray does not spread evenly. This brings partly unwetted tube bundle so that no heat transfer occurs on that part. Improving method being chosen in this case is the use of spray nozzle. For that reason, full cone and wide spread angle spray nozzle was installed to replace previous spraying system in evaporator.

Commercial nozzle spray is specified by its spray pattern, spray angle, volumetric flowrate at a particular pressure drop available, connection diameter. Since, the use of spray nozzle is a part of modification of the existing unit, their requirements is limited by tube bundle size, maximum available distance between nozzle and tube bundle, and estimated fluid flowrate. Therefore, nozzle configuration used is a full cone type with a diameter of 2.4 and 3.2 mm, spray angle of 80° and 75°, ¼ in and 3/8 in connection for evaporator and absorber respectively. The number of spray nozzle required is 5 units for the absorber and 4 units for the evaporator.

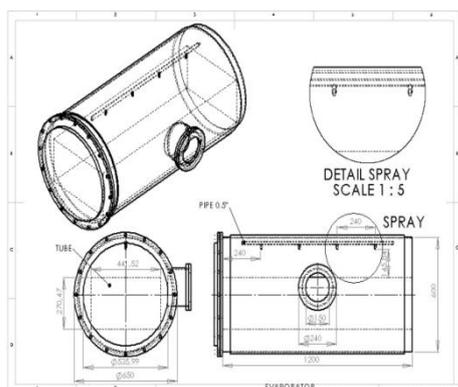


(a)



(b)

Figure 5. Absorber after Modification Technical Drawing (a) Spraying Nozzle Configuration(b) [5]



(a) (b)  
 Figure 6. Evaporator after Modification Technical Drawing (a) Spraying Nozzle Configuration (b) [5]

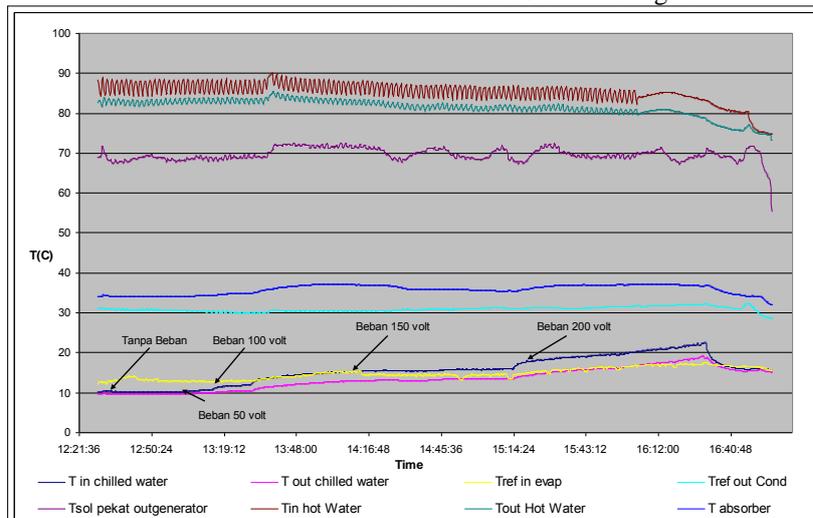
Before performing the test run of the modified chiller unit, spray nozzles are functionally tested to observe the size of the droplets and spray distribution capabilities. The results are shown in the following figure, and the spray nozzle configuration was able to produce granular and extensively better contact.



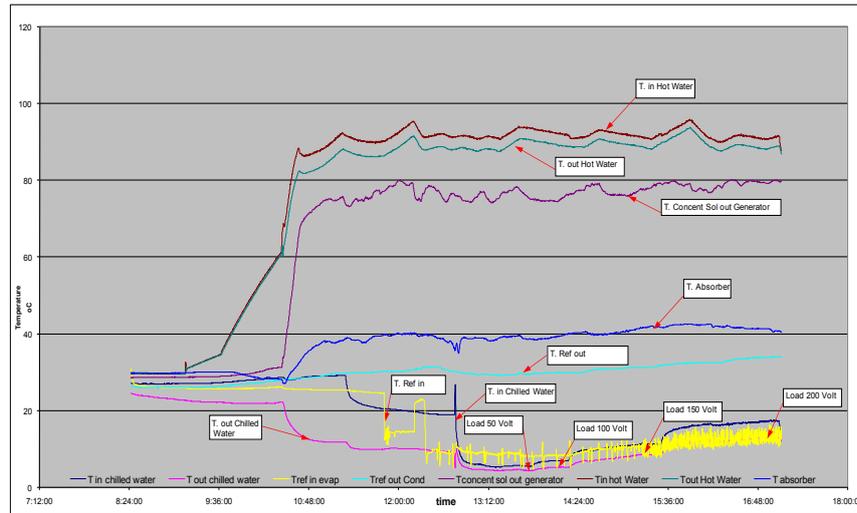
(a) (b)  
 Figure 7. Functional Test Nozzle Spraying in Absorber (a) and in Evaporator (b) [6]

### 3.3. Cooling Performance Evaluation

To evaluate chiller modification, test runs are conducted on 10 kW absorption chiller models by measuring the temperature of chilled water out. Based on the results obtained in the previous test run before chiller modification, the temperature of the chilled water out only reached 11.49 °C without load (design point 8 °C) [1,2]. After modification, the temperature of the chilled water out could have reached 4.32 °C at 2.28 kW cooling load.



(a)



(b)  
**ABSORPTION CHILLER TESTING**

Waktu	Siklus Refrigeran									Cooling Water Abs			
	Ts in	Ts out	Tsp in	Tsp out	T De	Tro Con	Tri Ev	Ta	Tro Gen	Fco-Abs	Ti	To	QCWAb
	°C	°C	°C	°C	°C	°C	°C	°C	°C	L/s	°C	°C	g/W
13:47:53	39,09	49,70	75,03	39,11	1,32	29,50	5,29	38,49	66,26	0,80	26,86	29,58	9,42
13:47:45	39,09	49,70	75,03	39,21	1,32	29,50	5,29	38,49	66,26	0,80	26,86	29,58	9,09
13:47:37	39,09	49,60	75,13	39,11	1,32	29,50	4,79	38,49	66,38	0,80	26,86	29,58	9,09
13:47:29	38,99	49,70	75,23	39,21	1,33	29,50	5,19	38,49	66,45	0,80	26,86	29,58	9,09
13:47:21	38,99	49,70	75,23	39,11	1,33	29,50	5,99	38,49	66,45	0,80	26,86	29,58	9,09
13:47:14	38,99	49,70	75,23	39,11	1,32	29,50	7,88	38,49	66,45	0,80	26,76	29,58	9,42
13:47:06	38,99	49,70	75,13	39,11	1,31	29,50	8,98	38,49	66,37	0,80	26,76	29,58	9,42
13:46:58	38,99	49,70	75,03	39,11	1,31	29,50	9,18	38,49	66,27	0,80	26,76	29,58	9,42
13:46:50	38,99	49,70	75,13	39,11	1,31	29,50	7,98	38,49	66,37	0,80	26,76	29,58	9,42
13:46:43	38,99	49,70	75,13	39,11	1,31	29,50	7,88	38,49	66,37	0,80	26,76	29,58	9,42
Rata-rata:	39,02	49,69	75,13	39,13	1,32	29,50	6,77	38,49	66,36	0,80	26,81	29,59	9,29

Waktu	Hot Water			Cooling Water Cond				Chilled Water				COP	
	Fco	Ti	To	QCWC	FcoCond	Ti	To	Qw.ch	Fch	Ti	To		Qw.ch
	L/s	°C	°C	g/W	L/s	°C	°C	g/W	L/s	°C	°C	g/W	
13:47:53	0,67	93,45	90,37	8,35	0,80	27,85	28,74	2,98	0,50	5,66	4,27	2,91	0,35
13:47:45	0,67	93,55	90,37	8,62	0,80	27,95	28,74	2,65	0,50	5,56	4,27	2,70	0,31
13:47:37	0,67	93,65	90,37	8,89	0,80	27,85	28,65	2,65	0,50	5,46	4,27	2,49	0,26
13:47:29	0,67	93,55	90,37	8,62	0,80	27,85	28,65	2,65	0,50	5,36	4,27	2,28	0,26
13:47:21	0,67	93,65	90,37	8,89	0,80	27,85	28,65	2,65	0,50	5,36	4,27	2,28	0,26
13:47:14	0,67	93,65	90,37	8,89	0,80	27,85	28,74	2,98	0,50	5,26	4,37	1,86	0,21
13:47:06	0,67	93,45	90,37	8,35	0,80	27,85	28,65	2,65	0,50	5,36	4,37	2,07	0,25
13:46:58	0,67	93,55	90,37	8,62	0,80	27,85	28,65	2,65	0,50	5,36	4,37	2,07	0,24
13:46:50	0,67	93,75	90,47	8,89	0,80	27,85	28,74	2,98	0,50	5,36	4,37	2,07	0,23
13:46:43	0,67	93,55	90,47	8,35	0,80	27,85	28,65	2,65	0,50	5,36	4,37	2,07	0,25
Rata-rata:	0,67	93,58	90,39	8,65	0,80	27,86	28,68	2,75	0,50	5,41	4,32	2,28	0,26

Beban 50 Volt  
 @4.32°C ±2.28 kW;  
 COP=0.26

test 14\_6\_12  
 Flow Hot Water : 0,67 L/s 0,65387  
 Flow Chilled Water : 0,5 L/s 0,4773  
 Flow Cooling Water Cond : 0,8 L/s 0,4197  
 Flow Cooling Water Abs : 0,8 L/s 0,56854

Figure 8. Temperature of chilled water out [6] (a) Before Modification (b) After Modification (c) data acquisition

**4. CONCLUSION**

There is a significant difference in the temperature of chilled water out after extensive modifications to the spraying system in absorber and evaporator of the 10 kW absorption chiller model unit. Modified spray nozzle can increase the cooling capacity with the temperature of chilled water out can reaches until 4.32 °C in conditions amounting to 2.28 kW cooling load. The modification to increase contact surface area in the absorber and to distribute the refrigerant spray evenly in the evaporator has improved overall chiller performance.

**ACKNOWLEDGEMENT**

We gratefully thank to the Agency for Assessment and Application of Technology (BPP Teknologi) for the budgeting of this project through the Centre for Thermodynamics Motor and Propulsion (BTMP), at Puspiptek Serpong South Tangerang Banten.

**REFERENCES**

- [1.] Sarwono, Maswan A., Sutriyanto H., *Uji Validasi Desain Small Single-Effect Absorption Chiller 10 kW*, Proceeding Seminar Nasional Thermofluid Jurusan Teknik Mesin dan Industri Universitas Gajah Mada, 2010, pp. 202-205.
- [2.] Sutriyanto H., Sarwono, Prawoto, *Pengembangan Small Single-Effek Absorption Chiller Dengan Daya Pendinginan 10 kW*, Proceeding Seminar Nasional Thermofluid Jurusan Teknik Mesin dan Industri Universitas Gajah Mada, 2010, pp. 196-201.
- [3.] Wang Shan K., *Handbook of Air Conditioning and Refrigeration*, McGraw-Hill, 2000, ed. 2, pp: 14.1-14.26.
- [4.] Wang X., Chua H.T., *Absorption Cooling: A Review of Lithium Bromide-Water Chiller Technologies*, Bentham Science Publishers Ltd., Recent Patents on Mechanical Engineering, 2009, ed. 2, pp 193-213.
- [5.] WBS-2 Pengujian dan Modifikasi, *Technical Document*, Rancang Bangun Generator Kondensor Chiller Absorpsi, BTMP, 2011.
- [6.] WP-1 Pengujian dan Modifikasi, *Working Sheet*, Rancang Bangun Evaporator Absorber Chiller Absorpsi, BTMP, 2012.

# Experimental Study of Liquid-Vapor Mass Flow Rate Ratio of LPG Through Swirling Nozzle with Variation of Swirling's Chamber Volume

I Made Kartika Dhiputra, Harnaldi, Setya Wijayanta.

Flame & Combustion Research Group, Thermodynamic Laboratory  
Mechanical Engineering Department, Universitas Indonesia  
Kampus UI Depok, Indonesia 16424  
Phone +62 21 7270032, +62 21 7864089, Fax +62 21 7270033  
Email: dhiputra\_made@yahoo.com

## ABSTRACT

The ratio of the liquid-vapor flow rate through the swirling nozzle with a swirl's chamber volume variation is investigated experimentally. The application of swirling nozzle is to vaporized liquid state of Liquefied Petroleum Gas (LPG) in order to prevent the liquid flow into regulator or gas stove which potentially become explosive (BLEVE). The results show that there is a significant relationship between the swirl volume with the liquid-vapor mass flow rate ratio of LPG through the swirling nozzle. By increasing the swirl's chamber volume intend to increase the liquid-vapor mass flow rate ratio of LPG. To increase the percentage of the vapor flow rate through the swirling nozzle, by adjusting swirling nozzle to the smallest swirl's chamber volume, 13 022 mm<sup>3</sup>. The phase of LPG before entry to swirling nozzle is 100 % liquid when the bottle of LPG turned until 90° to the horizontal, and the estimation results of the percentage vapor flow rate after swirling nozzle can be achieved by 50 % to 72.63 % if the flow rate of LPG regulated 0.016 liter /s to 0.025 liters / s.

## Keywords

Ratio of liquid-vapor LPG flow rate, Swirling nozzle, Swirling chamber.

---

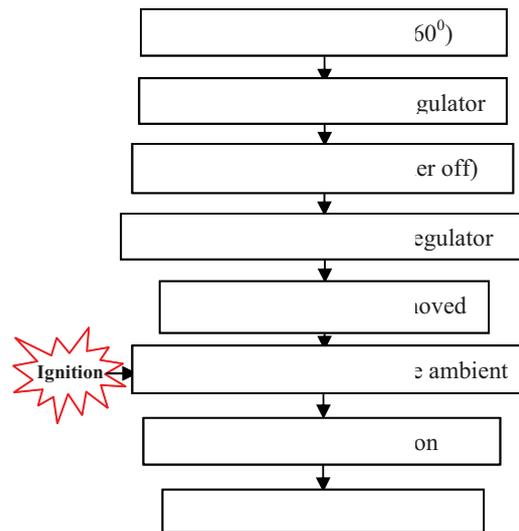
## 1. INTRODUCTION

Accidents caused by fire is a terrible disaster which so often made headlines in the media because it caused a lot of material loss and even death. For example, in Jakarta, electric and stove fires is a major cause for the household. Over the past 10 years there have been over 800 fires each year, or about 2 to 3 times per day fires, with casualties reached 27 people died and losses directly reaches a value of Rp 250 billion each year [1].

Related with the number of explosion cases, especially in the use of LPG gas stoves, some efforts to reduce the risk of explosion or increase security for users of gas (LPG) has been carried out, such as: the socialization of the use of gas stove at the time of the distribution of 3 Kg LPG cylinders and gas stoves to the community and the issuance of Indonesian National Standard (SNI) to ensure the quality of hardware and software: Steel Bottle (ISO 1452-2007), Valve of Bottle (ISO 1591-2008), Rubber seals (ISO 7655-2010), Low Pressure Regulator (SNI 7369 -2008), High pressure regulators (ISO 7618-2010), Rubber Hose (SNI 06-7213-2006), fuel LPG gas stove with a fireplace lighter mechanical systems (ISO 7368-2007).

Practically in field shows that efforts to reduce the risk of explosion and ensure the safety of users of LPG gas stove is still far from expectations. Until now, still an accident by the explosion of LPG as a result of low gas stove users' understanding of the design, construction, operation and maintenance of system hardware burner LPG (cylinder, regulator, hose and stove) and of the hardware and the software itself is apparently not able to ensure the safety of LPG explosion risk. It is shown from the results of field surveys and investigations conducted by the Indonesian Consumers Foundation (YLKI) delivered by the Chairman (YLKI) Sincere Eternal that states, 70% of cases of LPG gas explosion from a gas stove accessories that do not meet the standards and 30% due to consumer behavior [2].

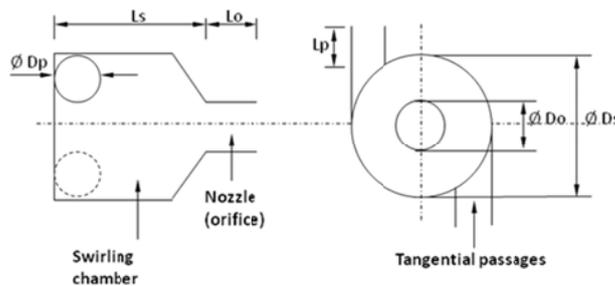
In the initial experiments in this study found that when 3 kg LPG tank toppled or tilted position more than 60 degrees from the upright / vertical and in a state of flow of LPG there will be started a flow of liquid phase's LPG to the Regulator. LPG liquid flow resulted in increased pressure on regulators thus causing the Lock Up (steel ball at the outlet of the regulator lock/close the flow of LPG). This causes the flame at the burner goes out, while the LPG liquid trapped inside the channel entrance and the room beneath the membrane on the regulator, so it may not exit and re-entry again into the tube. This phenomenon is rarely recognized by the users of LPG gas stove so that when the regulator is opened or removed from the valve tank, there will be a blast of liquid LPG from the inlet regulator that is potentially cause an explosion (cloud vapor explosion) if there is a heat source nearby. In the schematic, the sequence of explosion due to the potential overthrow of LPG tank can be described as follows:



**Figure 1.** The occurrence of sequence Potential Explosion Due to the slope of LPG > 60°

Potential for explosion due to the flow and trapping of liquid LPG in LPG regulators when cylinder rolled or tilted not recognized by the public users LPG gas stoves. Therefore, it is necessary to do an experimental study in order to prevent the LPG liquid's flow through regulator. Efforts to prevent the flow of liquid LPG can be done by changing the flow phase's of LPG liquid into a vapor phase's of LPG using a swirling nozzle as an atomizer. This study aims to determine the ratio of liquid-vapor flow rate through the nozzle if a swirling chamber volume variations

Often referred to as the swirling Nozzle Pressure or Pressure Swirl Nozzle atomizer serves to break the liquid into droplets form (small droplets). Nozzle swirling commonly found in many engineering applications such as in burning, drying or agriculture [3]. Figure 4. shows the basic scheme swirling Nozzle. The liquid is fed into the swirling chamber through a tangential line to give liquids with a high angular velocity, and formed a layer of fluid with the internal surface of free-floating in the swirling chamber, giving rise to the vortex core. The liquid is then removed from the nozzle in the form of a hollow conical sheet which breaks up into droplets (small droplets) [4].



**Figure 2.** Basic Scheme of Swirling Nozzle

Ls : min 0.5 mm, Lp : 0.34 mm, Lo : 0.6 mm Ds:5.76 mm, Dp : 0.51 mm, Do:1 mm

Research related to the thickness of the coating fluid produced swirling nozzle has been done by Han, Allocca, Aziz and Ali, and Khoo and Hargrave which showed that the liquid layer thickness decreases with increasing injection pressure, nozzle hole diameter shrink, adding to the length of the orifice, enlarging the diameter swirling chamber and shorten the length of swirling chamber [5].

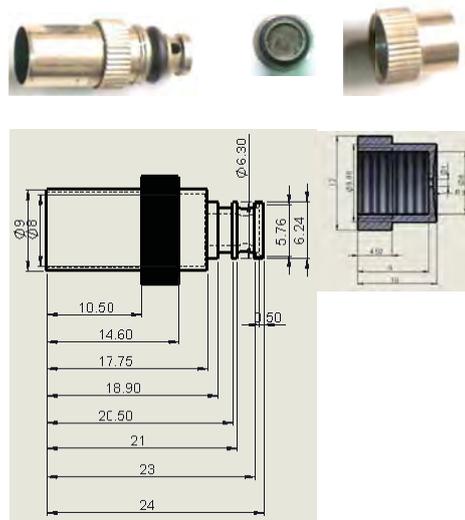
## 2. EXPERIMENTAL METHOD

The research based an experimental method and Research was done at Thermodynamic Laboratory conducted the Flame & Combustion Group at Department of Mechanical Engineering Universitas Indonesia. Experimental study of fluid mass flow rate ratio of LPG through the swirling nozzle atomizer with a swirling chamber volume variation is done with a slope angle

from the vertical bottle of LPG 90° to get 100 % liquid's phase of LPG out from the bottle of LPG. The experiment consisted of 4 stages:

- Measurement of mass flow rate ratio of LPG liquid-vapor through a nozzle with a swirling chamber volume of 13.022 mm<sup>3</sup>, variations in flow rate of LPG (0016, 0018, 0022 and 0025 Liter / second)
- Measurement of mass flow rate ratio of LPG liquid-vapor through a nozzle with a swirling chamber volume of 13.465 mm<sup>3</sup>, variations in flow rate of LPG (0016, 0018, 0022 and 0025 Liter / second)
- Measurement of mass flow rate ratio of LPG liquid-vapor through a nozzle with a swirling chamber volume of 13.882 mm<sup>3</sup>, variations in flow rate of LPG (0016, 0018, 0022 and 0025 Liter / second)
- Measurement of mass flow rate ratio of LPG liquid-vapor through a nozzle with a swirling chamber volume of 14.324 mm<sup>3</sup>, variations in flow rate of LPG (0016, 0018, 0022 and 0025 Liter / sec).

The dimensions of swirling nozzles which used in this study can be seen in figure 3 below:



**Figure 3.** Swirling Nozzle dimesion

Swirling chamber volume of swirling nozzle which used in this study can be varied by adjusting the length of swirling chamber.

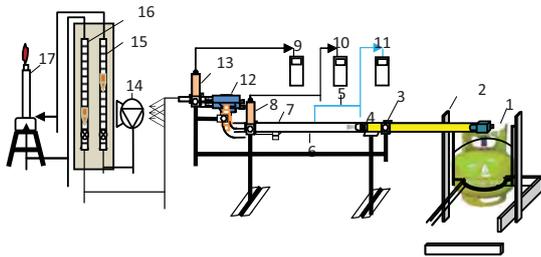


Figure 4. Installation Testing Scheme

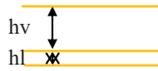


Installation testing scheme can be described as follows:

- a. Measurement of liquid-vapor mass flow rate ratio of LPG through a swirling nozzle with a swirling chamber volume 13.022 mm<sup>3</sup>
    - 1) Valve / valve on the fuel and air rotameter fully closed, while the stop valve is opened fully.
    - 2) In the LPG cylinders upright position (0° tilt from vertical position), LPG vapor flowed into the acrylic tube and pressure transducer.
    - 3) In the waiting about 15 minutes until the steam pressure readings on vapor pressure meters and temperature on the thermometer and record the results are stable
    - 4) Valves / fuel valve on the rotameter was opened just enough to drain the LPG to the burner and the flame ignited by lighters.
    - 5) The flow rate of LPG is set on a scale of 1 cm or equal to 0.016 liter / sec.
    - 6) The valve / air valve on the rotameter is set to obtain a stable flame.
    - 7) tank rotated so that the exact slope at position 90° of upright/vertical in its holder
    - 8) The height of the liquid LPG in the acrylic pipe was measured with a ruler and recorded in the first minute and the fifth to take an average.
    - 9) Play the LPG back to an upright position
    - 10) Close the stop valve and wait until the LPG in the acrylic pipe and fire up the burner goes out.
  - 10) Step 1) to 10) is repeated (with changes in flow rate of LPG in step 5)) respectively for 3 times repetition in accordance with the variation of the flow rate of LPG in step 5) (0018, 0022 and 0025 Liter / s)
  - b. Measurement of liquid-vapor mass flow rate ratio of LPG through a swirling nozzle next to the swirling chamber volume 13.465 mm<sup>3</sup>, 13.882 mm<sup>3</sup> and 14.324 mm<sup>3</sup>, performed with the same steps as above (step 1 to 11)
- The liquid-vapor mass flow rate ratio of LPG through the swirling nozzle which is calculated from the ratio of the volume of the liquid-vapor flows in the acrylic pipe installed after swirling nozzle.

$$= \frac{\text{Volume of LPG Liquid in Pipe}}{\text{Volume of LPG Vapor in Pipe}}$$

The volume of liquid and vapor LPG in the acrylic pipe can be calculated from the results of measurements of the radius of the pipe and high liquid LPG in the acrylic pipe. The formula for calculating the volume of liquid LPG in the acrylic pipe can be described as follows:



hv = height of vapor  
 hl = height of liquid



Figure 5. Image of height of LPG liquid and vapor in Acrylic Pipe

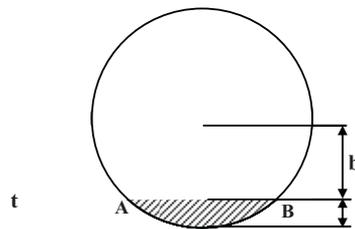


Figure 6. In Cross Section Pipes Acrylic

Description:

- $\alpha$  = angle pie
- r = radius of pipe
- t = height of liquid LPG

And then the volume of LPG liquid in the acrylic pipe can be calculated .

To calculate the cross-sectional area of fluid or shaded area in the cross-sectional images of the acrylic pipe with a height above the liquid is less than or equal to the radius of the pipe, earthenware widely used formula as follows [6]:

= Pie Area AOB - Triangle Area AOB

$$= \left( \frac{\alpha}{360^\circ} \pi r^2 \right) - \left( \frac{1}{2} \sin(\alpha) r^2 \right)$$

pie angle ( $\alpha$ ) is calculated using the following formula:

$$\alpha = 2 \arcsin \frac{r-t}{r}$$

Meanwhile, to calculate the cross-sectional area of fluid with a high fluid greater than the radius of the pipe, use the formula:

= cross-section area of pipe – vapor cross-section area

Vapor sectional area calculated by the formula above potsherd, with a value of t is a high vapor (pipe diameter – high of liquid).

The volume of LPG vapor in the pipe is calculated by the formula:

= Pipe volume – LPG liquid volume in the pipe

Percentage of LPG vapor in the pipe is calculated by the formula:

$$= \frac{\text{pipe volume} - \text{LPG liquid volume in the pipe}}{\text{pipe volume}} \times 100\%$$

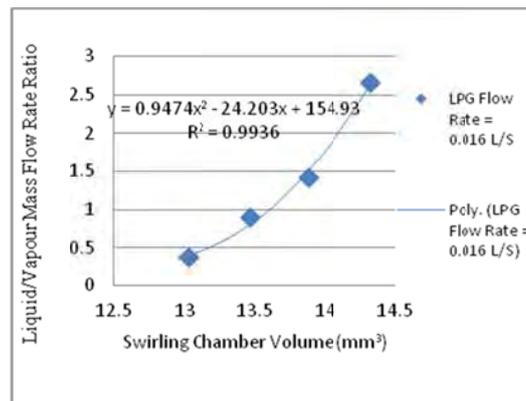
### 3. Result and Discussion

The measurement results can be seen in the following table:

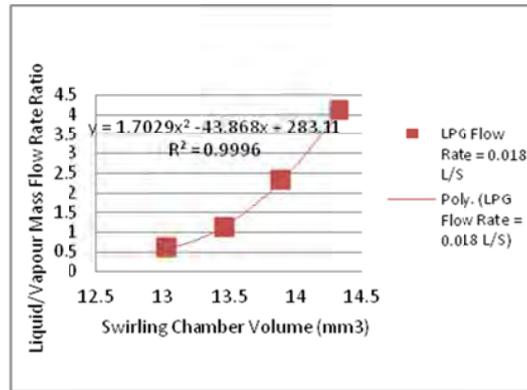
**Tabel.1**  
 Measurement result

LPG Flow Rate(L/s)	Swirling Chamber Volume(mm <sup>3</sup> )	Liquid-Vapor Rasio	Vapor Volume (%)
0.016	13.022	0.377	72.634
	13.465	0.891	52.893
	13.882	1.419	41.344
	14.324	2.654	27.366
0.018	13.022	0.626	61.514
	13.465	1.123	47.107
	13.882	2.324	30.086
	14.324	4.117	19.543
0.022	13.022	0.793	55.781
	13.465	1.598	38.486
	13.882	3.528	22.086
	14.324	5.805	14.695
0.025	13.022	1	50
	13.465	2.044	32.851
	13.882	4.856	17.076
	14.324	7.058	12.411

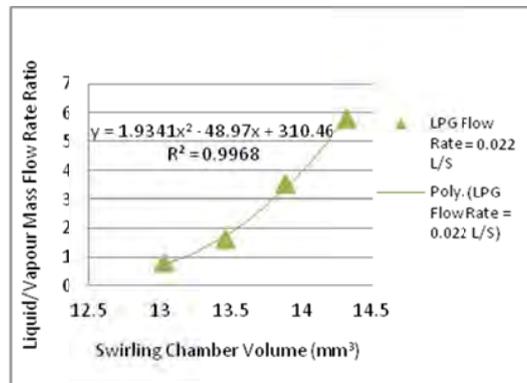
Relationship between swirling chamber volume variation with the liquid-vapor mass flow rate of LPG can be seen in the following graph:



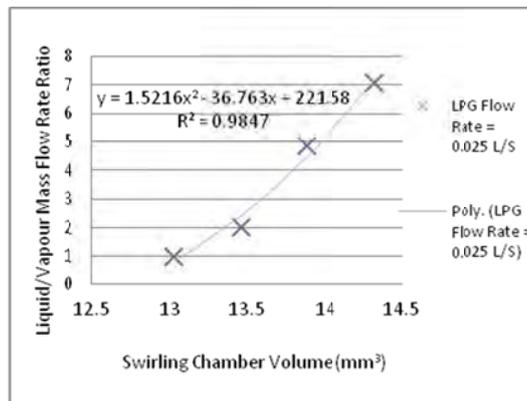
**Figure 7.** Relationship Between Swirling Chamber Volume with Liquid-Vapor Mass Flow Rate Ratio of LPG in 0.016 Liter / second



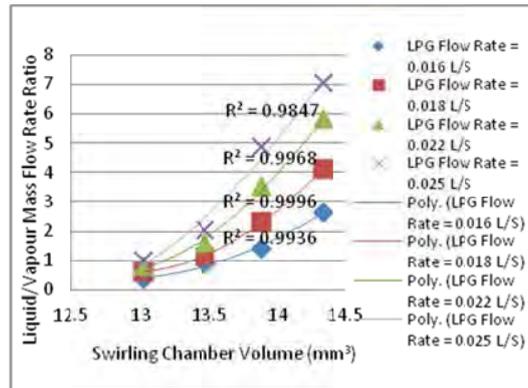
**Figure 8.** Relationship Between Swirling Chamber Volume with Liquid-Vapor Mass Flow Rate Ratio of LPG in 0.018 Liter / second



**Figure 9.** Relationship Between Swirling Chamber Volume with Liquid-Vapor Mass Flow Rate Ratio of LPG in 0.022 Liter / second



**Figure 10.** Relationship Between Swirling Chamber Volume with Liquid-Vapor Mass Flow Rate Ratio of LPG in 0.025 Liter / second

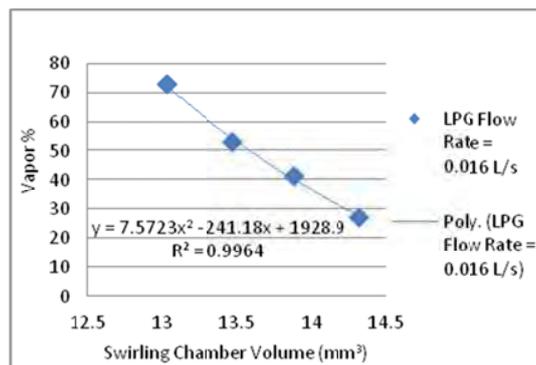


**Figure 11.** Relationship Between Swirling Chamber Volume with Liquid-Vapor Mass Flow Rate Ratio of LPG in 0.016, 0.018, 0.022 dan 0.025 Liter / second

From the graph above can be seen that, at a flow rate of LPG 0016 liters / second, the relationship between the swirling chamber volume with the liquid-Vapor mass flow rate ratio of LPG formed rank 2 polynomial regression equation:  $y = 0.9474x^2 - 154.9324.203x$  the value of  $R^2 = 0.9936$  or the correlation coefficient  $R = 0.9968$ . At LPG flow rate 0.018 liters / sec, the relationship between the swirling chamber volume with the liquid-Vapor mass flow rate ratio of LPG formed rank 2 polynomial regression equation:  $y = 1.7029x^2 - 43.868x + 283.11$  with  $R^2 = 0.9996$  value or correlation coefficient  $R = 0.999$ . At LPG flow rate 0.022 liters / sec, the relationship between the swirling chamber volume with the liquid-Vapor mass flow rate ratio of LPG formed rank 2 polynomial regression equation:  $y = 1.9341x^2 - 48.97x + 310.46$  with  $R^2 = 0.9968$  value or correlation coefficient  $R = 0.998$ . At LPG flow rate 0.025 liters / sec, the relationship between the swirling chamber volume with the liquid-Vapor mass flow rate ratio of LPG formed rank 2 polynomial regression equation:  $y = 1.5216x^2 - 36.763x + 221.58$  with  $R^2 = 0.9847$  value or correlation coefficient  $R = 0.992$ .

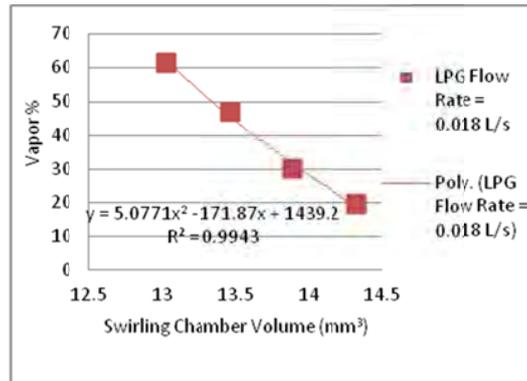
The value of correlation coefficient R on the graph the relationship between the swirling chamber volume with the liquid-Vapor mass flow rate ratio of 4 variations LPG flow rate (0.016, 0.018, 0.022 and 0.025 liters / sec) are all larger than the R product moment correlation table with significance level 5% and 1% respectively for 0.950 and 0.990 [15]. Thus it can be said that there is a significant relationship between the swirling chamber volume with the liquid-Vapor mass flow rate ratio of 4 variation of LPG flow rate (0.016, 0.018, 0.022 and 0.025 liters/sec). The greater the volume of swirling chamber, then the ratio of liquid-Vapor mass flow rate of LPG are also getting bigger. Conversely, the smaller the volume of swirling chamber, then the liquid-Vapor mass flow rate ratio of LPG are also getting smaller.

Meanwhile, the relationship between variations in the percentage volume of swirling chamber with Vapor flow rate of LPG can be seen in the following graph:

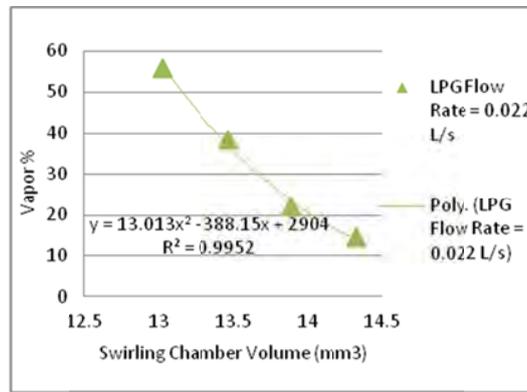


**Figure 12.** Relationship Between Swirling Chamber Volume with Vapor Flow Rate Percentage at Flow Rate of LPG 0016 L /

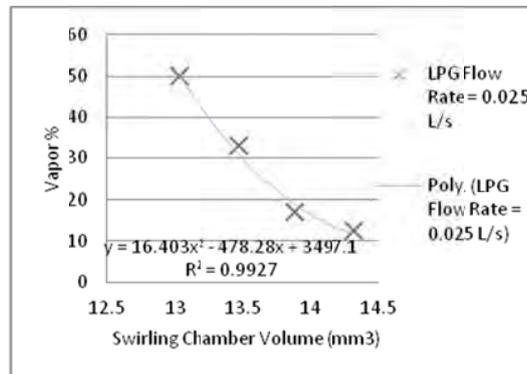
s



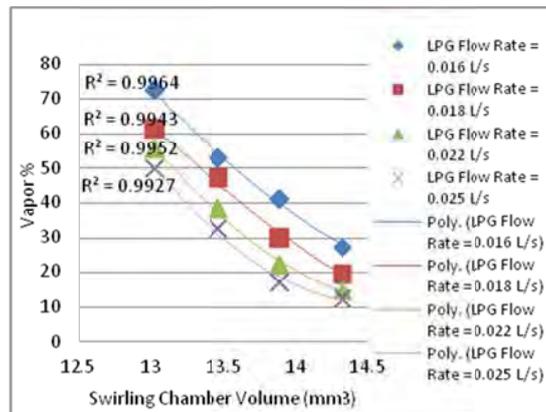
**Figure 13.** Relationship Between Swirling Chamber Volume with Vapor Flow Rate Percentage at Flow Rate of LPG 0.018 L/s



**Figure 14.** Relationship Between Swirling Chamber Volume with Vapor Flow Rate Percentage at Flow Rate of LPG 0.022 L/s



**Figure 15.** Relationship Between Swirling Chamber Volume with Vapor Flow Rate Percentage at Flow Rate of LPG 0.025 L/s



**Figure 16.** Relationship Between Swirling Chamber Volume with Vapor Flow Rate Percentage at Flow Rate of LPG 0.016, 0.018, 0.022 dan 0.025 L/s

From the graph above can be seen that, at a flow rate of LPG 0.016 liters / second, the relationship between the swirling chamber volume with percentage of LPG Vapor flow rate to form rank 2 polynomial regression equation:  $y = 7.5723x^2 - 241.18x + 1928.9$  with  $R^2 = 0.9964$  value or coefficient correlation  $R = 0.9982$ . At LPG flow rate 0.018 liters / sec, the relationship between the swirling chamber volume with percentage of LPG Vapor flow rate to form rank 2 polynomial regression equation:  $y = 5.0771x^2 - 171.87x + 1439.2$  with  $R^2 = 0.9943$  value or correlation coefficient  $R = 0.9971$ . In 0.022 LPG flow rate liters / sec, the relationship between the swirling chamber volume with percentage of LPG Vapor flow rate to form rank 2 polynomial regression equation:  $y = 13.013x^2 - 388.15x + 2904$  with a value of  $R^2 = 0.9952$  or correlation coefficient  $R = 0.9976$ . At LPG flow rate 0.025 liters / sec, the relationship between the swirling chamber volume with percentage of LPG Vapor flow rate to form rank 2 polynomial regression equation:  $y = 16.403x^2 - 478.28x + 3497.1$  with  $R^2 = 0.9927$  value or correlation coefficient  $R = 0.9963$ .

The value of correlation coefficient R on the figure/graph the relationship between the swirling chamber volume with percentage of LPG Vapor flow rate of 4 variations of LPG flow rate (0.016, 0.018, 0.022 and 0.025 liters/s) are all larger than the R product moment correlation table with a significance level of 5% and 1% respectively for 0950 and 0990 [7]. Thus it can be said that there is a significant relationship between swirling chamber volume and inversely proportional to the percentage of vapor flow rate at 4 variation of LPG flow rate (0.016, 0.018, 0.022 and 0.025 L/s). The larger the swirling chamber volume, the percentage of LPG vapor flow rate gets smaller. Conversely, the smaller the volume of swirling chamber, then the percentage of LPG vapor flow rate will be even greater.

#### 4. CONCLUSION

- There is a significant relationship between the volume ratio of swirling chamber with the liquid-Vapor flow rate at 4 variation of LPG flow rate (0.016, 0.018, 0.022 and 0.025 liters / sec). The greater the volume of swirling chamber, the bigger the ratio of liquid-Vapor flow rate of LPG through the regulator. Conversely, the smaller of the swirling chamber volume, the smaller the ratio of liquid-Vapor flow rate or better atomizing.
- There is a significant relationship between the percentage of vapor flow rate to the swirling volume chamber and the variations of flow rate LPG flow rate (0.016, 0.018, 0.022 and 0.025 liters / sec). The larger the swirling chamber volume, the percentage of LPG Vapor flow rate gets smaller. Conversely, the smaller the volume of swirling chamber, then the percentage of LPG Vapor flow rate will be even greater.
- The process of evaporation of a liquid to a Vapor of LPG due to swirling nozzle effect quite effective, where the minimum volume of swirling chamber, vapor quality can be achieved about 50% to 72.6%. Thus preventing the release of liquid LPG to the atmosphere or room air can be minimized in an effort to prevent fires and explosions caused by Vapor Cloud Explosion.

#### ACKNOWLEDGEMENT.

The authors greatly appreciate the financial support this work by Directorate of Research and Community Services of Universitas Indonesian (DRPM UI) under Research Grant – 2011 No. DRPM/RKBK-UI/2011/I/11151.

#### REFERENCE

- Listrik dan Kompom, Penyebab Kebakaran Utama Rumah Tangga. <http://KOMPAS.com> . Selasa, 6 Oktober 2009
- Mati Sia-Sia Karena Elpiji. Setidaknya 22 orang meninggal dunia dalam kasus ledakan elpiji selama program konversi. <http://vivanews.com>. Kamis, 8 Juli 2010

- [3]. Pedro Teixeira Lacava, Demétrio Bastos-Netto, Amílcar Porto Pimenta, *Design Procedure And Experimental Evaluation Of Pressure-Swirl Atomizers*, 24th International Congress Of The Aeronautical Sciences. Brazil. 2004
- [4]. Gino Boccardi, Roberto Bubbico, Gian Piero Celata, Barbara azzarotta, *Two-phase flow through pressure safety valve. Experimental investigation and model prediction*. Chemical Engineering Science. Elsevier. Science Direct. 2005
- [5]. Seoksu Moon, Essam Abo-Serie, Choongsik Bae. *Liquid film thickness inside the high pressure swirl injectors: Real scale measurement and evaluation of analytical equations*. Elsevier. Science Direct. Experimental Thermal and Fluid Science 34 (2010) 113–121
- [6]. Menghitung Luas Tembereng. <http://asimtot.wordpress.com/2010/05/24/luas-tembereng/>
- [7]. Sugiyono. *Statistik Untuk Penelitian*. Alfabeta. Bandung. 2003

## Low Speed Electric Machine Used for Electric Generating from Savonius Windmill

**YB. Lukiyanto**

*Mechanical Engineering, Faculty of Science and Technology,  
Sanata Dharma University, Yogyakarta, Indonesia, 55282  
E-mail : lukiyanto@usd.ac.id, ylukiyanto101@gmail.com*

### ABSTRACT

Savonius windmill having advantages very high starting torque and simple construction is applicable for Indonesia as a developing country with annual average wind speed 4,5 – 5,0 m/s. The purpose of the experiment is to identify characteristics of an electric machine used for low speed electric generator. The electric machine for the experiment is a permanent magnet electric motor usually used for electric bicycle. The electric motor is tested as an electric generator and rotated with variations of speed. Outputs of the generator are torque, voltage and current with 1) variation of lamps-load, 2) constant voltage-load for 12 volt and 24 volt battery charging and 3) combination of 12 volt battery charging and variation of lamps-load. The average efficiency of the generator is 59,8% and 65,4% for 12 volt and 24 volt battery charging. Battery charging starts at 95 rpm and maximum electric generating current is 20 Ampere at generator speed about 175 rpm.

### Keywords

*Savonius windmill, permanent magnet, electric generator*

This Paper is Published in Advanced Material Research Journal

# Optimization Design of Tandem Blade Rotor of Savonius Hydrokinetics Turbine Model

Bagus Wahyudi <sup>a</sup>, Slamet Wahyudi <sup>b</sup>, Sudjito Soeparman <sup>b</sup>

<sup>a</sup>Mechanical Engineering Dept. of State Polytechnic of Malang – INA.  
E-mail : baguspoliek@@gmail.com

<sup>b</sup>Faculty of Engineering University of Brawijaya, Malang 65145 – INA.  
Email: slamet\_w72@yahoo.co.id  
E-mail : sudjito\_spn@yahoo.com

## ABSTRACT

The energy performance of Tandem Blade Savonius (TBS) rotor was studied by CFD simulation within comparing pressure gap between upstream and downstream. These were three types of TBS: Overlap (Type I), symmetrically (Type II) and Convergence (Type III). Through a comprehensive study of pressure distribution in and around of rotor blade, it is possible to identify the power generation for each model, and to show that the optimum energy conversion is produced by convergence type of TBS (Type III). Furthermore, the convergence of TBS performance can be optimized by using Response Surface Method (RSM) through improved their partition space between blade and tandem. By using radius tandem blade (RTB) as variable of optimization, we obtain the optimum design of TBS geometrically which have good performance of new Savonius Rotor model

## Keywords

Optimization, RSM, CFD Simulation, Tandem Blade, Savonius.

## 1. INTRODUCTION

The effect of fast growing application of computational fluid dynamics (CFD) within the last two decades is the significance of numerical flow simulations in the design of hydraulic machinery that has grown to a considerable extent. At present, CFD simulations can often replace elaborate experiments due to the fact that even complex geometries and entire machines can be modeled. Separate numerical investigations for single turbo-machinery components has been common practice, yet these simulations are not referenced for interactions between the additional components which have strong influence on the operational behavior of the entire machine.

Many researches were conducted to demonstrate the influence of modified Savonius rotor blade geometry parameters such as twist blade, overlap ratio, amount of blade, multi-stage, sweep area, none circular blade, and additional guide blade on the aerodynamic performance of the rotor blade. However, the influence of geometrical design variables and their interactions on the rotor aerodynamic performance was not examined in detail in these works. From this point of view, the present research is focused on suggesting a rotor blade shape design using the numerical optimization method coupled with the statistical approach. Response surface method (RSM) is a collection of statistical and mathematical techniques useful for developing and improving the optimization process, which uses collectively design of experiment, regression analysis, and analysis of variance [1].

The Savonius hydrokinetic turbine is simple geometry and its construction is low-cost to manufacture. It starts rotating at lower speeds as compared to its counterpart hydraulic turbines, having a high starting torque. It produces low noise and can make use of the water river flowing in any horizontal direction to its rotation. However, in spite of these advantages, this turbine faces one main disadvantage of having low efficiency. The preliminary research has been done to choose the best design rotor tandem blade of savonius (TBS). By using the result CFD simulation of the three models i.e.: (a) Overlap TBS, (b) Symmetrically TBS and (c) Convergent TBS as shown in Fig. 1, one of the best choice to be deeply studied is obtained. The optimum turbine power generation predicted by taking into calculation maximum pressure gap ( $\Delta p$ ) between upstream and downstream is Type Convergent TBS [2].

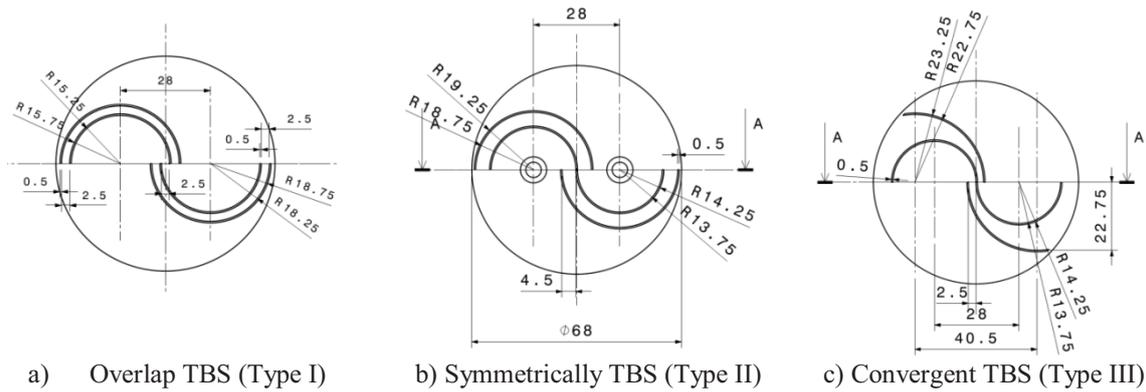


Figure 1: Three models and dimension of Tandem Blade of Savonius (TBS) Design [2].

The Savonius conventional has two pairs of cylindrical blade that look like a letter S which not connected to the middle or with gaps (overlapping) on both ends of the blade that serves as the entry of outflow from the first blade (thrust) to the second blade (return). As shown in Fig. 2, the first blade (advancing blade) got a drag force from the main flow (free flow) while the second blade (returning blade) got a returned force from the opposite direction outflow through the gap (overlap) resulting in a pair off couple force that is able to generate torque and power.

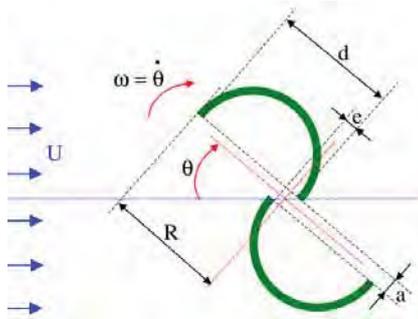


Figure 2: Original Savonius Rotor

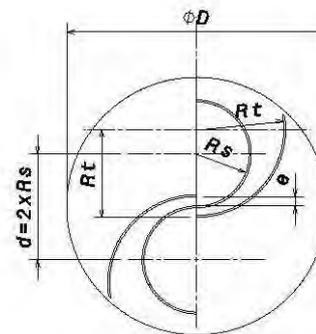


Figure 3: Convergent Tandem Blade Savonius

This paper focuses on optimization using RSM for designing geometry of Convergent TBS as shown in Fig.3 above. Objective of this study is to determine the value of the independent variables that cause the value of maximum pressure gap between upstream and downstream to be optimal. In these experiments, the response variable pressure gap (y) is affected by two independent variables: Radius Tandem Blade “ $R_t$ ” or ( $x_1$ ) and Clearance Blade “ $e$ ” or ( $x_2$ ). By using an appropriate model formulation, the value of independent variables ( $x_1, x_2$ ) which causes maximum pressure gap designation optimal can be obtained.

## 2. RESPONSE SURFACE METHOD

To understand how far the optimum process is influenced by number of variables, it is often necessary for experimental data to be large and takes a long time, which automatically also cost a huge amount. Several statistical and mathematical techniques are often used to make an approach to gain understanding of the optimum conditions of the process or design without requiring too much data. Among the commonly used method is the response surface method (RSM).

RSM is a set of mathematical and statistical techniques that are useful for analyzing problems where several independent variables affect the response variable and the ultimate goal is to optimize the response. The basic idea of this method is the use of statistical experimental design assisted to find the optimal value of the response. This method was first proposed in 1951 and has been used extensively in both the research and industrial applications until today. For example, by constructing a mathematical model, researchers can determine the value of the independent variables that lead to an optimal value of the response variable.

The first step of the RSM is to find a relationship between the response variable y with  $x_i$  independent through a first order polynomial equation (model order I). Independent variables denoted by  $x_1, x_2, \dots, x_k$ . These variables are assumed to be controlled by the researcher and the influence response variable y is assumed as a random variable. If the response is well modeled by a linear function of the independent variables  $x_i$ , the function approximation of the model order I are:

$$y = \beta_0 + \sum_{i=1}^k \beta_i x_i + \varepsilon \quad (1)$$

with,  $y$  : dependent variable (response)

$x_i$  : factors that influence response variables,  $i = 1, 2, \dots, k$

$\varepsilon$  : residual component (error) which is random and distributed identical and independent (Independent Identically Distributed-IID) Normal distribution with the average value of 0 and variance  $\sigma^2$ . In mathematically expressed by  $\varepsilon \approx \text{IID Normal}(0, \sigma^2)$ .

Furthermore, at the condition near the response, the second order model (order II) or more normally required to approximate the response due to the curvature in the surface. In many cases, the model order II two expressed in equation (2) is considered sufficient.

$$\hat{y} = \beta_0 + \sum_{i=1}^k \beta_i x_i + \sum_{i=1}^k \beta_{ii} x_i^2 + \sum_i \sum_j \beta_{ij} x_i x_j, i < j \quad (2)$$

Analysis of the response surface fitting Order II is often referred as the canonical analysis [1]. Least squares method is used to estimate parameters on the approximation functions. The subsequent RSM analysis can be used for surface fitting. If the surface fitting is a good approximation of a function of the response, surface fitting analysis would be equivalent with the actual analysis systems.

Analysis of variance and regression analysis are the statistical techniques to estimate regression coefficients in the quadratic polynomial model and also yield a measure of uncertainty in the coefficients. One of the important statistical parameters is the coefficient of determination,  $R^2$  which provides the summary statistic that measures how well the regression equation fits the data. It is given as:

$$R^2 = \frac{SSR}{SSTO} = 1 - \frac{SSE}{SSTO} \quad (3)$$

where SSTO is the total sum of squares, SSR is the regression sum of squares, and SSE is the error sum of squares. From the inspection of Equation (3), it is found that  $0 \leq R^2 \leq 1$ . However, a large value of  $R^2$  does not necessarily imply that the regression model is a good one. Adding a variable to the model always increases  $R^2$ , regardless of whether the additional variable is statistically significant or not. Thus, it is possible for the models that have large values of  $R^2$  to yield the poor predictions of new observations or estimates of the mean response. Because  $R^2$  always increases as we add terms to the model, the adjusted  $R^2$  statistic parameter,  $R^2_{adj}$  defined below is frequently used.

$$R^2_{adj} = 1 - \frac{SSE/(n_s - n_{rc})}{SSTO/(n_s - 1)} = 1 - \left( \frac{n_s - 1}{n_s - n_{rc}} \right) (1 - R^2) \quad (4)$$

In general, the adjusted- $R^2$  statistic does not always increase as variables are added to the model. In fact, if unnecessary terms are added, the value of  $R^2_{adj}$  often decreases.

It is important to determine the value of each regression variable in the regression model, because the model may be effective with the inclusion of additional variables or with the deletion of the variables already in the model. The test statistic (t-statistic) for testing the significance of any individual regression coefficient is

$$t = \frac{c_j}{\sqrt{\sigma^2 C_{jj}}}, \quad j = i, \dots, n_{rc} \quad (5)$$

Where  $\sigma^2$  is the estimation of variance and  $C_{jj}$  is the diagonal element of  $(X^T X)^{-1}$  corresponding to  $c_j$ .

### 3. DEVELOPMENT OF SAVONIUS ROTOR

Currently, the Savonius turbine has been developed with various modifications with the purpose of improving their performances. Cesar Humberto [3] combined the simulation and optimization method using genetic algorithm (GA) to design modified savonius rotor. Browsing point of optimization by using Polar Coordinate system for changing the shape of original rotor savonius combining with Banesh rotor produce a new shape of rotor savonius which is more efficient.

Menet, et.al.[4] has modified the savonius rotor which only changes the position of an off-set the second pair of rotor blades, now has three geometric parameters, namely: (1) primary overlap ( $e$ ), secondary overlap ( $e'$ ), and the angle between the axis blades ( $\beta$ ). The result is relatively expected s new rotor induces maximum value of static torque is much higher than those obtained with the conventional rotor. However, they found low values and negative torque when an angle  $\beta$  has large variations. Overall, the average value of the torque increased to  $C_m = 0.48$  or 60% more than the conventional rotor.

Fujisawa [5] has published a study comparing experimental results with a numerical study also using the discrete vortex method. He concluded that the numerical calculations were adequate to “predict the basic features of the variation in flow fields with rotor angle”. Nevertheless, the procreation of the flow field around a stationary rotor was poor, and Fujisawa supposed that it was due to false assumptions used in the calculations. Sometimes, some visualizations of the flow in and around the rotor are proposed, but with a poor description of the physical phenomena. Fujisawa [6] also presented an exclusive description of the Visualization study of the flow in and around a of the conventional Savonius rotor, they conclude that the overall pressure coefficient decreased due to the effect of the circulation generated by rotor rotation. This is a phenomenon of circulation persists in revolving condition compared with stationary rotor, where the flow through the overlap is reduced due to backflow. The flow is expected to reduce the effect of pressure recovery on the back side of blade behind because of the pressure distribution near the overlap.

Kamoji et al. [7] improved the coefficient of power and obtained uniform coefficient of static torque. To achieve these objectives, the rotors are being studied with and without central shaft between the end plates. Experimental tests in a closed jet wind tunnel on modified form of the conventional Savonius rotor with the central shaft have the value of  $C_p = 0.32$ . They studied the effect of geometrical parameters on the performance of the rotors in terms of coefficient of static torque, coefficient of torque and coefficient of power. The parameters studied are overlap ratio, blade arc angle, aspect ratio, and Reynolds number.

Performance of Savonius hydro-kinetic turbine has dependence with the principle to generate drag forces is formulated by  $F = p \cdot A = \frac{1}{2} \cdot \rho \cdot A \cdot U^2$ , thus optimizing torque and power turbine formation is highly dependent on the blades swept area (A) and velocity of fluid (U). Therefore, this paper introduced a new concept design of Savonius rotor by broadening swept area of tandem blade that can increase drag force production on the blade as shown as Fig. 3. To achieve the maximum power generation using convergent TBS rotor design, we use CFD simulation and RSM to realize optimum Radius Tandem Blade (Rt) and Clearance Blade (e) as independence variable.

#### 4. CFD SIMULATION

By adapting the law of Navier-Stokes model of rotation frame, the equations governing the behavior Savonius hydrokinetics turbines will be used in this study. The equations rule the behavior of fluid flow including conservation of mass (eq. 6) and momentum equations (eq. 7). Two types of acceleration in the momentum equation representing two Savonius hydrokinetics turbine rotation are the Coriolis acceleration,  $(2 \tilde{\omega} \times \bar{v}_r)$  and the centripetal acceleration  $(\tilde{\omega} \times \tilde{\omega} \times \hat{r})$ .

$$\frac{\partial \rho}{\partial t} + \nabla \cdot \rho \bar{v}_r = 0 \quad (6)$$

$$\frac{\partial}{\partial t} (\rho \bar{v}_r) + \nabla \cdot (\rho \bar{v}_r \cdot \bar{v}_r) + \rho (2 \tilde{\omega} \times \bar{v}_r + \tilde{\omega} \times \tilde{\omega} \times \hat{r}) = -\nabla p + \nabla \tau + F \quad (7)$$

In this equation,  $\hat{r}$  is the radial position of the rotating domain forms,  $\tilde{\omega}$  domain is the angular velocity of the rotor,  $\bar{v}_r$  is the relative velocity,  $p$  is the static pressure,  $\tau$  is the stress tensor and  $F$  represents the external body force. Adopting a combined formulation in cylindrical coordinates and Cartesian, in order to simulate two separate regions of the domain, i.e. inflows rotate the rotor-stator and external. Standard K- $\epsilon$  model, Eq. (8) and (9), is used to simulate the turbulence in the flow field [8]. They are coupled to the Navier-Stokes equations although included in the convection zone. It is a widely used and provides sufficient accuracy and worthy to represent the various types of flow. K- $\epsilon$  model is a two-equation models involving turbulent kinetic energy,  $k$ , and the dissipation rate,  $\epsilon$ , as follows,

$$\frac{\partial}{\partial t} (\rho k) + \frac{\partial}{\partial x_i} (\rho k u_i) = \frac{\partial}{\partial x_j} \left[ \left( \mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + G_k + G_b - \rho \epsilon - Y_M + S_k \quad (8)$$

$$\frac{\partial}{\partial t} (\rho \epsilon) + \frac{\partial}{\partial x_i} (\rho \epsilon u_i) = \frac{\partial}{\partial x_j} \left[ \left( \mu + \frac{\mu_t}{\sigma_\epsilon} \right) \frac{\partial \epsilon}{\partial x_j} \right] + C_{1\epsilon} \frac{\epsilon}{k} (G_K + C_{3\epsilon} G_b) - C_{2\epsilon} \rho \frac{\epsilon^2}{k} + S_\epsilon \quad (9)$$

$$\mu_t = \rho C_\mu \frac{k^2}{\epsilon} \quad (10)$$

In this model,  $G_k$  represents the generation of turbulence kinetic energy due to the velocity gradient, whereas  $G_b$  describe the generation of turbulence kinetic energy due to buoyancy, and  $Y_M$  is the contribution of the fluctuating dilatation to the overall dissipation rate. Variable  $\sigma_k$  and  $\sigma_\epsilon$  are Prandtl numbers for the turbulent with value of  $k = 1.0$  and  $\epsilon = 1.3$ . Constants  $C_{1\epsilon} = 1.44$  and  $C_{2\epsilon} = 1.92$ . Turbulent viscosity (or Eddy current),  $\mu_t$  is computed by combining  $k$  and  $\epsilon$  as shown in Eq. 10, where  $C_\mu = 0.09$ .

This equation will be used to predict fluid flow through a turbine that will improve its performance.

By using simulation software ANSYS Release 14.0 it's the following boundary conditions that have been applied. The stationary domain has a free stream velocity. The hydrodynamic pressure conditions are applied and the initialization is done. Inlet and Outlet are default boundary conditions in simulation software. Inlet requires the speed of inlet velocity of water and the outlet requires the relative pressure,  $1.0132 \times 10^5$  [Pa], at the initial conditions. The blade surfaces are enabled a "wall"

condition. This condition enables the calculation of properties such as force, torque on the surface. Once the domains have been specified, a default fluid-fluid interface is detected between the rotating and stationary domain.

A two-dimensional view of the rotor model was considered. It is because the rotor blades rotate in the same plane as the approaching water flow stream. The computational domain was discretized using two-dimensional unstructured mesh (triangular mesh). The left boundary had Velocity Inlet condition while the right boundary had Outflow condition. The top and bottom boundaries for the open channel sidewalls had symmetry conditions. The moving wall condition was employed for the rotor model to study the effect of fluid motion in and around the rotating Savonius rotor. The dimensions of the computational domain were 500 mm in length and 75,5 [mm] in width, which were also similar to the experimental conditions. For the various model conditions, the geometry of the rotor was changed and accordingly different meshes were generated for each condition.

Steps in the simulation solutions consist of:

1. Solver (Pressure Based, Steady, 2D)
2. Viscous Model: Standard k-epsilon (k-ε) / Near-Wall Treatment: Standard Wall Functions
3. Material: Water ( $\mu= 1.002 \times 10^{-3}$  [kg/m-s],  $\rho= 1.000$  [kg/m<sup>3</sup>])
4. Operating conditions: Atmospheric Pressure (1.0132 [bar])
5. Boundary Conditions:
  - Inlet: Velocity Inlet
  - Sides: No slip wall
  - Blades: Stationary Wall
  - Outlet: Outlet
6. Solution controls:
  - Pressure Velocity Coupling: SIMPLE
  - Discretization: fluids
7. Pressure (Standard) / Inlet Velocity: 1 [m/s]

## 5. RESULT AND DISCUSSION

In the contour plots as shown at Figure 5, the blade on the left hand side is the returning blade and that on the right hand side is the advancing blade. The contour plots predict the variations in velocity and pressure in various regions near the blades within the flow domain. It can be observed from the pressure contour plots that pressure gap occur across the rotor from upstream to downstream side. This pressure gap indicates power extracted by the rotor causing its rotation [5]. The static pressure on the convex side of both the blades can be observed to be lower than those on the concave side of the blades; in fact, a region of negative pressure exists on the convex side of the blades. This occurs due to the high flow velocity over the convex side of the blades. As a result, a pressure difference acts across the concave and convex side of the blades, which provide the necessary torque for causing rotation of the blades.

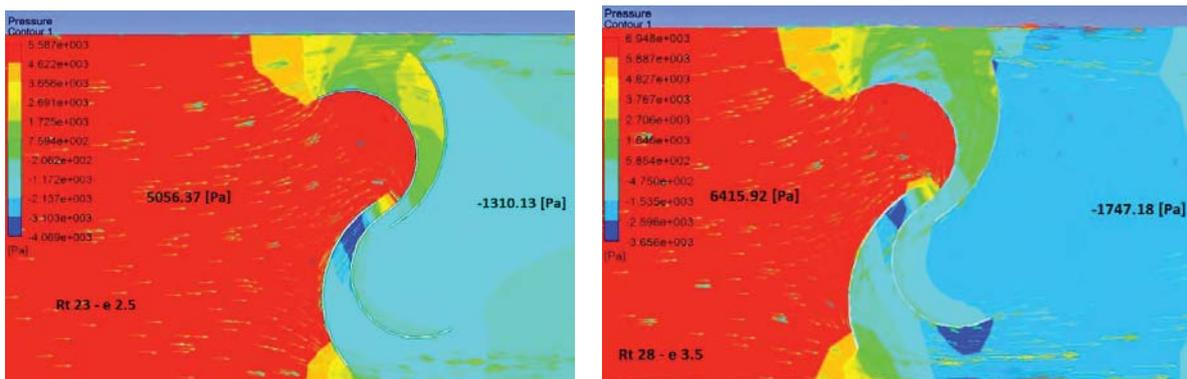


Figure 5: CFD simulation demonstrate the effect of Radius Tandem (Rt) and Clearance (e) caused pressure drop ( $\Delta P$ ).

Table 1: Data from CFD simulation

No	Rt (mm)	E (mm)	$P_1$ (Pa)	$P_2$ (Pa)	$\Delta P = P_1 - P_2$ (Pa)
1	23	2.5	5056.37	-1310.13	6366.5
2	25.5	2.5	7569.63	-1927.14	9496.77
3	28	2.5	7269.63	-1865.28	9134.91
4	23	3	4634.96	-1179.26	5814.22
5	25.5	3	7190.55	-1760.67	8951.22

6	28	3	6836.54	-1838	8674.54
7	23	3.5	4103.14	-1162.18	5265.32
8	25.5	3.5	6899.43	-1859.63	8759.06
9	28	3.5	6415.92	-1747.18	8163.1

Table 2: Center Composite Design Using Minitab R 14

Run Order	PtType	Blocks	Rt (mm)	e (mm)	ΔP (Pa)
1	1	1	23.0000	2.50000	6366.50
2	1	1	28.0000	2.50000	9134.91
3	1	1	23.0000	3.50000	5265.32
4	1	1	28.0000	3.50000	8163.10
5	-1	1	21.9645	3.00000	5039.54
6	-1	1	29.0355	3.00000	8817.03
7	-1	1	25.5000	2.29289	8721.59
8	-1	1	25.5000	3.70711	8835.92
9	0	1	25.5000	3.00000	8951.22
10	0	1	25.5000	3.00000	8951.22
11	0	1	25.5000	3.00000	8951.22
12	0	1	25.5000	3.00000	8951.22
13	0	1	25.5000	3.00000	8951.22

Table 3: Regression Coefficient Order II

Term	Coef	SE Coef	T	P
Constant	8951.2	187.9	47.626	0.000
RADIUS TANDEM BLADE	1376.0	148.6	9.261	0.000
CLEARANCE	-238.9	148.6	-1.608	0.147
RADIUS TANDEM BLADE*	-1166.7	159.3	-7.322	0.000
RADIUS TANDEM BLADE CLEARANCE*CLEARANCE	-241.5	159.3	-1.516	0.168

S = 420.3    R-Sq = 94.7%    R-Sq(adj) = 92.0%

Table 4: Analysis of Variance for Pressure Gap

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	4	25130794	25130794	6282699	35.57	0.000
Linear	2	15604656	15604656	7802328	44.18	0.000
Square	2	9526138	9526138	4763069	26.97	0.000
Residual Error	8	1412972	1412972	176622		
Lack-of-Fit	4	1412972	1412972	353243	*	*
Pure Error	4	0	0	0		
Total	12	26543766				

To discuss the results of RSM optimization, as shown in Table 1 presented the CFD simulation data of rotor convergent TBS model using variable tandem radius (Rt) and Blade Clearance (e) with the lowest value of 23 mm - 2.5 mm and the highest 28 mm - 3.5 mm, both pressure gap indicates that each  $\Delta p = 6366.5$  (Pa) and  $\Delta p = 8163.1$  (Pa). The two independent variables were considered as variables that affect maximize pressure gap (y), i.e., Radius ( $x_1$ ) and Clearance ( $x_2$ ). Experimental design used in the DoE is three-level factorial design (3k) using the Central Composite Design (CCD) which is presented in Table 2.

The first step has been tested using a linear regression equation (Order I) with obtained R-square is only 54% and a P-value > 0.05 so it does not show any significance of the model. Furthermore, similar test attempted to Order II model equations (linear + square) obtained a significant regression coefficient. To check the significance of the second-order model, it can be seen that p-value = 0.000 is less than the significance level  $\alpha = 5\%$ , see also that the independent variables  $x_1$  made a significant contribution in the model, but  $x_2$  is not significant. But, overall this model it is able to demonstrate the high value of R-square = 94.7 % in Table 3, which means that the regression equation model is consistent with the real condition of the model studied. The model regression equation is expressed in the form:

$$\Delta P = 8951.2 + 1376 (Rt) - 238.9 (e) - 1166.7 (Rt)^2 - 241.5 (e)^2 + \varepsilon$$

After the optimization model has determined, the next step is to determine the conditions optimum of significant factors. From the contour plot of the image below, it can be concluded that the image does not have a stationary point. Consequently that calculation of the stationary point and surface characteristics of the response is not necessary. The result of response ( $\Delta P$ ) optimization will be obtained after value of (Rt) and (e) which substituted into the model equation above with constant value of Rt = 27 [mm] and variable e = 2.5 [mm] ÷ 3.5 [mm]. By using Minitab Software, it is more simple to obtain the result of peak

point in the curvature as shown in Fig. 7 which show optimal value of  $R_t = 27$  [mm] and  $e = 2.75$  [mm] with response of maximum  $\Delta P = 9415.91$  [Pa].

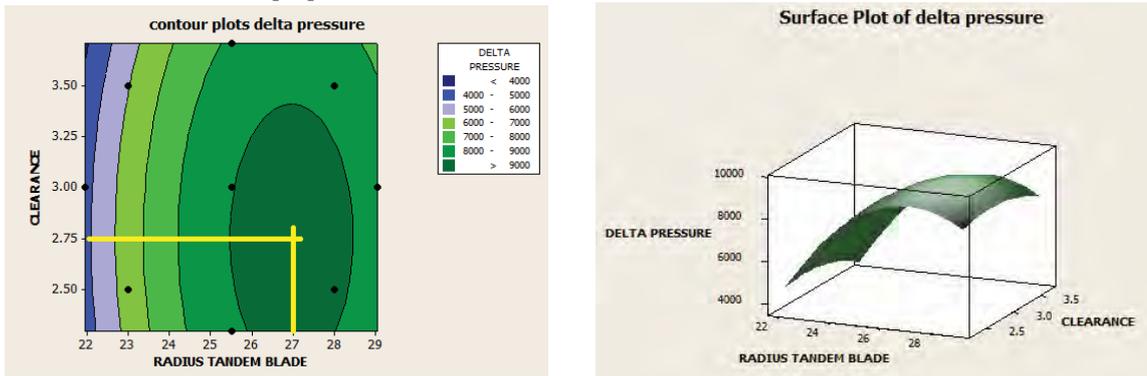


Figure 6: Contour Plot and Surface Plot

Optimal		RADIUS T	CLEARANC
D	Hi	29.0355	3.7071
0.94394	Cur	[27.0000]	[2.7521]
	Lo	21.9645	2.2929
DELTA PR			
Maximum			
y = 9415.9119			
d = 0.94394			

Figure 7: Response Optimization Result

## 6. CONCLUSION

Finally, with applied CFD simulation and optimization using RSM, we are able to assist design engineering of the critical part of convergent tandem blade of Savonius rotor that capable to generate maximum power on hydrokinetic turbine model. The result of design optimization of Savonius tandem blade is showed in Fig. 8 below with  $R_t = 27$  [mm] and  $e = 2.75$  [mm].

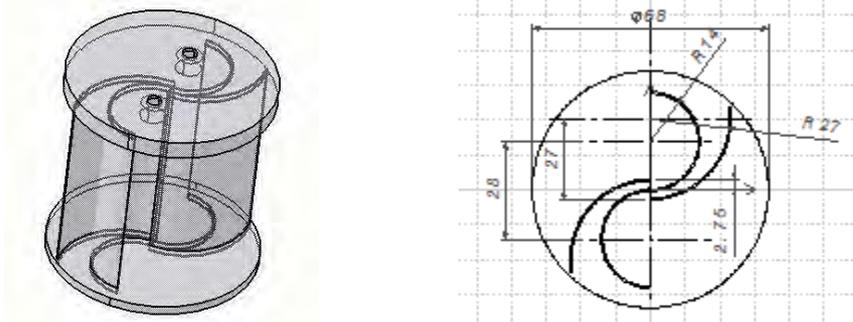


Figure 8: The result design of convergent tandem blade of Savonius Rotor

## ACKNOWLEDGMENT

The authors acknowledge with thanks the assistance rendered by Dr. Eng. Agus Choiron, (Lecturer) and Tri Handoko (Assistant Lecturer), Manufacture and Engineering Design Laboratory Department of Mechanical Engineering, Brawijaya University of Malang - Indonesia), for providing crucial insights during the course of the research work.

## REFERENCES

- [1] Montgomery, D. C. (1984), "Design and Analysis of Experiments", John Wiley & Sons, Canada.
- [2] Bagus Wahyudi, et al. (2013), "A Simulation Study of Flow and Pressure Distribution Patterns in and around of Tandem Blade Rotor of Savonius (TBS) Hydrokinetic Turbine Model", Paper Presentation of International Congress on Informatics, Environment, Energy and Application IEEA-2013 in Bali.

- [3] Cesar Humberto, (2008), “*Optimization of the efficiency of a Savonius wind turbine for urban media using Genetic Algorithm*”, Master Thesis, Instituto Tecnológico De Monterrey.
- [4] Menet, J. (2004), “*Increase in the Savonius Rotors Efficiency via a Parametric Investigation*”. Available on [http://www.2004ewec.info/files/23\\_1400\\_jeanlucmenet\\_01.pdf](http://www.2004ewec.info/files/23_1400_jeanlucmenet_01.pdf)
- [5] N . Fujisawa and F. Gotoh (1992) : “*Visualization study of the flow in and around a Savonius rotor*. Experiments in Fluids”, 12(6),: pp. 407-412
- [6] N. Fujisawa, (1996), “*Velocity measurements and numerical calculations of flow fields in and around Savonius rotors*. J. Wind Eng. Ind. Aero.; 59 , pp.: 39-50.
- [7] M.A. Kamoji, S.B. Kedare, S.V. Prabhu, (2009), “*Experimental investigations on single stage modified Savonius rotor*”, Applied Energy, vol. 86, no. 7-8 pp.: 1064-1073.
- [8] Pope Kevin (2009), “*Performance Assesment of Transient Behaviour of Small Wind Turbines*”, Master Thesis in Applied Science, University of Ontario Institute of Technology.

# Combustion of Diesel-Biodiesel Blend Using *OpenFoam*: Calculation of Pressure and Temperature in Combustion Chamber

<sup>1</sup>Bambang Sugiarto, <sup>2</sup>Rizqon Fajar, <sup>3</sup>Dody Darsono

<sup>1,3</sup>Departement of Mechanical Engineering, University of Indonesia, Depok Indonesia  
E-mail: bangsugi@eng.ui.ac.id

<sup>2</sup>Center for Thermodynamics, Motor & Propulsion System, Serpong Indonesia  
E-mail: rizqon66@gmail.com

## ABSTRACT

This paper presents a study of the combustion of mineral diesel and biodiesel in a direct injection diesel engine. For this, a numerical simulation using the CFD code *OpenFoam*, the simulation of injection, evaporation and combustion process were carried out. The comparison was made in terms of combustion characteristics such as the pressure and temperature in the combustion chamber between the mineral diesel, biodiesel and its blend. These combustion characteristics can then be used for calculating the heat release and combustion efficiency. It was found that the calculated pressure and temperature in the combustion chamber tend to be similar with which the experimental data. The results demonstrate the benefits and the ability of the open source CFD software for analysis and optimization of the combustion in diesel engines.

## Keywords

*Combustion, CFD, Biodiesel, temperature, combustion*

## 1. INTRODUCTION

This study aims to develop a calculation method using open source-based software package (*OpenFoam*) for combustion parameters in diesel engine. The method developed is expected to perform the calculations that are comparable with of commercial softwares such as *FLUENT*, *AVL-FIRE* and *STAR-CD*. For the visualization of the simulation results, the other open-source code is also used, the so called *ParaView*. This study is design to support the Indonesian National Research Agenda [1] and the topic of this study related to the design and optimization of combustion process of the alternative fuels such as biodiesel, bi-oil and biogas according to recent studies though biodiesel has been implemented in Indonesia in the transport sector, but there are still many problems found regarding the performance of the engine (deposit formation). Therefore, a numerical study is needed on the effects of mixtures of biodiesel on the mechanism of combustion in diesel engines [2].

## 2. METHOD

### 2.1 Generating Drawing and Mesh for Combustion Chamber

To simulate the combustion process in diesel engine, drawing of the combustion chamber is required, consisting of a space that is confined by top piston with bowl at the bottom, cylinder liner as the wall and cylinder head at the top. Furthermore the drawing of the combustion chamber is generated using an open source software (for example: *OpenOffice Draw*) or generated first using the popular package such as *AutoCad* and then transferred to *OpenFoam* format with *OpenOfficeDraw*.

The space of combustion chamber should then be divided into mesh consisting of many tiny compartments where it will represent the unique parameters of combustion process (temperature, pressure, concentration etc.). *OpenFoam* has a procedure for generating the mesh, so called *blockMesh*.

### 2.2 Setting Parameters before Simulation (Pre-processing)

A package in the *OpenFoam* for simulating the combustion in diesel engine (Solver) is the *dieselEngineFoam* [3], [4], [5]. Solver *dieselEngineFoam* can simulate the dynamic combustion process in the diesel engine by giving the output in the form of profiles of combustion parameters as a function of crank angle (crank angle). Before starting with the simulation, the following setting or adjustment are needed:

#### Setting of initial and boundary conditions [4], [5], [6]

Setting of initial and boundary conditions include the condition of the fuel injector, fuel flow profile, type of injector, the parameters associated with composition of incoming air ( $O_2$ ,  $N_2$ ) and the physical-chemical properties such as pressure, temperature, concentration of exhaust gas emission. Boundary conditions include the position and direction injection injector, nozzle diameter, temperature, mass flow rate profile of the injected fuel etc. In addition, the fuel injector used in this study is **unitInjector**. Furthermore the model for fuel atomization can be selected from a variety of options (contained in the file **constant / sprayProperties**). The initial conditions in the simulation can be edited in the directory (**/ 0**).

#### Determination of Physical Properties [4], [5]

Before running the simulation, there are some files in the OpenFoam that should be edited, relating to the physical-chemical properties: **chemistryProperties**, **environmentalProperties**, **combustionProperties** and **thermophysicalProperties**. **chemistryProperties** includes definition of chemical reactions, **environmentalProperties** includes gravity and **combustionProperties** includes setting combustion calculations with or without ignition, timing and duration of ignition. **thermophysicalProperties** includes the setting and type of reaction scheme to be used in the simulation.

#### 2.3 Running Solver [4], [5]

For running the simulation, the following multiple procedures are used:

- Open the case that we will run in the file / 0
- Determine the reaction and ignition
- Generate the drawing and mesh of the combustion chamber
- Running the dieselEngineFoam

#### 2.4 Post-Processing

The simulation results can then be processed using the open source software ParaView. Processing of the simulation results will provide the temperature and pressure distribution profile, diameter of fuel droplets, and exhaust emission concentration before/after combustion. Figure 1 is an example of the results of processing using ParaView.

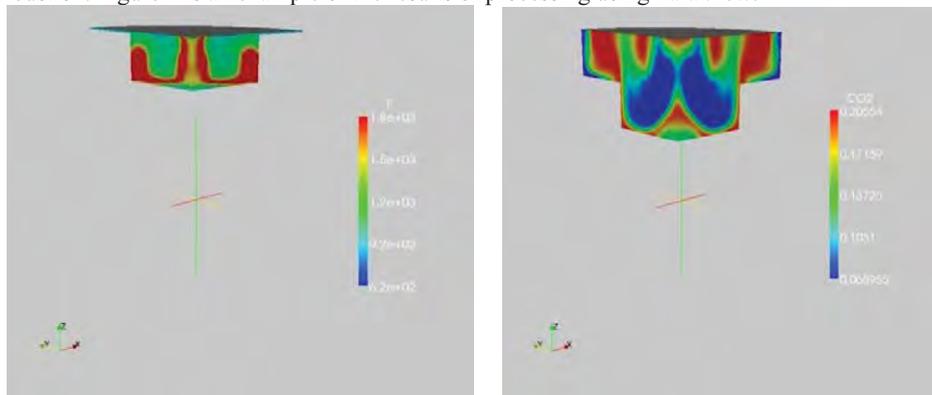


Figure 1: Temperature and CO<sub>2</sub> distribution in combustion chamber after combustion

### 3. RESULTS AND DISCUSSION

The dynamics simulations are performed on a cylindrical combustion chamber with the following sizes:

- Stroke (Conrod Length): 0.22 meters
- Bore: 0.104 meters
- Stroke: 0.115 meters
- Clearance: 0.0005 meters

Dynamics simulation are performed during the movement of piston (up and down) with the rotational speed of 1500 RPM. Figure 2 shows the piston head used in the simulation and fitted valley

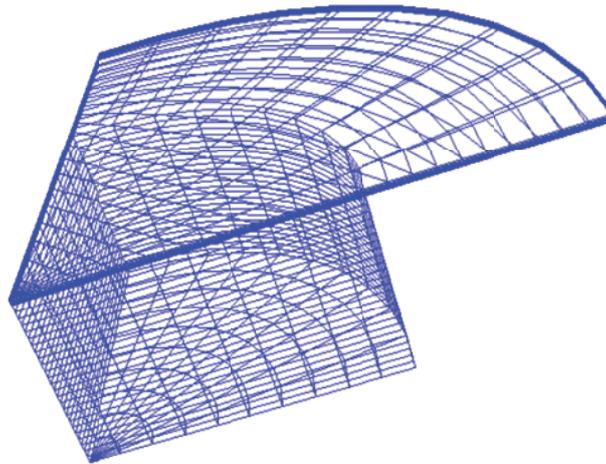


Figure 2: Top piston geometry for dynamic simulation

The parameters and conditions used in the simulation are shown in Table 1. The simulation for combustion is applied for two types of fuels namely mineral diesel fuel and biodiesel-mineral diesel fuel blend (w/w-50%, B50)

Table 1: Simulation parameter in combustion chamber for two different condition

Simulation Parameter	Values	
	Condition 1	Condition 2
Speed (RPM)	1500 RPM	1500 RPM
Injected Fuel Mass	0,00003 Kg	0,00003 Kg
Start of Injection	-20 °CA	-24°CA
End of Injection	-2 °CA	-6°CA

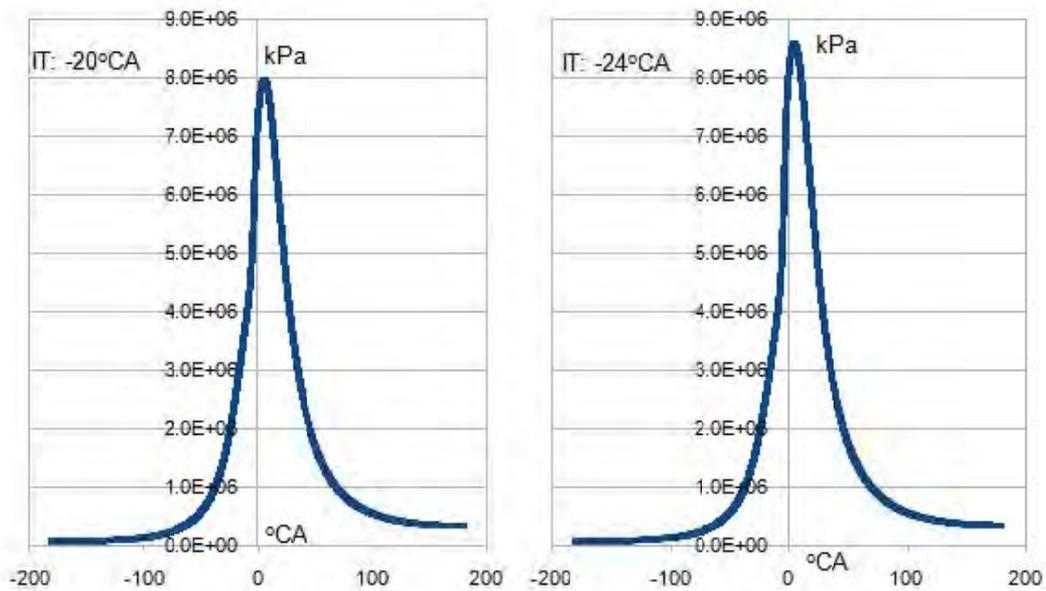


Figure 3: Pressure profile in combustion chamber at injection timing of -20 and -24°CA for mineral diesel fuel

The simulations are performed at two different injection times, the first injection time is started at -20°CA and ended at -2°CA. While the second injection time is started at -24°CA and ended at -6°CA. Their results of dynamics simulation for pressure and temperature in the combustion chamber can be seen in Figure 3 to 6. Results in Figure 3 shows the pressure profile in the combustion chamber when mineral diesel fuel is burned at two different injection time. It appears that at the time after the combustion pressures begin to rise until it reaches a peak at between 4-5°CA, the pressure then goes down after burning of the mineral diesel fuel finish. The peak pressure at injection time of -20°CA is about  $8.10^6$  kPa (80 bar) and the value at

injection time of  $-24^{\circ}\text{CA}$  is higher ( $8,5 \cdot 10^6$  kPa).

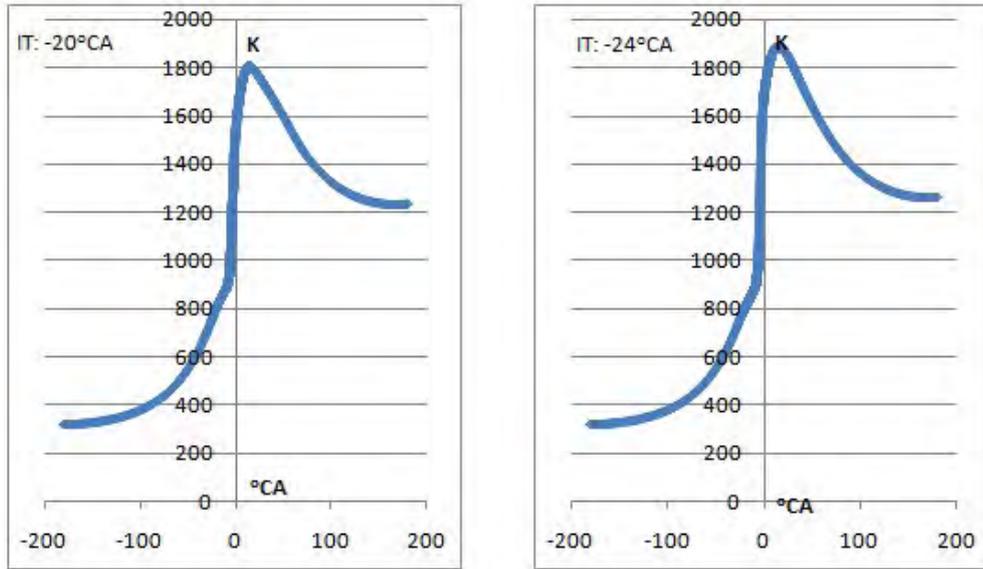


Figure 4: Temperature profile in combustion chamber at injection timing of  $-20^{\circ}$  and  $-24^{\circ}\text{CA}$  for mineral diesel fuel

The results in Figure 4 shows the temperature profile in the combustion chamber at injection time of  $-20^{\circ}$  and  $-24^{\circ}\text{CA}$ . It appears that at the time after the the injection, when the combustion of mineral diesel fuel starts, the temperature profile began to rise suddenly until it reaches a peak value at about  $11-12^{\circ}\text{CA}$ , then decreased drastically at stage of exhaust stroke.

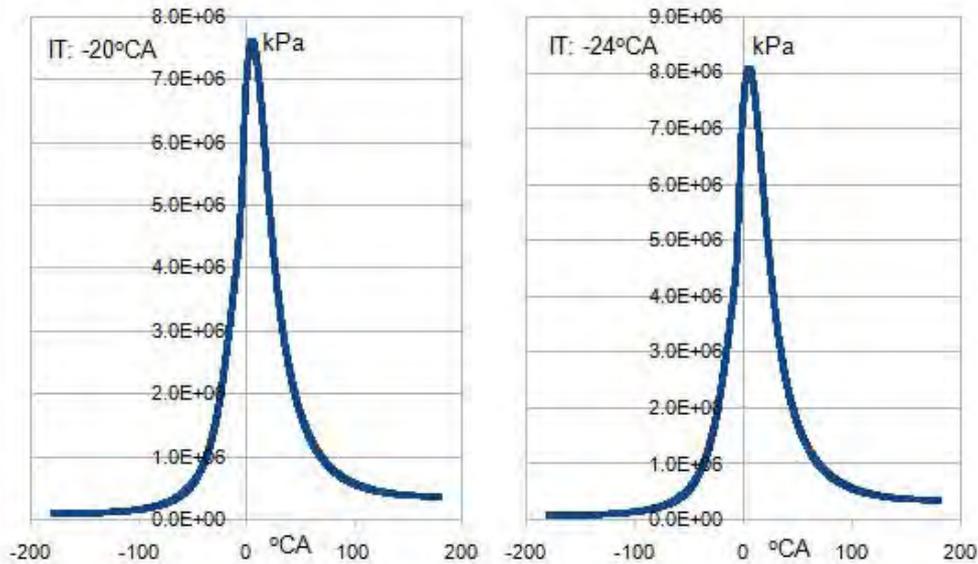


Figure 5: Pressure profile in combustion chamber at injection timing of  $-20$  and  $-24^{\circ}\text{CA}$  for biodiesel blend (B50)

The results in Figure 5 shows the dynamic pressure profile in the combustion chamber of the biodiesel blend (B50) at injection timing of  $-20$  and  $-24^{\circ}\text{CA}$ . It is shown that the peak pressure of combustion at injection time of  $-24^{\circ}\text{CA}$  is higher than that of  $-20^{\circ}\text{CA}$ . This phenomenon is similar to the combustion of mineral diesel, if the fuel is injected earlier then the relting peak pressure will be higher. It also appears the pressure reaches the peak value at  $5-6^{\circ}\text{CA}$  for both values of injection timing.

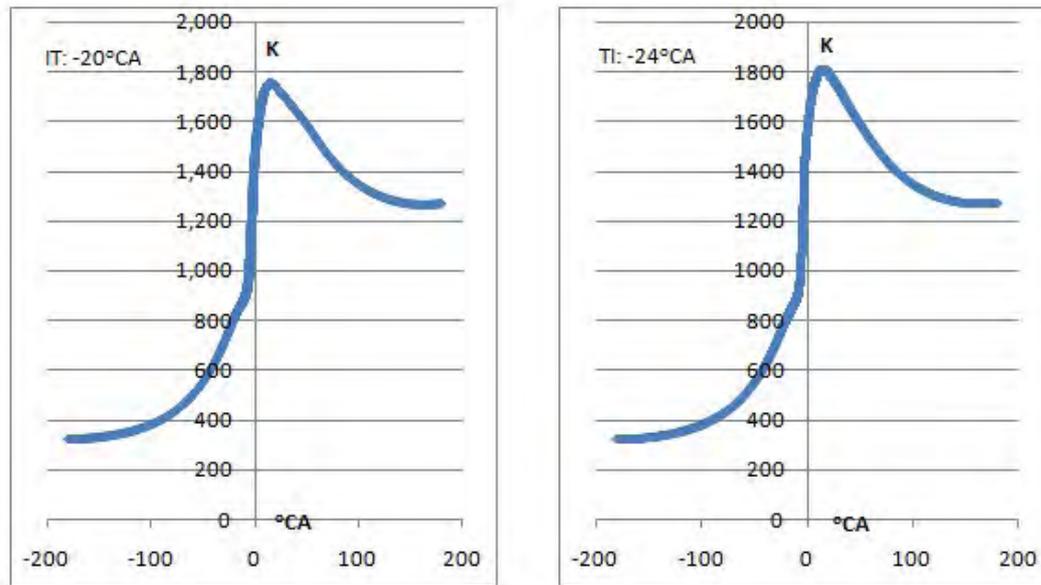


Figure 6: Temperature profile in combustion chamber at injection timing of -20 and -24°CA for biodiesel blend (B50)  
 Figure 6 shows the temperature profile in the combustion chamber for at injection timing of -20 and -24°CA. The trend in peak temperature for both mineral diesel fuel and B50 are similar. The peak temperature for combustion of B50 at injection timing of -24°CA is about 1800 K and this is higher than that of injection timing of -20°CA (1750 K). The values of the peak pressure and peak temperature for the combustion both mineral diesel fuel and B50 are summarized in Table 2. The results show that the peak pressure and temperature of combustion with mineral diesel are higher than that of B50 at injection timing of -20 as well as of -24°CA. This corresponds to the value of the calorie content of the mineral diesel which is higher than that of B50. Thus, the combustion of mineral diesel will produce and release higher heat and also the peak pressure and temperature.

Table 2: The values of the peak pressure and temperature for the combustion of mineral diesel and B50

Combustion Characteristics	Mineral Diesel		B50	
	-20°CA	-24°CA	-20°CA	-24°CA
Peak Pressure (10 <sup>5</sup> kPa)	80	86	76	81
Peak Temperature (K)	1805	1880	1750	1800

#### 4. CONCLUSION AND RECOMMENDATION

The conclusion that can be derived from the results of the dynamic simulation of a diesel engine combustion chamber is as follows:

- Simulation using CFD software opensource (OpenFoam) can be done easily using the solver dieselEngineFoam and is relatively fast
- The simulation results of the pressure and temperature profile has shown a correlation with the physical properties of the fuel (mineral diesel and B50), especially with the calorie content.

Recommendations that can be given for the next study are as follows:

- Need further simulation with more variations in injection pressure injection, biodiesel blends (fuel properties) and engine design parameter (injection angle, bowl design, load etc).
- Need validation of the simulation results by comparing with experimental data or secondary data from the literature

This study is still ongoing with calculation and visualization of emission profiles (CO, NOx and unburned hydrocarbon) using opensource software ParaView, and will be reported soon.

#### ACKNOWLEDGMENT

This project is financially supported by University of Indonesia through the RUUI 2012 research project. The assistance of Mr. Himawan Sutrianto from BTMP BPP Teknologi in conducting the numerical study using OpenFoam is also highly appreciated.

#### REFERENCES

- [1] Agenda Riset Nasional, Keputusan Menteri Riset & Teknologi No. 193/M/Kp/IV/2010
- [2] R. Fajar, "Re-formulasi Biodiesel Jatropa: Optimasi key-properties dengan modifikasi komposisi FAME (Fatty Acid Methyl Esters) dan karakterisasi pembakaran pada motor diesel," Universitas Indonesia, Juni, 2012

- [3] D. Errico et al., "Development of OpenFOAM application for internal combustion engine simulation," <http://www.engines.polimi.it/CFD.html>
- [4] Agudeldo et al., "Study of diesel sprays using computational fluid dynamics," *Rev. Fac. Ing. Univ. Antioquia* N.º 49. pp. 61-69. Septiembre, 2009
- [5] P. Carlsson, "Tutorial dieselFoam," Energy Technology Center Lulea University of Technology, February 17, 2009
- [6] Salvador et al., "Influence of biofuels on the internal flow in Diesel injector nozzles," *Mathematical and Computer Modelling*, December 14, 2010

## Flow Pattern Map of Steam-Condensate Flow in a Horizontal Double Pipe

Sukamta<sup>a</sup>, Indarto<sup>b</sup>, Purnomo<sup>b</sup>, Tri Agung Rohmat<sup>b</sup>

<sup>a</sup>Department of Mechanical Engineering, Faculty of Engineering,  
 Universitas Muhammadiyah Yogyakarta, Jl. Ringroad Selatan, Tamantirto, Kasihan, Bantul,  
 Yogyakarta, Indonesia,  
 phone +628157998996, email : msukamta@gmail.com, sukamta@umy.ac.id

<sup>b</sup>Department of Mechanical and Industrial Engineering,  
 Faculty of Engineering, Gadjah Mada University,  
 Jl. Grafika no. 2 Yogyakarta, Indonesia

### ABSTRACT

There has been some success story in the formulating models for different flow regimes, and a number of corresponding flow maps for horizontal has been developed. Furthermore, most of the maps were generated based on visual observations and are, therefore, subjective in nature. Meanwhile, slugging phenomenon that can be defined as initiation of a water hammer is a very interesting topic because it has a strategic impact on safety factor of the equipment in piping systems i.e. pressurized water reactor (PWR), heat exchanger, steam or gas transportation in chemical industry, air conditioning, etc. The objective of the present research was to investigate the slugging as an initiating water hammer phenomena through non directly contact steam condensing in a horizontal pipe to develop the flow pattern map of steam-condensate flow in a horizontal double pipe. The experimental apparatus used in the present experimental study consisted of an inner annulus pipe made of copper ( $d_{in} = 17.2$  mm,  $d_o = 19$  mm) with a length of 1.8 m. The outer pipe annulus was a galvanized iron pipe ( $d_{in} = 108.3$  mm,  $d_o = 114.3$  mm) with a length of 1.6 m. The liquid being tested was water. The experiments were conducted at a static pressure of  $P_s = 108.825$  kPa and the temperature of  $T = 119.7$  °C. The pressure drop in axial direction of the test was directly measured by using a differential pressure transducer (validyne, accuracy of  $\pm 0.25\%$ ) with a sampling rate of 7.353 kHz. The obtained experimental data of temperature and differential pressure fluctuations during the steam condensation in a horizontal pipe was analyzed using a statistical analysis. It was found that: 1) the flow pattern map of non slugging (stratified and wavy flow), transition (wavy-slug flow), and slugging (slug and large-slug), were determined, here the transition flow pattern of slug and large-slug is defined as a initiating of water hammer, 2) transition area range of wavy-slug flow pattern are from  $\dot{m}_{co} = 1 \times 10^{-1}$  kg/s to  $\dot{m}_{co} = 6 \times 10^{-1}$  kg/s for  $\dot{m}_{st} = 6 \times 10^{-3}$  kg/s to  $\dot{m}_{st} = 7.5 \times 10^{-3}$  kg/s, and  $\dot{m}_{co} < 3 \times 10^{-1}$  kg/s for  $\dot{m}_{st} = 8 \times 10^{-3}$  kg/s to  $\dot{m}_{st} = 9 \times 10^{-3}$  kg/s. These obtained data are very important in order to develop a database for input in a safe early warning system design of two-phase flow piping installation system during the steam condensation.

### Keywords

Flow pattern map, slugging, steam-condensate, horizontal double pipe, water hammer

### 1. INTRODUCTION

Research in relation to the condensation heat transfer coefficient on a vertical pipe. The test section consisted of a vertical, double-pipe cylinder made of stainless steel SUS304 has been conducted by Nagae T, Murase M, Wu T, Vierow K. [1]. The inner tube was the heat transfer tube with inside diameter of 19.3 mm, wall thickness of 3.04 mm and height of 1.8 m. The mixture of steam and air flowed into the tube from the bottom inlet. The coolant water flows along the outer surface of the heat transfer tube. The temperature distribution in the axial direction under pressure of 0.1 MPa, at an inlet steam flow rate of 1.23g/s is found. Since the steam condenses and its partial pressure drops as it flows downstream, steam-air mixture temperature decreases accordingly. While the enthalpy of the steam is higher near the inlet, and thus the temperature decrease rate is low, the enthalpy decreases with the temperature decrease and the temperature decrease rate tends to grow higher.

More than five decades there have been studies efforts toward better understanding the mechanism of two-phase flow. Meanwhile because of the complex nature of two-phase flow, a complete understanding has not yet been achieved. Many investigations have postulated that the mechanisms are different for each flow regimes or pattern. Accordingly, there has been some success story in the formulating models for different flow regimes, and a number of corresponding flow maps for horizontal has been developed. A well known flow pattern map was proposed by Mandane et al. [2]. Furthermore, many of the maps are the product of visual observations and are, therefore, subjective in nature. By far the most commonly used methods to discriminate flow regimes, particularly in early years, were application of visual and high speed cameras. More modern methods use analysis of the time series on experimental data from X-ray, conductance probes, pressure transducers in attempt to classify the pattern objectively. Matsui [3,4] used differential pressure transducers, Tutu [5] used absolute pressure transducers, Brauner D., O. Shaham, and Y. Taitel [6] used conductance probes, Jones and Zuber [7] used an X-ray void measurement system for the vertical upflow in a tube. Elkow and Rezkallah [8] used a capacitance sensor to measure void fluctuation. In most

cases the analysis of the power spectrum density (PSD) function are usually employed to extract the periodic feature of a signal. Matsui [4] calculated the PSD and probability density function (PDF) of the transient pressure drop signal to identify flow pattern of two-phase flow in a vertical pipe. Franca F., Acikgoz M., Lahey R.T. Jr., Clause A. [9] and Cai, Y., Wambsgans M.W., Jendrzeczyk J.A. [10] employed PSD and other fractal techniques for flow pattern identification as well. Wang [11, 12] used Nonlinear analysis to analyze differential pressure fluctuations of two phase flow through a T-junction with the aim to make clear the two-phase flow behavior splitting at a T-junction. These results may be significant for better understanding the flow structure and also for establishing valid models different from conventional viewpoints.

Based on the above description, an investigation of steam condensation and two phase flow is very wide-ranging. Many things can still be explored to explain the phenomena of two phase flow, especially related to condensation, both in the geometry, orientation or position of the pipe, and condensation process. From those facts, the objectives of this research are to study the two-phase flow pattern map of steam-condensate flow in a horizontal double pipe.

## 2. METHODOLOGY

The experiment apparatus used in present experimental study is shown in Fig. 1 and the detail of the test pipe is in Fig. 2.

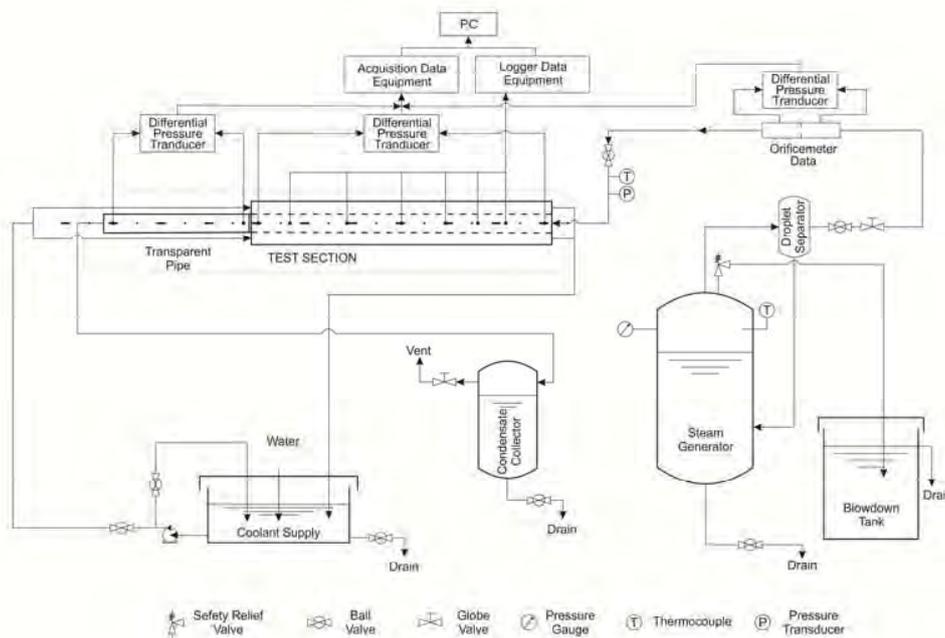


Figure 1: Experiment apparatus used in the present study

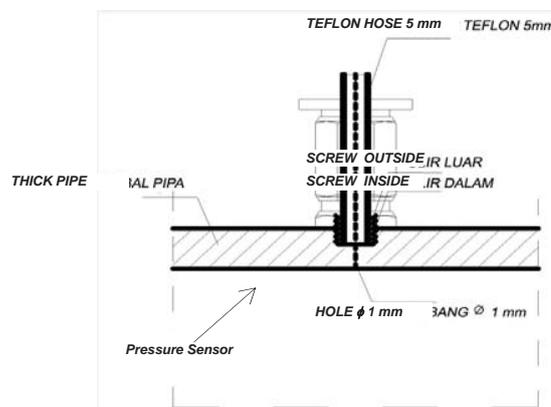


Figure 2: The detail installation of the differential pressure sensor

The Tested liquid was water. The experiment apparatus consisted of the inner annulus pipe made from copper ( $d_{in} = 17.2$  mm,  $d_o = 19$  mm) with a length of 1.8 m. The outer pipe annulus is a galvanized iron pipe ( $d_{in} = 108.3$  mm,  $d_o = 114.3$  mm) with a length of 1.6 m. In the present experimental study, the water was heated using a boiler to generate steam which was then flowed and condensed inside the annulus pipe to form a steam-condensate two-phase flow in horizontal pipe. The experiments were conducted at a static pressure of  $P_s = 108.825$  kPa dan the temperature of  $T = 119.7$  °C. The water was used as a coolant in the outer of annulus pipe. The pressure drop in the axial direction of the test was directly measured by using a differential pressure transducer with a sampling rate of 7.353 kHz.

### 3. RESULTS AND DISCUSSION

Flow pattern transition region map between non-slugging and slugging can be seen in Fig. 3. This map are derived from statistical analysis of pressure difference fluctuation data with the frequency domain (power spectra density) and time domain (root mean square, standard deviation, Skewness, Kurtosis and normal distribution). Based on the results of statistical analysis it can be concluded that at different cooling water mass flow rate ranging from  $\dot{m}_{co} = 1.24 \times 10^{-1}$  kg/s to  $\dot{m}_{co} = 5.78 \times 10^{-1}$  kg/s for steam mass flow rate less than  $\dot{m}_{st} = 6 \times 10^{-3}$  kg/s, the flow pattern is stratified or wavy flow that categorized as non-slugging. In the same range of cooling water mass flow rate, for steam mass flow rate  $\dot{m}_{st} = 6 \times 10^{-3}$  kg/s to  $\dot{m}_{st} = 7.5 \times 10^{-3}$  kg/s, the flow pattern is Wavy-slug that then classified as transitional. Furthermore, for the small cooling water mass flow rate (less than  $\dot{m}_{co} = 3 \times 10^{-1}$  kg/s) and for high steam mass flow rate ( $\dot{m}_{st} = 8 \times 10^{-3}$  kg/s to  $\dot{m}_{st} = 9 \times 10^{-3}$  kg/s) re-establish the wavy-slug flow pattern (transition) and stratified (non-slugging). However, for the large cooling water mass flow rate ( $\dot{m}_{co} = 4 \times 10^{-1}$  kg/s to  $\dot{m}_{co} = 6 \times 10^{-1}$  kg/s) and the steam mass flow rate ( $\dot{m}_{st} = 8 \times 10^{-3}$  kg/s to  $\dot{m}_{st} = 9 \times 10^{-3}$  kg/s), the flow patterns occurred slug or large-slug.

Next, for the small cooling water mass flow rate (less than  $\dot{m}_{co} = 2 \times 10^{-1}$  kg/s) and steam mass flow rates between  $\dot{m}_{st} = 7 \times 10^{-3}$  kg/s to  $\dot{m}_{st} = 8 \times 10^{-3}$  kg/s is also slug flow pattern occurred. Based on the above description, it can be concluded that the flow pattern that occurs is the start from stratified and Wavy (non-slugging), Wavy-slug (transitions) and slug or large slug (slugging). These data are very important to complete the database that can be used as an input in early warning system design for plant safety piping system. Next, visualization of flow pattern in a horizontal transparent pipe ( $d_i = 17$  mm, *plexiglass*) is shown in Fig. 4. Position of the transparent pipe is after the condenser pipe.

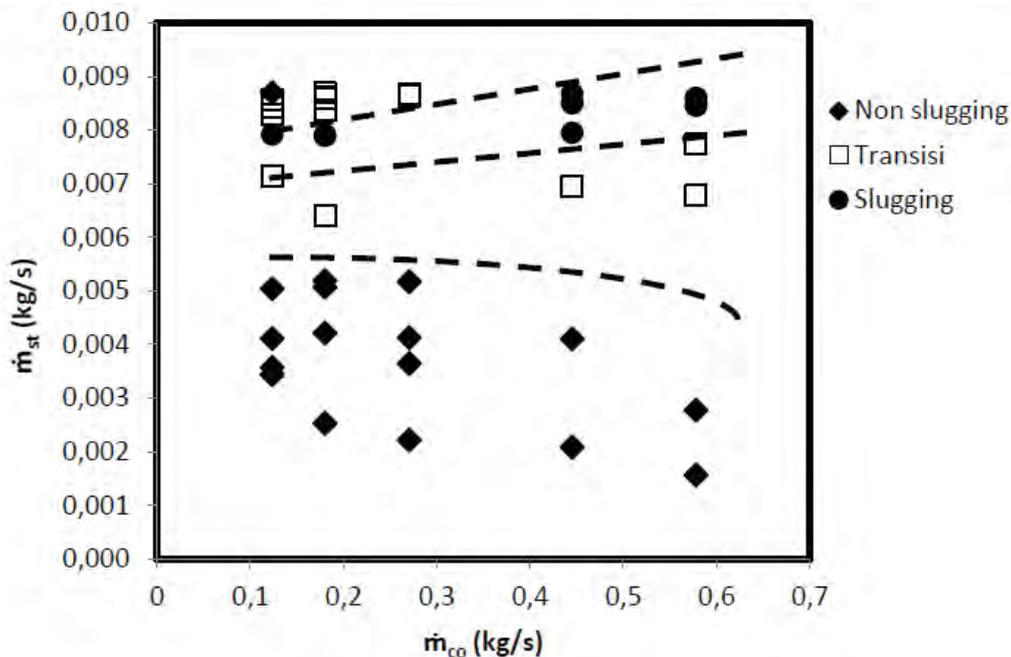


Figure 3: Flow pattern map of slugging and non slugging

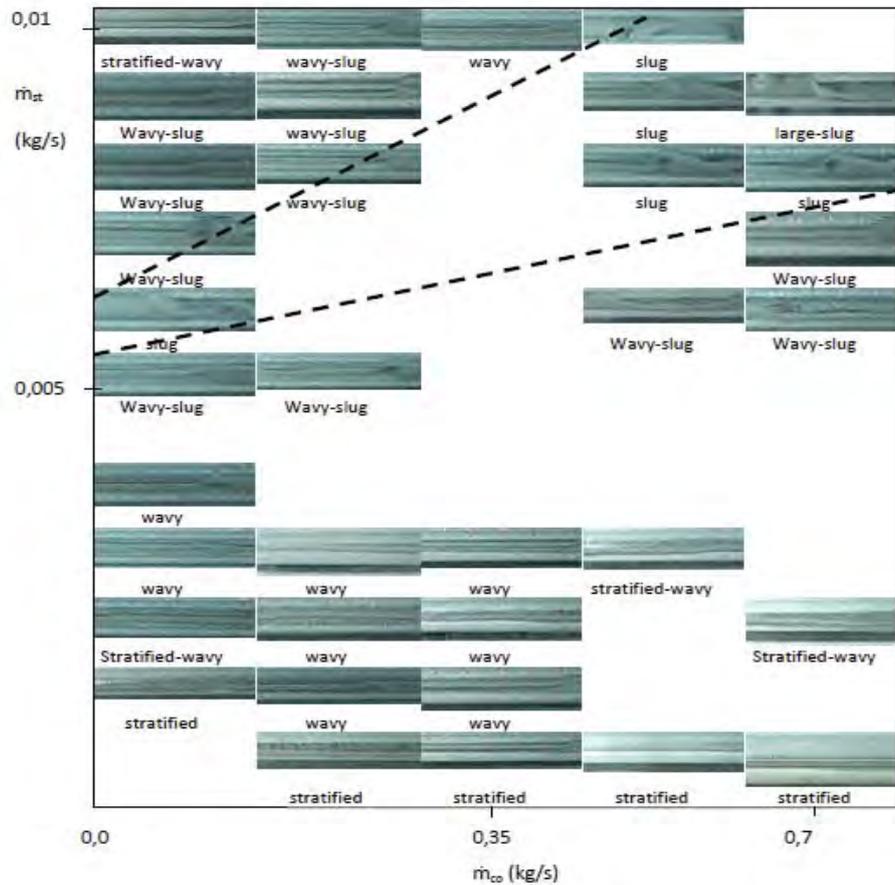


Figure 4: Visualization of flow pattern map

From this figure, it can be shown that the stratified, stratified-wavy dan wavy flow were obtained for the lowest of  $\dot{m}_{st}$  and the lowest to highest of  $\dot{m}_{co}$ . Meanwhile, for the highest of  $\dot{m}_{st}$  with the lowest of  $\dot{m}_{co}$ , the stratified-wavy dan wavy-slug were obtained. While, for the highest of  $\dot{m}_{st}$  and  $\dot{m}_{co}$ , the slug dan large-slug flow pattern were obtained. In addition, the wavy-slug flow pattern as transition from non-slugging to slugging flow pattern were obtained also for the medium of  $\dot{m}_{st}$  and lowest to highest of  $\dot{m}_{co}$ . Based on the analysis, it can be concluded that the flow pattern are stratified, stratified-wavy dan wavy (non slugging), wavy-slug (transition), slug and large-slug (slugging). These data are important for completing the database as input of early warning system design in two phase flow piping installation safety i.e. in the hotleg of pressurized water reactor (PWR), steam transportation, etc.

#### 4. CONCLUSION

As a result it was found as : 1) the flow pattern area of non slugging (stratified and wavy flow), transition (wavy-slug flow), and slugging (slug and large-slug), were determined, here the transition flow pattern of slug and large-slug is defined as a initiating of water hammer, 2) transition area range of wavy-slug flow pattern are from  $\dot{m}_{co}=1 \times 10^{-1}$  kg/s to  $\dot{m}_{co}= 6 \times 10^{-1}$  kg/s for  $\dot{m}_{st}=6 \times 10^{-3}$  kg/s to  $\dot{m}_{st}=7.5 \times 10^{-3}$  kg/s, and  $\dot{m}_{co} < 3 \times 10^{-1}$  kg/s for  $\dot{m}_{st}=8 \times 10^{-3}$  kg/s to  $\dot{m}_{st}=9 \times 10^{-3}$  kg/s. These obtained data are very important in order to develop the database for input the early warning system design in a safety of two-phase flow installation piping system during the steam condensation.

## NOMENCLATURE

d = diameter (m)  
 A=area (m<sup>2</sup>)  
 $Q_{TS}$  =Heat transfer rate (kW)  
 $\dot{m}$ =steam mass flow rate (kg/s)  
 sat=saturated  
 T = temperature (°C)  
 h = local heat transfer coefficient  
 (W/m<sup>2</sup>.K)  
 k = conduction thermal coefficient  
 (W/m.K)  
 r = radius (m)  
 $\dot{m}$  = mass flow rate (kg/m<sup>3</sup>)  
 L = length (m)  
 s = second  
 Hz = hertz

## Subscript

i = inner  
 o =outer  
 w = wall  
 cl = centerline  
 co = coolant water  
 wo= wall-outer  
 wi=wall-inner  
 bott=bottom  
 st=steam  
 av=average

## ACKNOWLEDGEMENTS

The authors gratefully acknowledge financial support of this research by Ministry of National Education of Indonesia and Muhammadiyah University of Yogyakarta to conduct this work.

## REFERENCES

- [1] Nagae T , Murase M, Wu T , Vierow K., *Evaluation Of Reflux Condensation Heat Transfer Of Steam-Air Mixtures Under Gas-Liquid Countercurrent Flow In A Vertical Tube*, Journal Of Nuclear Science and Technology, **Vol. 42, No.1**, 2005, pp. 50-57
- [2] Mandhane, J. M, Gregory G. A., and Aziz K., 1974, *A flow pattern map for gas-liquid flow in horizontal pipes*," in: Int. J. Multiphase Flow, 1, 537
- [3] Matsui G., (1984), *Identification of flow regimes in vertical gas liquid two-phase flow using differential pressure fluctuations*, Int. J. Multiphase Flow 10, 711–720.
- [4] Mastui G., (1986), *Automatic identification of flow regimes in vertical two-phase flow using differential pressure fluctuations*, Nucl. Eng. Des. 95, 221–231.
- [5] Tutu N.K.. 1984. *Pressure Drop Fluctuations and Bubble-Slug. Transition in a Vertical Two-Phase Water Flow*. Int. J. Multiphase Flow 10, 211-216
- [6] Brauner D., O. Shaham, and Y. Taitel, (1980), Int. J. Multiphase Flow, 6, 387.
- [7] Jones O.C. and Zuber N., (1975), *The interrelation between void fraction fluctuations and flow patterns in two-phase flow*. Int. J. Multiphase Flow 2, pp. 273–306
- [8] Elkow K. J. And Rezkallah K. S., (1997), *Statistical Analysis Of Void Fluctuations In Gas-Liquid Flows Under 1-g And  $\mu$ -G Conditions Using A Capacitance Sensor*, Int. J. Multiphase Flow Vol. 23, No. 5, pp. 831-844
- [9] Franca F., Acikgoz M., Lahey R.T. Jr., Clause A., (1991), *The use of fractal techniques for flow regime identification*, Int. J. Multiphase Flow 17, 545–552
- [10] Cai, Y., Wambsgans M.W., Jendrzeczyk J.A., (1996), *Application of chaos theory in identification of two-phase flow patterns and transitions in a small, horizontal, rectangular channel*, ASME J. Fluid Eng. 118, 383–390.
- [11] Wang, W.C., Ma, X.H., Wei, Z.D., dan Yu, P., 1998. *Two Phase Flow Patterns and Transition Characteristic for in-tube Condensation with different Surface inclination*, Int. J. Heat Mass Transfer, 41, 4341-4349.
- [12] Wang S.F., Mosdorf R., Shoji M., (2003), *Nonlinear analysis on fluctuation feature of two-phase flow through a T-junction*, International Journal of Heat and Mass Transfer 46, 1519–1528

# Solar Absorption Air-Conditioning System

Hajime Yabase

Kawasaki Thermal Engineering Co.,Ltd., Engineering Office,  
E-mail : yabase\_h-kte@corp.khi.co.jp

## ABSTRACT

Absorption chillers use thermal energy as driving source, and have a feature of being capable of saving electricity. Meanwhile, the global warming issue has worsened markedly in recent years, which causes us to be confronted with the urgent task of realization of low-carbon society. Under these situations, we developed single-double effect combined absorption chillers for "Solar air-conditioning system". This chiller is composed of a highly-efficient gas absorption chiller/heater with COP1.3 (gross calorific value) as a main machine. It enables low temp. solar hot water at 75degreeC under operation at the cooling rating (load factor: 100%, cooling water temp: 32degreeC). We constructed the demonstration plant in Japan. Cooling capacity is 738kW, and evacuated glass tube type solar energy collectors supply 75-90degreeC hot water to the absorption chiller. In summer, fuel gas reduction by 10% could be achieved and the results as estimated were obtained.

## Keywords

*Absorption chiller, Solar heat, Solar air-conditioning system, solar collector, Demonstration plant.*

## 1. INTRODUCTION

Absorption chillers are units to supply chilled water using gas and oil as fuel. In Japan, absorption chillers have been widely used for industrial and commercial central air-conditioning because they contribute to electric-load leveling in summer because of capable of cooling using little power, and use water having zero ozone depletion potential (ODP) as refrigerant.

Meanwhile, the global warming issue has worsened markedly in recent years, which causes us to be confronted with the urgent task of realization of low-carbon society. In Japan, power for air-conditioning accounts for 43% of total power consumption used for office buildings and absorption chillers are also strongly required saving-energy.

Under these situations, a solar cooling system which performs cooling by introducing hot water obtained from solar heat into absorption chillers using thermal energy as driving source has received increasing attention and undergone promotion of development toward practical use recently. This is because this cooling system is capable of using solar heat whose reserve amount is much abundant and whose energy conversion efficiency is higher among renewable energy for air-conditioning application with high power consumption rate in industrial and commercial fields.

We has developed a single-double effect combined absorption chiller exclusively designed for the solar cooling system and launched in June 2010. The aspect is shown in Figure 1.

We constructed the demonstration plant of this system in Japan. we report the outline and the performance of the chillers and demonstration plant.



Figure 1: Aspect of Solar Absorption Chiller

## 2. SOLAR ABSORPTION CHILLERS (SINGLE-DOUBLE EFFECT COMB-INED)

## 2.1 Use and Problem of Solar Heat

Among renewable energy, solar energy is rich in reserve, which undergoes promotion of application, however, it is almost applicable to solar battery (photovoltaic energy) but solar energy has been not picked up as the method for using as heat source so much. However, as shown in Figure 2, photovoltaic energy generation is as low as approx. 10% in generating efficiency and in case that solar energy is picked up as hot water at approx. 90°C, the energy conversion efficiency is as high as 40% and the high-end evacuated tubular type reaches 50%. The system using solar hot water as driving source is applicable only to absorption chillers practically. The conventional air-conditioning system is shown in Figure 3.

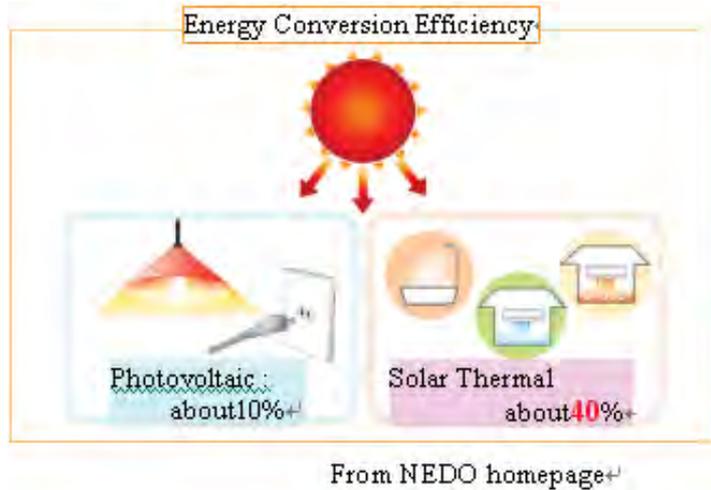


Figure 2: Solar energy conversion efficiency

However, solar heat is unstable heat source which is easily influenced by weather and it is difficult to use it according to fluctuating air-conditioning loads. Solar thermal air-conditioning system has been tried to be diffused since 1980's, however, they have been familiarized fully. The reasons are shown as follows:

- (1) As shown in Figure 3, in the solar thermal air-conditioning system, in addition to the absorption chiller, the backup boiler and accompanying machines are required, which causes the system composition to be complicated and the investment efficiency using renewable energy is not expected.
- (2) It is necessary to control the solar hot water and backup system according to fluctuations in solar heat and air-conditioning loads, however, it is difficult to control and establish an optimal control system to use solar heat efficiently, and it is necessary to familiarize local operators to learn as well.
- (3) The double-effect type which is mainly used as an absorption chiller, which requires heat at 120°C or more as driving source. In case that solar heat at approx. 90°C is used, only the single-effect system functions. In case that the backup system functions, even if fuel is used, the efficiency is low because of single effect system, the effect of introduction by renewable energy is not expected so much.

## 2.2 Improvement from Conventional System

In consideration with the problems in the above-mentioned solar thermal air conditioning, we developed single-double effect combined absorption chillers for using solar hot water preferentially in combination with backup heat source such as gas, oil, etc. (hereinafter referred to as the Solar Absorption Chillers). The improved system using them is shown in Figure 4.



Figure 3 ventional Solar Thermal Air-Conditioning System

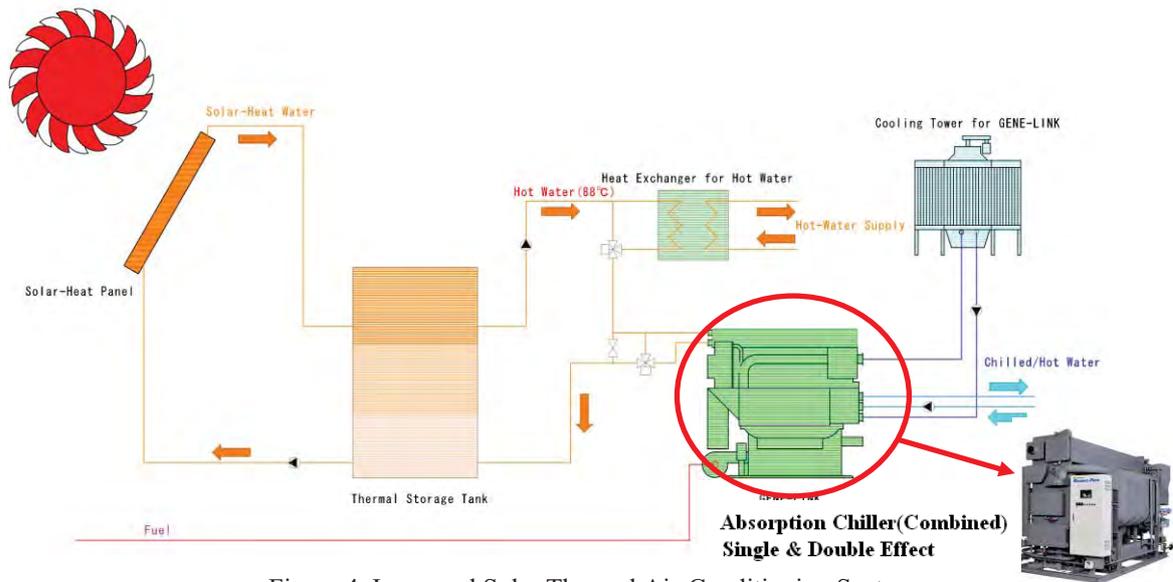


Figure 4. Improved Solar Thermal Air-Conditioning System

The features are shown as follows:

- (1) Since these solar absorption chillers are equipped with generators driven by solar hot water based on direct-fired absorption chillers, a backup system are unnecessary to be prepared, No. of composition elements are reduced, which simplifies the air-conditioning system
- (2) These solar absorption chillers control so as to use solar hot water preferentially based on driving by fuel such as gas, oil, etc. In addition, control of loading is performed according to fluctuations in air-conditioning loading.
- (3) When driving by fuel, double-effect operation is performed, the same efficiency as absorption chillers which are currently diffused is obtained, which allows saving energy operation because renewable energy is used.

### 2.3 Outline of Solar Absorption Chillers

Solar Absorption Chillers are composed of highly-efficient gas absorption chillers with COP1.3 (gross calorific value) as main machines which are equipped with a solar heat recovery unit comprising a heat recovery heat exchanger and special condenser.

As shown in the cycle-flow diagram in Figure 5, solar heat hot water is used for heating and regenerating absorbing solution at the heat recovery heat exchanger. Using refrigerant generated during this regeneration process for cooling enables the amount of fuel used for the high temp. generator to be reduced.

Generally, solar energy collectors have characteristics in which the smaller the difference in temperature between the collection temperature and outside air temperature is, the higher the collection efficiency is, therefore, it is necessary to allow solar absorption chillers to use even low temp. hot water to increase the efficiency of the overall system.

As chillers which are capable of reducing fuel consumption by introducing hot water, exhaust heat introduction absorption chillers (Gene-Link) can be considered, however, Gene-Links are products designed to use exhaust heat hot water at stably high temperature (83 to 90°C) obtained by cogeneration systems, etc. and cannot use low temp. hot water.

The reason is that Gene-Links are composed as shown in the principle drawing in Figure 6, in which refrigerant vapor generated at the heat recovery heat exchanger and refrigerant vapor generated at the low temp. regenerator are condensed in the condenser of the base absorption chillers. Therefore, the saturated temperature of the heat recovery heat exchanger is restricted by the saturated temperature of the condenser of this absorption chiller body, which prevents the log-mean temperature difference to collect low temp. hot water from being maintained.

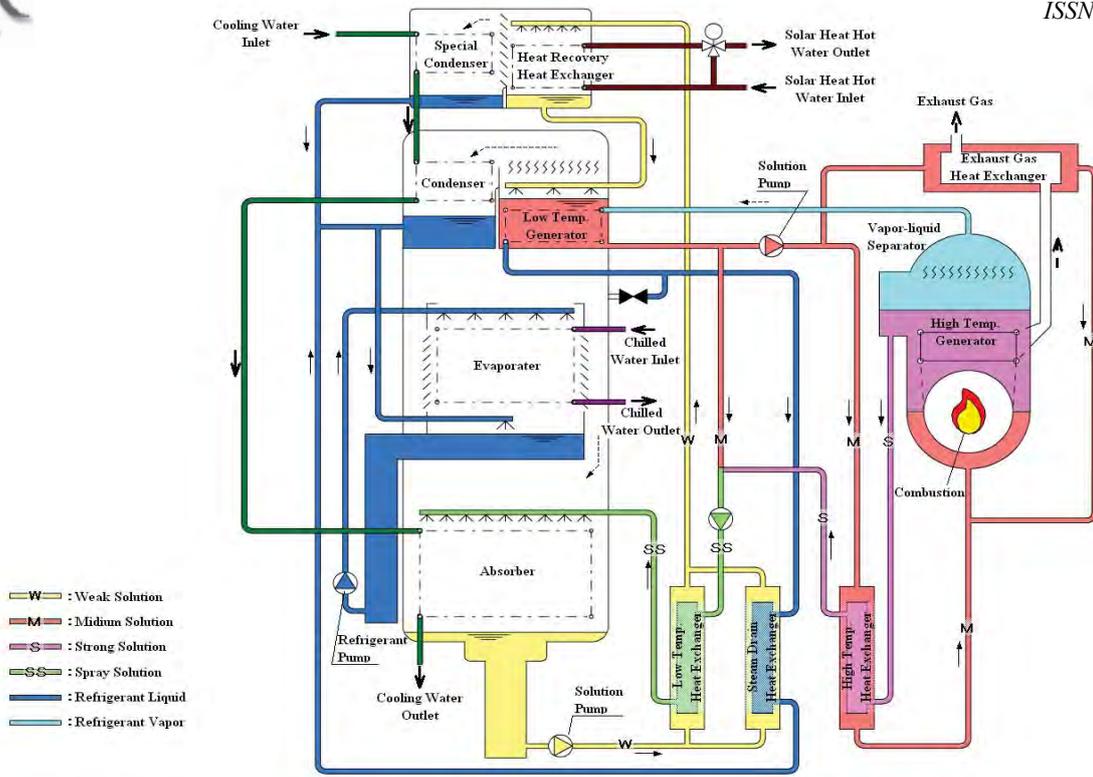


Figure 5: Cycle flow-diagram of Solar Absorption Chiller

Consequently, as shown in the principle drawing in Figure 7, in Solar Absorption Chillers, a condenser exclusive for the heat recovery heat exchanger is newly provided to separate the heat recovery unit and the base absorption chiller and a structure to initially introduce cooling water to the special condenser is employed, which reduces the pressure in the heat recovery unit and maintains the log-mean temperature difference to collect low temp. hot water.

As shown in Figure 8, these chillers enable low temp. hot water at 75°C under operation at the cooling rating (load factor: 100%, cooling water temp: 32 °C) or even lower temp. hot water depending on loading conditions and cooling water conditions to be used

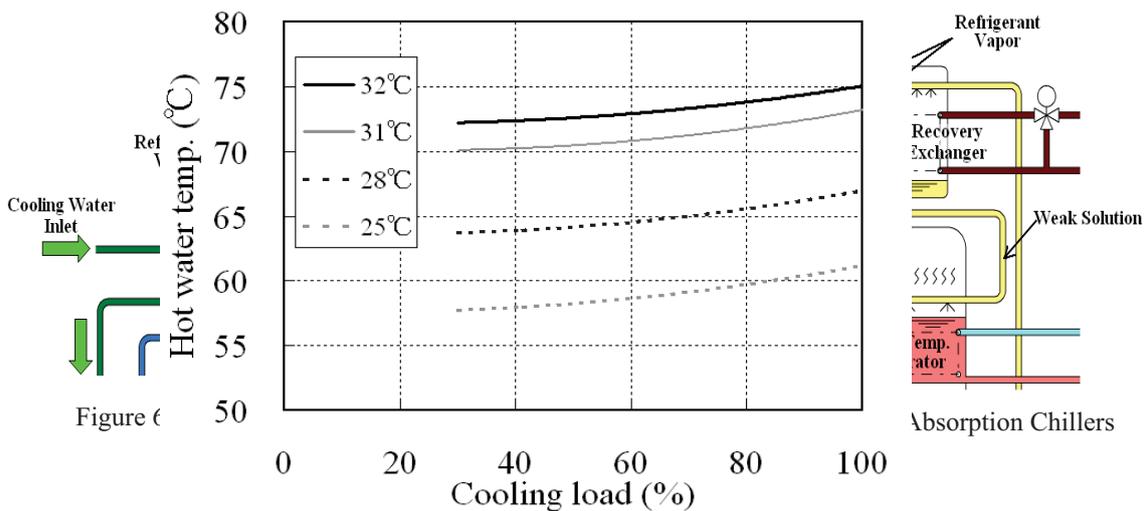


Figure 8: Hot water temperature for which Solar-Driven Hybrid Chiller can be used

### 3. SOLAR COOLING SYSTEM

#### 3.1 Outline of Solar Cooling System

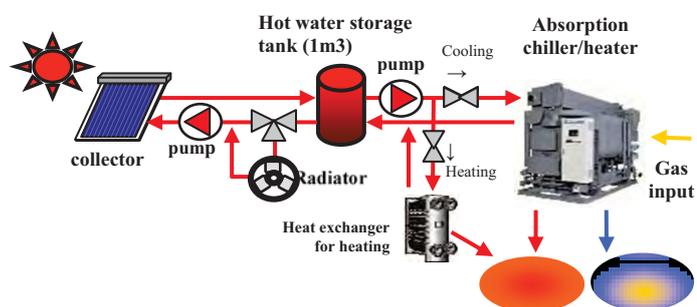


Figure 9: Schematic diagram of system

The demonstration plants are installed in our factory located in Kusatsu City of Shiga Prefecture, Japan. This system was completed in Dec. 2010 and started to undergo full-sized verification test in Feb. 2011. The flow diagram of this system is shown in Figure 9.

Solar heat (hot water at 75°C to 90°C) is introduced into the Solar Absorption Chiller. In addition, if solar heat is insufficient, the backup system to compensate for the energy through gas is available.

Evacuated glass tube type solar energy collectors which are highly efficient in a high-temp area at 75°C to 90°C is used for the solar energy collector. 160 sheets of collectors (260m<sup>2</sup>) which satisfy the exhaust heat recovery amount (0.6kW/RT, 126kW \*cooling water at 31°C) during rated operation in case of solar heat hot water of Solar Absorption Chiller at 75°C were installed on the roof of the office.

The hot water storage tank is provided to absorb the difference of flow rate between the solar energy collector and Solar Absorption Chiller and serves as a temporal cushion if solar radiation fluctuates suddenly.

The radiator is provided to prevent hot water from boiling by excessive heat collection by operating when collected solar heat cannot be used on holidays, etc.



Figure 10: Aspect of Collector

### 3.2 Feature of Solar cooling system

#### 3.2.1 Lowering the temperature of solar heat usable area

Collector	<evacuated tube> 1.62m <sup>2</sup> ×160 sets	total area: 260m <sup>2</sup> (aperture area: 213m <sup>2</sup> ) conductor: water tilt angle: 8° azimuth angle: SSE35° output(Max): 128kW
absorption chiller	cooling capacity 738 [kW](210RT)	

Generally, solar energy collectors have characteristics in which the smaller the difference in temperature between the collection temperature and outside air temperature is, the higher the collection efficiency is, therefore, it is necessary to allow solar absorption chillers to use even low temp. hot water to increase the efficiency of the overall system.

As section 2 already described, in the Solar Absorption Chiller in this system, solar heat at 75°C (rated) and approx. 60 °C (under partial loading) can be used by employing a hot water heat exchanger optimized for use of solar heat and improving the flow of cooling water.

#### 3.2.2 Simplifying and downsizing the solar system

The auxiliaries (Figure 11) such as pumps, etc. to supply hot water obtained from the solar energy collector to the Solar Absorption Chiller are required, however, those items are simplified as much as possible while considering packaging with the Solar Absorption Chiller.

Packaging after reflecting these verification results can reduce the details of work at site and costs for building up the system as one of targets.

#### 3.2.3 Controlling and Monitoring System

When introducing the solar cooling system, it was necessary to specially build up the control functions such as starting/stopping the heat collecting facility and excessive solar heat collection of the solar energy collector, however, these control functions are assembled into the Solar Absorption Chiller in this system and control of the overall system is enabled.

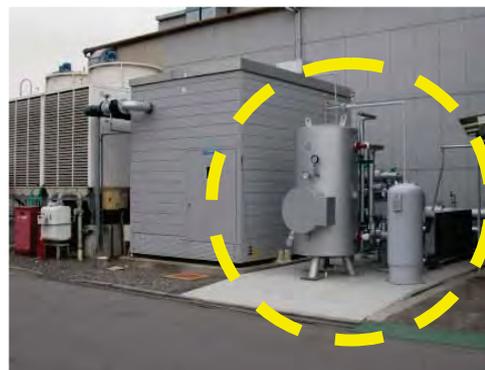


Figure 11: Collection of heat facility

Assembling the control functions into the Solar Absorption Chiller maximizes the saving energy effect based on the use of solar heat by strengthening the linkage with the control functions of the Solar

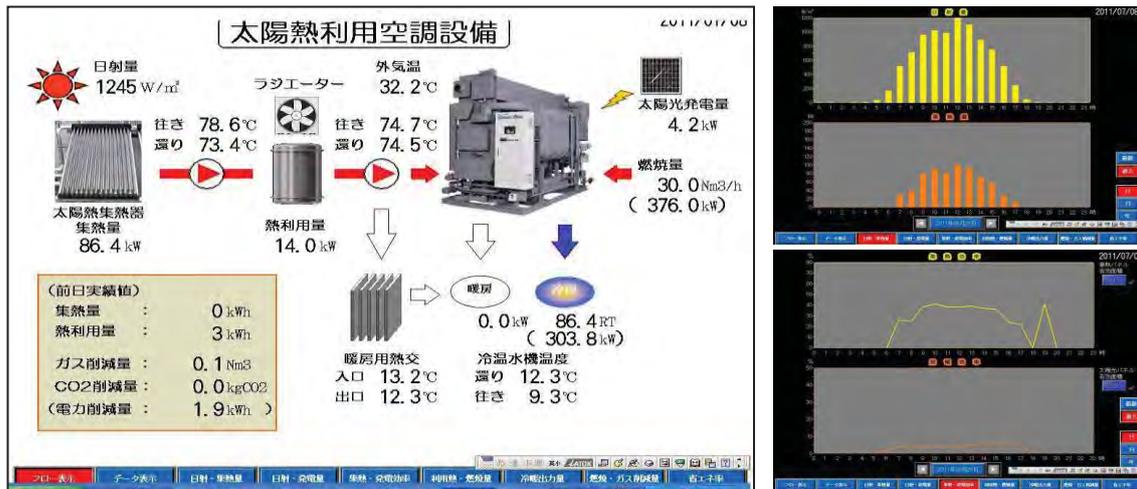


Figure.12: Monitoring System

Absorption Chiller in addition to eliminating the needs of the special control equipment.

Some examples of linkage control with the Solar Absorption Chiller added to this system are shown as follows:

- (1) Backup linkage at the Solar Absorption Chiller
- (2) Interlocking control in response to change in the temperature setting

Further, the system is equipped also with the information collection function to monitor the system operation status and energy-saving effect.

Figure 12 shows a part of the monitor system to display the collection data. The monitor system enables daily and hourly collection amount and efficiency to be displayed, which contributes to the grasping of operation conditions and review for improvement of system.

As mentioned above, when building up the solar cooling system, cost reduction is a big issue. Assembling the control system and monitor system into the Solar Absorption Chiller greatly serves to reduce the cost for building up the system.

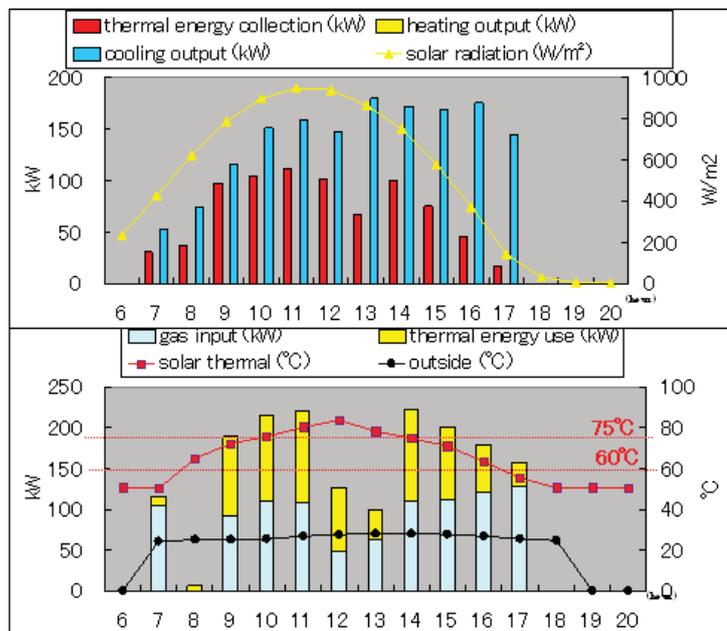


Figure 13: Operation data of cooling (20th May)

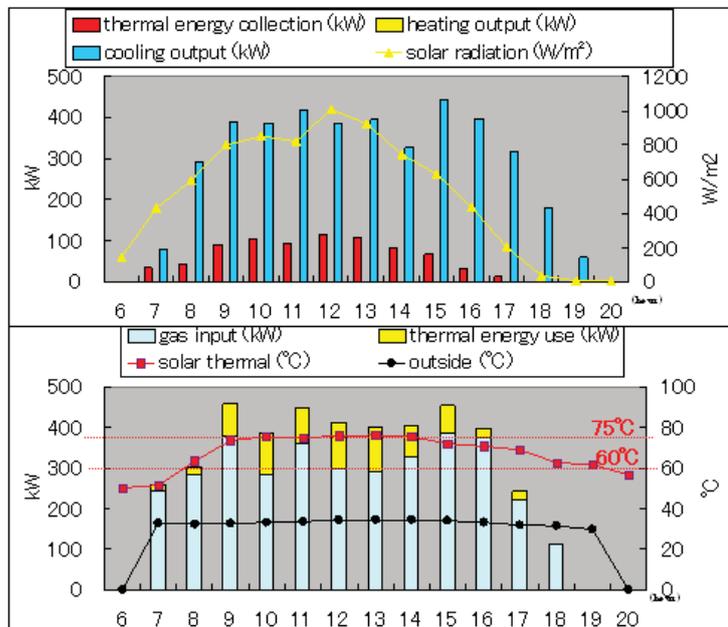


Figure 14: Operation data of cooling (28th July)

### 3.3 Evaluation status and results

#### 3.3.1 Operation conditions

Figure 13 shows the operation data on May 20 and Figure 14 shows the operation data on June 28. From the data, it was confirmed that the solar heat priority usage function and gas-based backup function operate properly and overall system functions normally.

Because of operations with comparatively-low loads on the conditions where the maximum temperature was 28.4°C and the air-conditioning loading factor was 23% on May 20, the gas amount could be reduced by 25%. Meanwhile, the maximum temperature was 34.5 °C and the air-conditioning loading factor was as high as 60% on June 28, however, the gas amount could be reduced by 11%.

Cooling operation starts in late May, therefore, the monthly reduction rate shows the data only in June, however, reduction by 10% could be achieved and the results as estimated were obtained.

#### 3.3.2 Effect of Solar Absorption Chiller

It was confirmed that hot water obtained from the solar energy collector is constantly used at 75°C or less and can be used even at approx. 60 °C during low-load operations.

In the actual system, the effect could not be quantified because fluctuation in solar radiation and load should be considered, however, use of Solar Absorption Chiller developed exclusively for use of solar heat can reduce the hot water temperature from the solar energy collector more than use of conventional exhaust heat introduction type absorption chiller (Gene-Link) , therefore, it was confirmed that this system increased the collection efficiency of the solar energy collector and improves the efficiency of overall system.

#### 3.3.3 Improvement points

When changing to the low-load operation mode where the refrigerant pump of the chiller activates the start/stop control, introduction of hot water is turned on and off interlinking with start/stop of the refrigerant pump, however, even in operable load only by solar heat hot water, it is confirmed that the pick-up temperature increases due to output delay when turning on and backup control by combustion activates. We plan to review the control to minimize the delay and add it to the system.

## 4. CONCLUSION

- (1) The Combination of the heat recovery exchanger and special condenser of Solar Absorption Chiller enables the machine to be operable even if the temperature decreases up to 75°C and does not require the backup by combustion gas in an area with 30% or less of load factor
- (2) In case where the temperature of hot water is 90 °C, the reduction rate of combustion gas at 100% load factor becomes 32%, therefore, the performance increased in comparison with 26% of the conventional Gene-Link. In addition, the cooling load area operable only by hot water was expanded to approx. 57%.
- (3) From the verification of the demonstration plant of solar cooling system, the usefulness of the Solar Absorption Chiller developed exclusively for use of solar heat was confirmed.
- (4) Further, we make sure that our built-up system is useful to make it easier to introduce a solar cooling system. By commercializing the system into which improvement points during verification were fed back in the future, we aim to make the solar cooling system to be recognized as a useful solution tool for global warming problem and promote them..

## REFERENCES

- [1] Hyodo, Y., 2011, *Solar Absorption Chillers using solar heat for cooling of Kawasaki Thermal Engineering Co., Ltd*, Clean Energy, vol.20, no.3, pp.5-9.
- [2] R. Kajii, H. Yabase, M. Ohta, 2011, *Development of Solar Absorption Chillers-Heaters*, Trans. Of the JSRAE, vol.28, no.3, pp.249-256.

# Comparison between CFD Simulation and Experimental Heat Transfer Coefficient of Natural Refrigerants in Minichannel

Nguyen-Ba Chien<sup>a</sup>, Kwang-II Choi<sup>b</sup>, Jong-Taek Oh<sup>b\*</sup>, Kiyoshi Saito<sup>c</sup>, Jong SooJeong<sup>c</sup>

<sup>a</sup>Graduate School, Chonnam National University, San 96-1, Dunduk-Dong, Yeosu, Chonnam 550-749, Republic of Korea

<sup>b</sup>Department of Refrigeration and Air Conditioning Engineering, Chonnam National University, San 96-1, Dunduk-Dong, Yeosu, Chonnam 550-749, Republic of Korea

<sup>c</sup>Department of Applied Mechanics and Aerospace Engineering, Waseda University, 1-104, Totsuka-machi, Shinjuku0ku, Tokyo 169-8050, Japan

## ABSTRACT

The comparison between computer fluid dynamic (CFD) simulation and experimental heat transfer coefficient of natural refrigerants in minichannel was investigated in this studied. The experimental data were conducted in the horizontal circular small tubes of 1.5 and 3.0 mm inner diameter, the length of 1000 and 2000 mm, the conditions of experiment were described as following: the mass flux range from 200 – 650 kg/m<sup>2</sup>s, the heat flux varied from 5 to 40 kW/m<sup>2</sup> and saturation temperature changed from 0 to 10°C. The boiling heat transfer coefficient of natural refrigerant was evaluated and compared to CFD predictions. The results showed that the simulation were able to reproduce the general features acquired in the experiments.

**Keywords:** Heat transfer coefficient; Correlation; CFD simulation; natural refrigerant; minichannel.

\* Corresponding Author: **Email:** ohjt@chonnam.ac.kr, **Tel:** +82-61-659-7273; **Fax:** +82-61-659-7279

## 1. INTRODUCTION

During the development of the refrigeration and air conditioning industry, refrigerants have gone to the 4<sup>th</sup> generation (James M. Calm, 2008). Due to the implement of Global warming and the Ozone depletion, the future refrigerants should meet the demand of the environmental criterions, such as: low global warming and Ozone depletion potential. In addition, the future ones also might to be compatible with new technology, market as well as passing the safety policy.

In improvement process of the next refrigerant generation, natural refrigerant; that has been used widely in refrigerant industry such as CO<sub>2</sub> and ammoniac, paid the considerable attentions to researchers. Many studies have been evaluating their fluid flow and heat transfer through the experimental and numerical methods recently.

Pettersen et al. (2004), Yun et al. (2005), Choi et al. (2007), Hihara et al. (2009) and Wu et al. (2011) investigated the heat transfer and pressure drop of CO<sub>2</sub> experimentally. Pamitran et al. (2011) estimated the evaporative heat transfer of three natural refrigerants include CO<sub>2</sub>, NH<sub>3</sub> and C<sub>3</sub>H<sub>8</sub>. The results were compared to many existing correlation and the modified correlation of heat transfer coefficient of three refrigerants also were developed.

He et al. (2005) and Masoud (2009) investigated numerically the convective heat transfer of CO<sub>2</sub> in a porous tube. Masoud used FLUENT code 6.1 to simulate the single phase flow and the force convective heat transfer of CO<sub>2</sub> at the supercritical pressure.

In this study, the comparison between CFD simulation and experimental heat transfer coefficient of two natural refrigerants CO<sub>2</sub> and NH<sub>3</sub> was presented. The effects of mass flux, heat flux, saturation temperature and inner diameter on the heat transfer coefficient were analyzed. The results of CFD simulation show a good agreement with experimental ones.

## 2. EXPERIMENTAL SETUP

### 2.1 Experimental facility

The experimental apparatus is comprised of a refrigerant loop, three water loops, and a data acquisition system. A schematic diagram of the refrigerant loop was shown in Figure 1. The refrigerant flow system consists of a condensing unit, receiver, refrigerant pump, mass flow meter, and pre-heater. Vapor phase refrigerant from the evaporative test

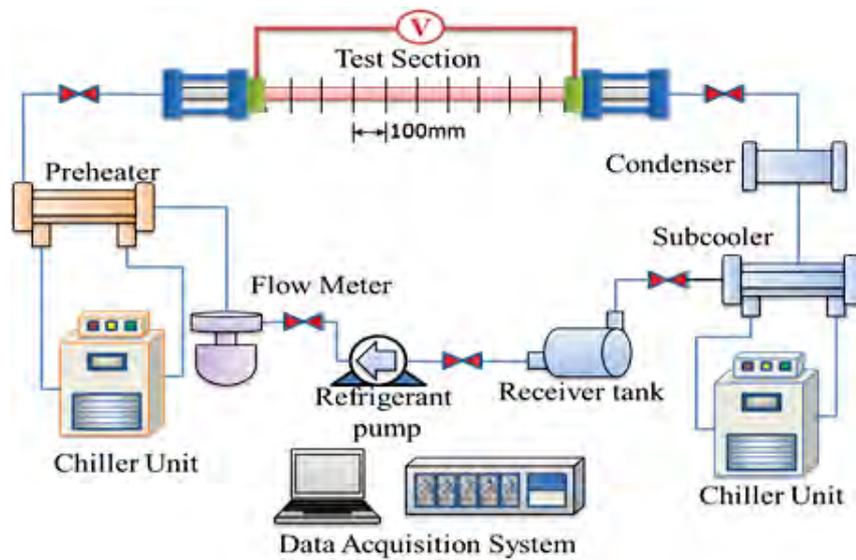


Figure1. Schematic of experimental apparatus

section was condensed into the liquid phase in the condensing unit. The condensed refrigerant was then supplied to the receiver and pumped by the refrigerant pump, which is connected to an electric motor controller used to control the flow rate of the refrigerant. A Coriolis-type mass flow meter was used to measure the refrigerant flow rate. The mass vapor quality at the inlet of the test section was controlled using a pre-heater. Temperatures of condenser, sub-cooler and pre-heater were adjusted by three individual water loops.

The test sections were made of circular stainless steel smooth tubes with inner diameters of 1.5 and 3.0 mm, a heated lengths of 1000 and 2000mm in the horizontal orientation. For evaporation at the test section, power was supplied from an electric transformer to the test section. The input electric voltage and current were adjusted to control the input power. The test section was well insulated with rubber and foam. The outside tube wall temperatures at the top and bottom side were measured at every 100 mm axial intervals of the heated length using thermocouples at each measured site. The local saturation pressure, which was used to determine the saturation temperature, was measured using Bourdon tube-type pressure gauges at the inlet and the outlet of the test section, as shown in Figure 1. A pressure transducer was installed to measure the pressure gradient of the refrigerant flowing along from the inlet to outlet of the test section. Sight glasses with the same inner diameter as the test section and a length of 200 mm were installed to visualize the flow and to enhance the flow stability of the fluid when entering the test section.

The physical properties of the refrigerant were obtained from REFPROP 8. The temperature and flow rate data were recorded using data acquisition and flow meter, respectively. Table 1 gives a summary of the estimated uncertainty associated with all the parameters at a 95% confidence interval. The uncertainties were obtained using both random and systematic errors, and these changed values according to the flow conditions, so their minimum to maximum ranges were shown.

## 2.2 Experimental data reduction

The local heat transfer coefficients at position  $z$  along the length of the test section were defined as follow, with  $q$  is heat flux and  $T$  is temperature.

$$h = \frac{q}{T_{wi} - T_{sat}} \quad (1)$$

The inside tube wall temperature,  $T_{wi}$  was the average temperature of the top, left sides, and the bottom wall temperatures, and was determined based on the steady-state one-dimensional radial conduction heat transfer through the wall with internal heat generation. The vapor quality,  $x$ , at the measurement locations,  $z$ , were determined based on the thermodynamic properties.

$$x = \frac{i - i_l}{i_{lv}} \quad (2)$$

Table1 Summary of the estimated uncertainty

Parameter	Uncertainty
$T_{wi}$ (%)	$\pm 0.18$ to $\pm 5.58$
$P$ (kPa)	$\pm 2.5$
$G$ (%)	$\pm 1.85$ to $\pm 9.78$
$q$ (%)	$\pm 1.67$ to $\pm 3.58$
$x$ (%)	$\pm 1.79$ to $\pm 9.89$
$h$	$\pm 1.78$ to $\pm 27.6$

The refrigerant flow at the inlet of the test section was not completely saturated. The subcooled length was calculated using the following equation to determine the initial point of saturation.

$$z_{sc} = L \frac{i_l - i_{li}}{\Delta i} = L \frac{i_l - i_{li}}{\left(\frac{q}{W}\right)} \quad (3)$$

In eq. (2) and (3),  $i_{li}$  is enthalpy and  $L$  is tube length.

### 3. NUMERICAL SETUP

In this study, the ANSYS FLUENT v14 was used to simulate force convective boiling heat transfer of the natural refrigerants in the minichannel. The Eulerian multiphase and the RGN  $k-\epsilon$  model for each phase were applied. A computer with Intel E3-Xeon 1230V2 (8Mb cache, 3.3 GHz) with 16 GB ram was used in this simulation.

#### 3.1 Computational grid

The geometry was created in ANSYS WORKBENCH 14 and meshed later in ANSYS MESH ICEM. In this simulation, both the pipe and the fluid control volume were modeled. The meshing of domains was shown in Figure 2. The inflation with 5 layers was used at the fluid region near tube wall. The interior of fluid and pipe was meshed by sweep method. The grid was composed of 97497 nodes and 90022 elements. The maximum and minimum skewness values were reported at 0.53 and  $2.7 \times 10^{-2}$ , respectively. This meshing solution was selected after comparing to some further refinements.

#### 3.2 Wall boiling models

In this study, the two-phase flow convective boiling of the mini tube was carried out in five conditions of CO<sub>2</sub>. The solver was set up in steady state, pressure base type with an absolute velocity formulation. The properties of materials obtained in REFPROP 8 were set up in piecewise-linear mode for each phase. To model multiphase flow, the Eulerian model was used with boiling parameter. The wall boiling in nucleate boiling regime was modified from the model of Kurul and Podowski. To resolve for departed nucleate boiling regime, its formulation extended by Lavieville et al was used. The total wall heat flux was defined as following equation:

$$q_w = (q_c + q_Q + q_E) f(\alpha_l) + (1 - f(\alpha_l)) q_v + q_G \quad (4)$$

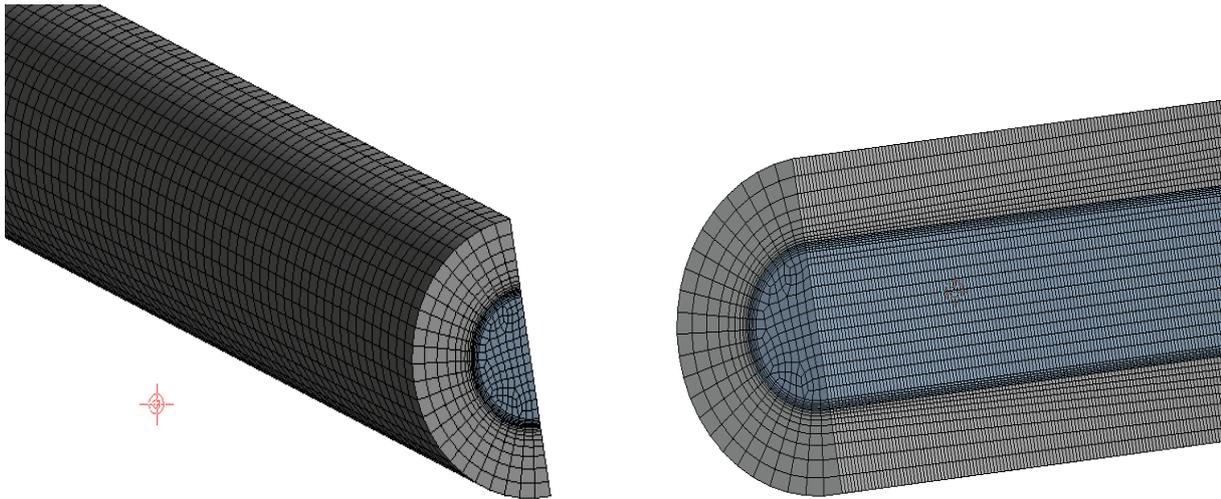
Where  $q_c$ ,  $q_Q$ ,  $q_E$  are convective heat, quenching heat flux, evaporative heat flux in the single phase, respectively.  $q_c$  models the heat flux transferred to the near wall liquid phase outside of nucleating bubbles influence area  $A_b$ .  $q_c$  was expressed as:

$$q_c = h_c (T_w - T_l) (1 - A_b) \quad (5)$$

Here,  $h_c$  is single phase heat transfer coefficient.  $T_w$  and  $T_l$  are the temperatures of wall and liquid phase near the wall, respectively.

The quenching heat flux  $q_Q$  in Eq. (4) models the cyclic averaged transient energy transfer related to liquid filling the wall vicinity after bubble detachment defined by equation:

$$q_Q = \frac{2k_l}{\sqrt{\pi \lambda_l T}} (T_w - T_l) \quad (6)$$



**Figure 2** The grid of test section

Because the velocity and temperature profiles in the bubbly boundary layer deviate from single-phase counterparts, the quenching model correction was used with the  $y^+$  value fixed to 250 as default. The evaporative flux  $q_E$  is determined as:

$$q_E = V_d N_w \rho_v i_{lv} f \quad (7)$$

In the Eq. (4),  $q_v$  and  $q_G$  present the convective heat flux of vapor phase and any others possible gas phase in a system, respectively. These parameters can be derived as:

$$q_V = h_V (T_W - T_V) \quad (8)$$

$$q_G = h_G (T_W - T_G) \quad (9)$$

The function  $f(\alpha_l)$  was proposed by Lavieville et al. (2005). That value could depend on the local liquid volume fraction  $\alpha_l$  with similar limiting values  $\alpha_{l,crit}$  as the the liquid volume fraction. The critical value for the liquid and vapor volume fraction is 0.2 and 0.8, respectively.

$$f(\alpha_l) = \begin{cases} 1 - \frac{1}{2} e^{-20(\alpha_l - \alpha_{l,crit})} & \alpha_l \geq \alpha_{l,crit} \\ \frac{1}{2} \left(\frac{\alpha_l}{\alpha_{l,crit}}\right)^{20\alpha_{l,crit}} & \alpha_l < \alpha_{l,crit} \end{cases} \quad (10)$$

The area of bubbles influence is defined as

$$A_b = \min \left( 1, K \frac{N_w \pi D_w^2}{4} \right) \quad (11)$$

The size of the bubble influence area around the nucleation site on the heated wall  $K$  is defined based on the Del Valle and Kenning's study. According to his study,  $K$  varies between 1.8 and 5:

$$K = 4.8 e^{\left(-\frac{Ja_{sub}}{50}\right)} \quad (12)$$

Here,  $Ja_{sub}$  is the subcooled Jacob number and defined as

$$Ja_{sub} = \frac{\rho_l c_{pl} (T_{sat} - T_l)}{\rho_v i_{lv}} \quad (13)$$

The nucleate site density  $N_w$  is presented by a correlation based on the wall superheat. In Lemmert and Chawla's study, the empirical parameters  $n$  and  $C$  were set equal 1.805 and 210, respectively

$$N_w = C^n (T_w - T_{sat})^n \quad (14)$$

In Eq. (11),  $D_w$  is the bubble departure diameter. It is defined by the model of Tolubinski as:

$$D_w = \min \left( 0.0014, 0.0006 e^{-\frac{Ja_{sub}}{45}} \right) (\text{mm}) \quad (15)$$

The frequency of bubble departure is denoted by  $f$  parameter based on Cole study.

$$f = \frac{1}{T} = \sqrt{\frac{4g(\rho_l - \rho_v)}{3\rho_l D_w}} \quad (16)$$

### 3.3 Interfacial area

The interaction between two-phase is modeled with the interfacial forces including drag force  $\vec{F}_D$ , lift force  $\vec{F}_L$  and turbulence drift forces,  $\vec{F}_{iv}^{TD}$ . The drag force was denoted as:

$$\vec{F}_D = \frac{3}{4} \frac{C_D}{d_b} \alpha_g \rho_i |\vec{u}_g - \vec{u}_i| (\vec{u}_g - \vec{u}_i) \quad (17)$$

Where  $d_b$  is the Sauter men bubble diameter from the interfacial area transport equation and  $C_D$  is the drag coefficient. In this study, the drag force of Ishii and Zuber correlation was used. The lift force can be calculated as

$$F_{iv}^L = -F_{iv}^L = -C_L \alpha_v \rho_i (\vec{u}_v - \vec{u}_i) \times (\nabla \times \vec{u}_i) \quad (18)$$

The lift coefficient  $C_L$  was determined via correlation of Tomiyama et al. It combines the action of classical aero dynamic lift force and the interaction between the bubble and the vortices shed by the bubble wake. The equation is described as:

$$C_{Lift} = C_{LF} + C_{WK} \quad (19)$$

The turbulence drift force in ANSYS FLUENT Eulerian multiphase model is based on the correlation of Simonin. It was modified from Rhee and Chow correlation to stable the volume flux calculation. This study used the default turbulent drift force model:

$$\vec{F}_{iv}^{TD} = -\vec{F}_{vi}^{TD} = -C_{TD} \rho_1 k \nabla \alpha_v \quad (20)$$

Here, the turbulent dispersion coefficient  $C_{TD}$  is set to 1.0 as default value.

## 4. RESULTS AND DISCUSSION

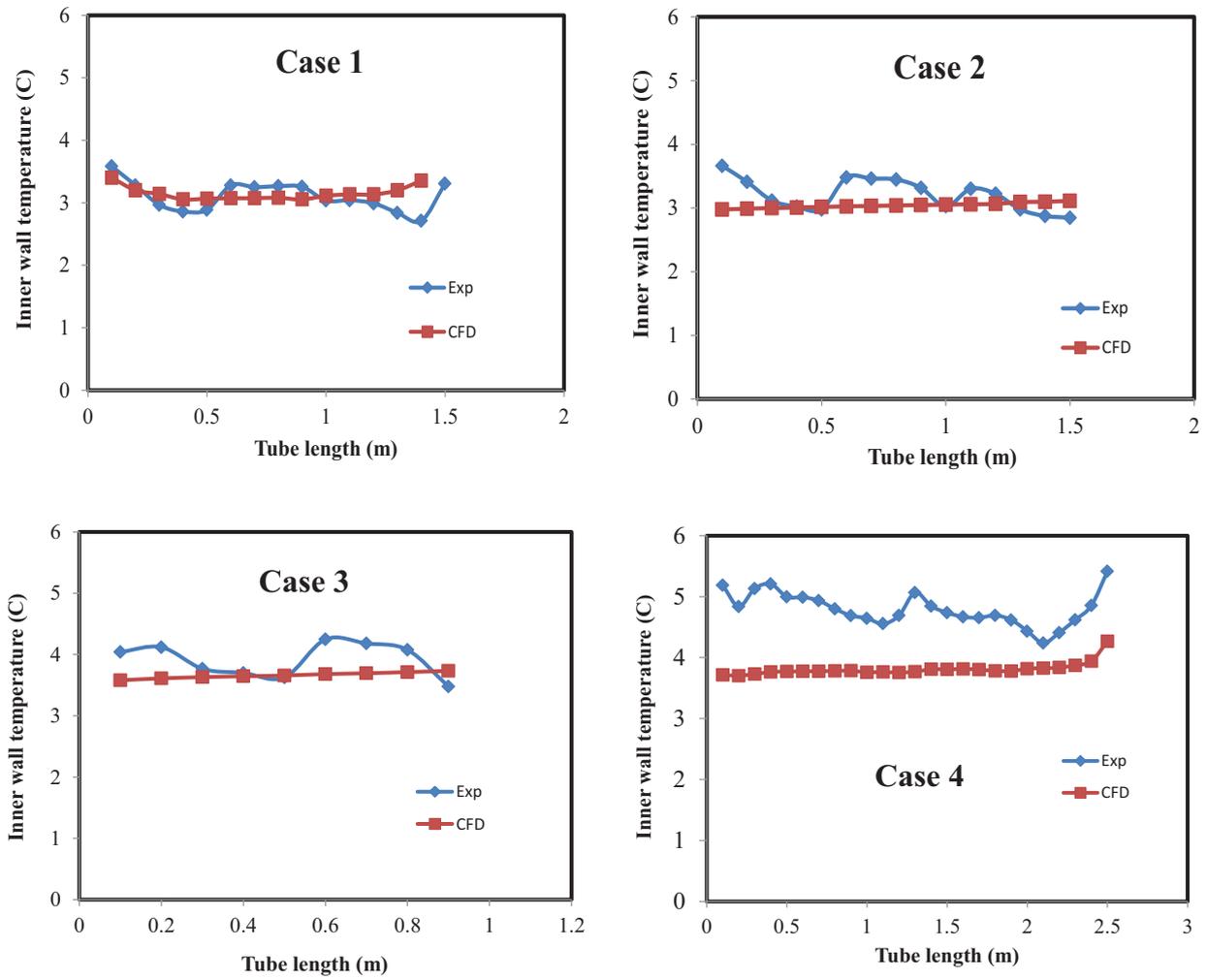
According to the explanation above, four experimental testing results of CO<sub>2</sub> analyzed in the discussion were simulated in ANSYS FLUENT for a comparison. The details of testing conditions were shown in the table 2.

Figure 3 illustrated the comparison of inner tube surface temperatures between the experimental test and CFD simulation. Both the temperatures of experimental test and CFD are average values taken at the top, mid and bottom of the test section. The results showed a good prediction of CFD simulation exception of case 4. This experimental temperature of case 4 is higher than the simulated one.

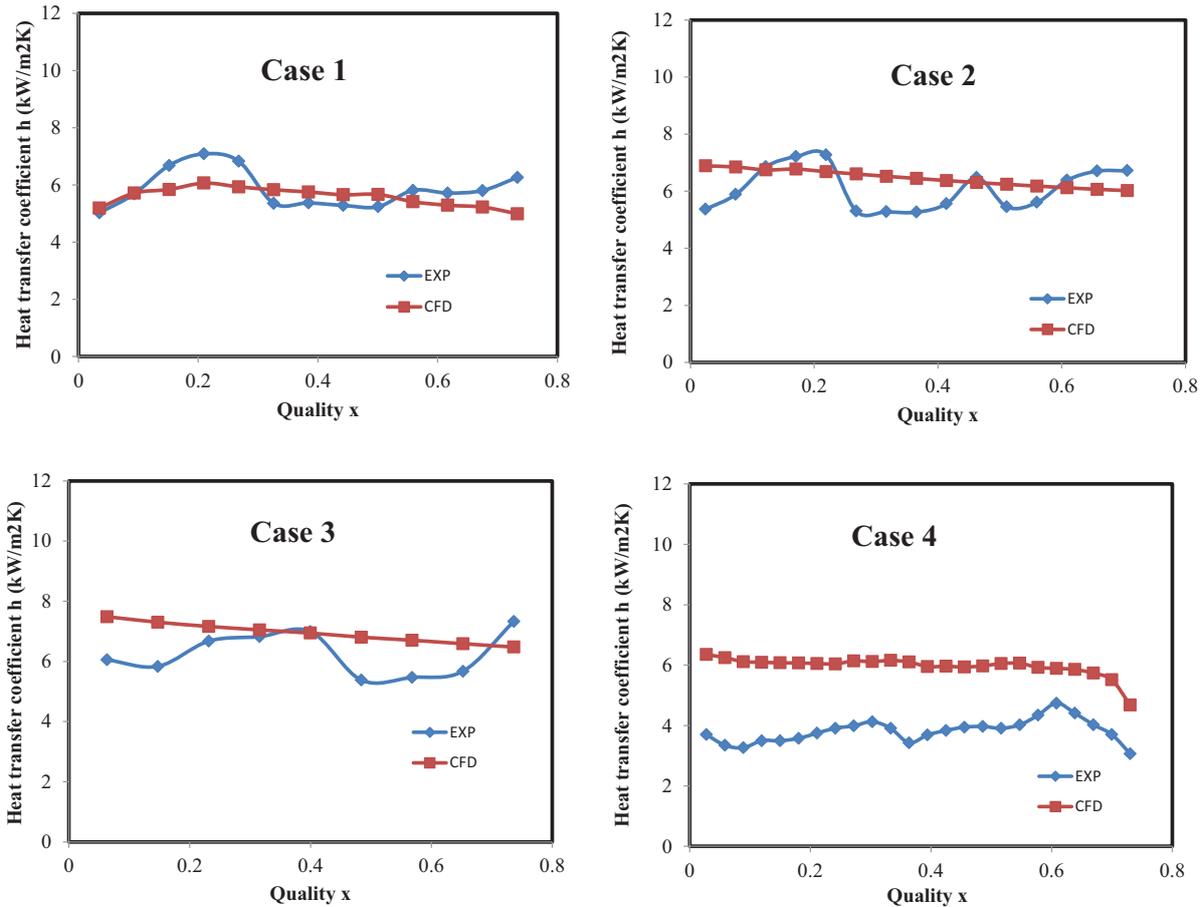
The comparison of heat transfer coefficient between the experimental test and the CFD simulation was depicted in Figure 4. The heat transfer coefficient in simulation results showed the closed values to the experimental ones.

**Table 2.** Experimental conditions

Case	Refrigerant	Diameter(mm)	Tsat (°C)	q (kW/m <sup>2</sup> )	G (kg/m <sup>2</sup> s)	T inlet (°C)
1	CO <sub>2</sub>	1.5	0	10	400	3.58
2		1.5	0	10	500	3.66
3		1.5	0	15	400	4.04
4		3.0	0	10	400	5.18



**Figure 3** Comparison of inner wall surface temperature between experimental test and CFD simulation in four cases (table 2).



**Figure 4** Comparison of heat transfer coefficient between the experimental results and CFD simulation in four cases (Table 2)

## 5. CONCLUSIONS

In this study, the convective heat transfer coefficient of two natural refrigerants CO<sub>2</sub> and NH<sub>3</sub> were carried out through experimental test and CFD simulation. The effect of mass flux, heat flux, inner tube diameter and the saturation temperature were analyzed. The results presented that the heat transfer coefficient increased with the increasing of mass flux, heat flux, saturation temperature and the decreasing of inner tube diameter. The Eulerian model in FLUENT was used to simulation the convective boiling heat transfer. The prediction shows a good result comparing to the one of experimental test.

## 6. ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea(NRF) Grant(NRF-2010-D00093) of the NRF-JSPS cooperative program.

## 7. REFERENCES

- [1] REFPROP 8, 2007, NIST Reference Fluid Thermodynamic and Transport Properties, National Institute of Standards and Technology, Boulder, Colorado 80305, USA.
- [2] N. Kurul and M. Z. Podowski. "On the modeling of multidimensional effects in boiling channels". In Proceedings of the 27th National Heat Transfer Conference, Minneapolis, Minnesota, USA. 1991.
- [3] J. Lavieville, E. Quemerais, S. Mimouni, M. Boucker and N. Mechtoua. "NEPTUNE CFD V1.0 Theory Manual", EDF, 2005.
- [4] V. H. Del Valle and D. B. R. Kenning. "Subcooled flow boiling at high heat flux". International Journal of Heat and Mass Transfer. 28(10). 1907–1920. 1985.
- [5] M. Lemmert and L. M. Chawla. Influence of flow velocity on surface boiling heat transfer coefficient in Heat Transfer in Boiling. E. Hahne and U. Grigull, Eds., Academic Press and Hemisphere, New York, NY, USA. 1977.
- [6] R. Cole. "A Photographic Study of Pool Boiling in the Region of the Critical Heat Flux". AIChEJ.. 6. 533–542. 1960.

- [7] A. Tomiyama, H. Tarnai, I. Zun and S. Hosokama. "Transverse Migration of Single Bubbles in Simple Shear Flow". *Chem. Eng. Sci.* 57. 1849–1858. 2002.
- [8] C. Simonin and P. L. Violette. "Predictions of an Oxygen Droplet Pulverization in a Compressible Subsonic Coflowing Hydrogen Flow". *Numerical Methods for Multiphase Flows. FED91*. 65–82. 1990.
- [9] Z.Y. Bao, D.F. Fletcher, B.S. Haynes. "Flow boiling heat transfer of freon R11 and HCFC123 in narrow passages". *Int. J. Heat Mass Transfer*, 43 (2000), pp. 3347–3358.
- [10] M. Ishii, N. Zuber, Drag coefficient and relative velocity in bubbly, droplet or particulate flows, *AIChE J.* 25 (1979) 843-855
- [11] J. Pettersen. Flow vaporization of CO<sub>2</sub> in microchannels tubes. *Exp. Therm. Fluid Sci.*, 28 (2004), pp. 111–121
- [12] Yun, Y. Kim, M.S. Kim. Flow boiling heat transfer of carbon dioxide in horizontal mini tubes. *Int. J. Heat Fluid Flow*, 26 (2005), pp. 801–809
- [13] Hihara, E., Haraguchi, N., Dang, C., 2009. Boiling heat transfer of carbon dioxide inside a small size internal grooved tube. In: *Proc. 3rd IIR Conf. on Thermophysical Properties and Transfer Processes of Refrigerants*, Boulder, CO, Paper no. 117.
- [14] P.A. Kew, K. Cornwell. Correlations for the prediction of boiling heat transfer in small-diameter channels. *Appl. Therm. Eng.*, 17 (1997), pp. 705–715.
- [15] J. Wu, T. Koettig, C. Franke, D. Helmer, T. Eisel, F. Haug, J. Bremer. Investigation of heat transfer and pressure drop of CO<sub>2</sub> two-phase flow in a horizontal minichannel. *Int. J. Heat Mass Transf.*, 54 (2011), pp. 2154–2162.
- [16] K.-Il. Choi, A.S. Pamitran, J.-T. Oh. Two-phase flow heat transfer of CO<sub>2</sub> vaporization in smooth horizontal minichannels. *Int. J. Refrigeration*, 30 (2007), pp. 767–777.
- [17] S. He, et al., A computational study of convection heat transfer to CO<sub>2</sub> at supercritical pressure in a vertical mini tube, *International Journal of Thermal Science* 44 (2005) 521–530.
- [18] Masoud Haghshenas Fard. CFD modeling of heat transfer of CO<sub>2</sub> at supercritical pressures flowing vertically in porous tubes. *International Communications in Heat and Mass Transfers*, Volume 37, Issue 1, January 2010, Pages 98-102.
- [19] James M. Calm. The next generation of refrigerant-History review, consideration and outlook. *International journal of refrigeration* 31 (2008) 1123-1133.

# Experimental Study of Premix Air/LPG Flame Flashback's Depth Of Penetration in Tube Tubes of *Bunsen* Burner As A Function of The Tube's Diameters

I Made Kartika Dhiputra<sup>a</sup>, Dea Adreanni<sup>b</sup>

<sup>a,b</sup>Flame & Combustion Research Group, Thermodynamics Laboratory  
 Mechanical Engineering Department, Universitas Indonesia  
 Kampus Baru UI Depok 16242  
 Phone +62 21 7270032, +62 21 7864089, Fax +62 21 7270033  
 E-mail : dhiputra\_made@yahoo.com

## ABSTRACT

The flame flashback of premixed Air/LPG in acrylics tube tubes of Bunsen burner is investigated experimentally with a variation of tube's diameters (10 mm; 15 mm and 20 mm). The quantitative numerical results for the flame depth of penetrations and the flame propagation velocity are presented in this paper were calculated based on the predictions using empirical formulas of non dimensional factors, such :  $X_p/d_b$  ;  $S_p/U$  ; dilution coefficient,  $\phi$  ; Froude numbers,  $Fr$  ; and Lewis numbers,  $Le$  . In previous experiments, it has been known that fuel air mixture getting lean have an influence that the flame penetration distance,  $X_p$ , will be smaller. However, the flame propagation velocity,  $S_p$ , will be higher. The visualization of the flame's based position which is not attach anymore to the burner tip, rather move down and tilted flame tip stabilized in vertical tube were captured the imaging of flame using digital camera Canon EOS 60 Da, with image stabilizer ultrasonic EF 28-135 mm f/3.5 – 5.6 IS USM lenses, and the result is presented also in this paper.

## Keywords

Flame flashback, Premix Air/LPG flame propagation , Empirical formulas.

## Nomenclature

$X_p$	flame penetration distance [mm]
$S_p$	flame propagation velocity [mm/s]
$d_b$	diameter of tube [mm]
$U$	unburned gas velocity [mm/s]
$\phi$	dilution coefficient
$Fr$	<i>Froud</i> number
$Le$	<i>Lewis</i> number
$Da$	<i>Damkohler</i> number

## 1. INTRODUCTION

Liquefied Petroleum Gas or LPG is one of fuel which widely used for many different applications such as household needs, motor vehicle and industries [1]. Indonesia's government also has policy about conversion kerosene to LPG for household need or cooking [2]. LPG consists of propane and butane which is stored in liquid form by pressurization. Liquefied petroleum gas, or LP gas, is one of the most common alternative fuels used in the world today. In fact, in many places, it isn't an alternative fuel at all. Beside of alternative fuel, future combustion also concern about lean premixed at which this issue brings to fuel variability and reduce pollution. However, lean premixed burners require the flammable mixture to be prepared upstream the combustion chamber or flashback.

Flashback is a combustion condition at which the flame propagates upstream against the gas stream into the burner tube [3-4]. This phenomena is a critical issue for premixed combustor designs because causes serious hardware damage. Flashback may occur due to (i) boundary layer flame propagation (critical velocity gradient), (ii) turbulent flame propagation in core flow, (iii) combustion instabilities and (iv) upstream flame propagation induced by combustion induced vortex breakdown. Flashback due to mechanism has been studied for pure fuels [3], hydrogen blended [5-6], *synthetic gas* [7]. Those researches related to

composition, gas velocity and burner variation (swirl burner). Numerical simulation on flashback phenomena also has been investigated [8-10]. However, combustion with LPG fuel on flashback propensity is largely unknown.

In previous experiments, it has been known that fuel air mixture of LPG flame flashback getting lean have an influence that the flame penetration distance will be smaller and caused the flame propagation velocity will be higher [11-12]. Motivated by previous study, the following study presents flame flashback of premixed air-LPG on Pyrex tube with variation of ratio air-LPG and tube's diameter particularly for flame flashback limit. Upstream velocity and depth of penetration of flame will be also discussed.

## 2. EXPERIMENTAL METHOD

The burner is a vertical Pyrex tube 0.5 m long, and having variation of inner diameter 10 mm, 15 mm and 20 mm. The mixture of air-LPG is injected through the base of the tube. Mixture is assumed fill all of the tube.

Canon EOS 60 Da 18 megapixels is used to record flame flashback on LPG combustion. This camera has CMOS sensor with *digit 4* processor. *Canon EF 28-125 IS USM* is used as lens connected to the camera. The camera is placed in front of the tube to visualize any phenomena. The shutter speed is set to 1/60s with ISO 6400.

The experiments conducted by supplying mixture air-LPG into the burner. Flow rate of air and LPG are appropriate themselves by *rotameter* for air and *Dwyer RMA-2" flowmeter* for LPG. *Rotameter* is connected to *Bunsen burner Flame Propagation and Stability Unit P.A. Hilton Ltd C551* directly. Air and gas enter to Bunsen burner and then burn as shown in Pyrex tube. Flashback is occurred when the flow rate is gradually reduced and this critical flow rate cause the flame enters the tube and propagates along the wall. The flame movement can be stopped at any vertical location along the tube by rapidly increasing the flow rate to a value above critical. This procedure can observe a stationary inclined flame stabilized on the wall in a velocity gradient. Setup experiment and scheme of experiment are shown in Fig. 1 and Fig.2.

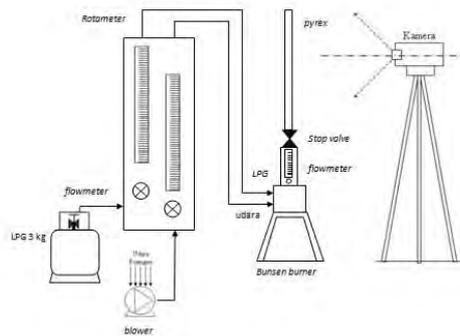


Fig. 1 Setup experiment

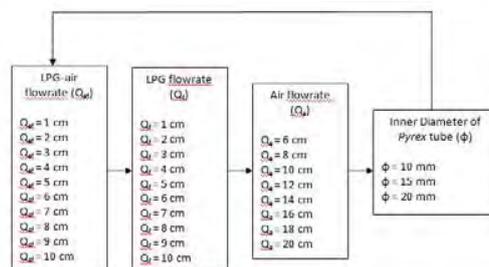


Figure 2: Scheme of experiments (by scale flow meter and rotameter)

## 3. RESULTS AND DISCUSSION

Flame propagation or flashback data were processed by convert video into still image. Result was obtained as depth of penetration or flame penetration distance and flame propagation velocity. Software *Zoombrowser EX* and

ImageJ are used to process the result. Visualization on this experiment showed that flame flashback occurred along the wall of Pyrex tube.

Experiments on a Pyrex tube with a diameter of 10 mm showed that the reduction in the fuel flow rate does not caused a flashback phenomena. In this experiment, the flame will show the lift-off phenomena and then followed by a blow-off flame. The flame will be extinguished immediately. This occurrence can be seen in Fig. 3.

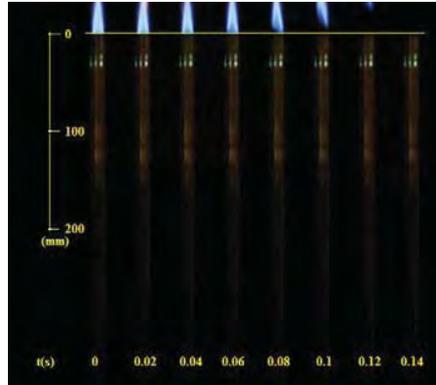


Figure 3: Blow-off phenomena on the tube with a diameter of 10 mm

In a tube with a diameter of 15 mm and 20 mm flashback phenomena occurred in certain air-fuel ratio. Examples of phenomena can be seen in Fig. flashback. 4.

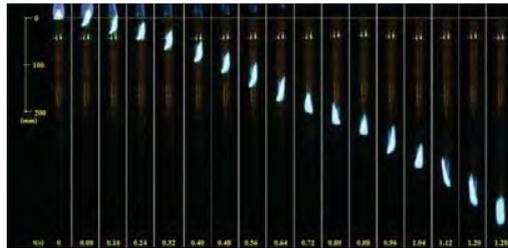


Figure 4: Examples of flashback phenomena on the tube diameter 15 mm

Burning load versus air fuel ratio on flame flashback experiments at the fuel mass rate range 0-0.024 kg/s for the diameter tube 15 mm and 20 mm can be seen in Fig.5. The air mass rate has range 0 – 0.3766 kg/s.

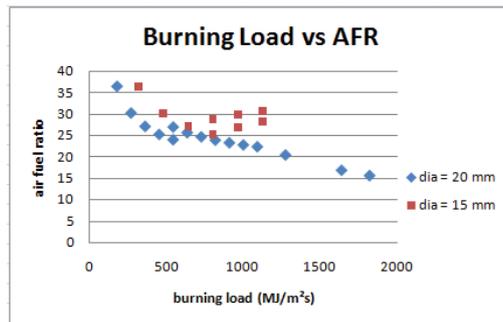


Figure 5: Burning load versus air fuel ratio on flame flashback experiment

Based on Fig.5, it can be shown that the tube with a diameter of 20 mm has the greater burning load when the air fuel ratio getting smaller as the limit of flashback phenomena. Whereas flame flashback on the tube with a diameter of 15 mm occurred when the fuel mass rate has range 0-0.0084 kg/s. these data obtained was not as much flame flashback data on the tube with a diameter of 20 mm.

The relationship between time and flame penetration in flashback phenomena with burner tube 15 mm and 20 mm are shown in Fig.6 and Fig.7. In the burner tube diameter of 15 mm, different charts shown on air fuel ratio AFR = 27.016 or the mass

rate of air 0.1305 kg / s and the rate of fuel mass 0.0048 kg / s. Meanwhile, other fuel blends show a nearly proportional relationship.

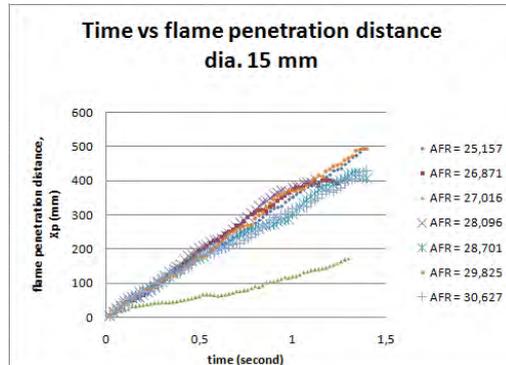


Figure 6: Time versus flame penetration distance in diameter 15 mm

Based on Fig. 7, the greatest flame penetration distance shown in AFR = 25.564 or the air mass flow rate 0.2161 kg/s and the fuel mass flow rate 0.0084 kg/s.

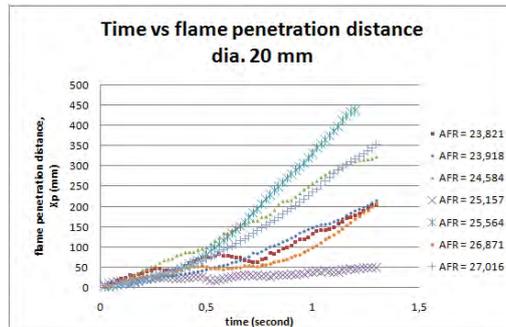


Figure 7: Time versus flame penetration distance in diameter 20 mm.

The relationship between time and flame propagation velocity on the diameter of 15 mm is shown in Fig. 8. Form of a graph is the same as Fig. 6, only the value of the flame propagation velocity reaches 25 m/s at AFR = 29.825 or air mass flow rate 0.2161 kg/s and the mass flow rate of fuel 0.072 kg/s. Meanwhile, the smallest value at the same time shown on the graph with the air fuel ratio AFR = 27.016 or the mass rate of air 0.1305 kg/s and the fuel mass rate of 0.0048 kg/s.

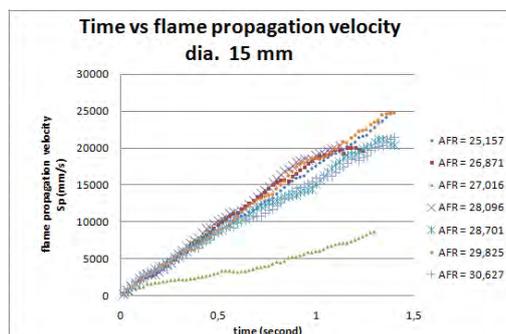


Figure 8: Time versus flame propagation velocity in diameter 15 mm

The relationship between time versus flame propagation velocity of tube diameter 20 mm is shown in Fig. 9. The greatest flame propagation velocity occurred when AFR = 25.564 or the air mass flow rate 0.2161 kg/s and the fuel mass flow rate 0.0084 kg/s. While the smallest flame propagation velocity is shown in AFR 25.157 or air mass flow rate 0.1519 kg/s and the mass flow rate of fuel 0.006 kg/s.

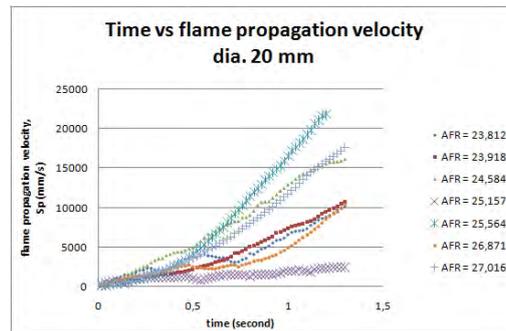


Figure 9: Time versus flame propagation velocity in diameter 20 mm

#### 4. SUMMARY AND CONCLUSION

From the analysis of the results is concluded:

- There is no flame flashback in a tube with a diameter 10 mm, however, there was a blow-off phenomena occurred.
- The relationship between time and flame penetration distance and the relationship between time and flame propagation velocity on the tube diameter of 15 mm, has a graphic that huddled together except the AFR = 25.564 or the air mass flow rate 0.2161 kg/s and the mass flow rate of fuel 0.0084 kg/s.
- Furthermore, empirical formula will be defined based on experiment data to obtained the relationship between air fuel ratio, flame penetration distance and flame propagation velocity, include dilution coefficient,  $\phi$  ; Froud numbers,  $Fr$  ; and Lewis numbers,  $Le$ .
- Numerical simulation of flame flashback phenomena on LPG combustion will be also presented as comparison by experiment.

#### ACKNOWLEDGEMENTS

The author greatly appreciate the principal support this work by Directorate of Research and Community Services of Universitas Indonesia (DPRM-UI) under research grant – 2012 No. DRPM/R/447/RU-UI/2012

#### REFERENCES

- [1] Ed Grabianowski, "How Liquefied Petroleum Gas Works". January 2013. <http://auto.howstuffworks.com/fuel-efficiency/alternative-fuels/lpg.htm>
- [2] Departemen ESDM. *Program Pengalihan Minyak Tanah ke LPG Blueprint*. Indonesia, Jakarta, 2007
- [3] Lewis B, von Elbe G. *Combustion, flames and explosion of gases*. 3<sup>rd</sup> edition. Orlando: Academic Press; 1987
- [4] Kroner M, Fritz J, Sattelmayer T. *Flashback limits for combustion induced vortex breakdown in a swirl burner*. J eng gas turbines power 2003;125:693-700.
- [5] Syred, Nicholas, Mohammed Abdulsada, Anthony Griffiths, Tim O'Doherty, Phil Bowen. 2010. *The effect of hydrogen containing fuel blends upon flashback in swirl burner*. Science Direct Journal of Applied Energy 89 (2012) 106-110
- [6] O. Tuncher, S, Acharya, J.H. Uhm. 2008. *Dynamics, NOx and flashback characteristic of confined premixed hydrogen-enriched methane flames*. Science Direct Journal of Hydrogen Energy 34 (2009) 496-506
- [7] Dam, Bidhan, Norman Love, Ahsan Chouduri. *Flashback propensity of syngas fuels*. Science direct fuel 90 (2011) 618-625
- [8] Kurdyumov, V et al. *Experimental and numerical study of premixed flame flashback*. Science direct proceeding of the combustion institute 31 (2007) 1275-1282
- [9] Thibaut, Denis, Sebastian Candel. 1998. *Numerical study of unsteady turbulent premixed combustion: Application to flashback simulation*. EM2C laboratory, CNRS, Ecole Centrale Paris. F-92295 Chatenay-Malabry, France
- [10] Lammers, F.A., L.P.H. de Goey. 2002. *A numerical study of flashback of laminar premixed flames in ceramic-foam surface burners*. Elsevier Combustion and Flame 133 (2003) 47-61.
- [11] Rondonuwu, Irfan. 2012. *Kajian eksperimental fenomena reattachment flame sebagai dasar pencegahan flame flashback pada Bunsen burner dengan bahan bakar LPG*. Tesis Departemen Teknik Mesin Fakultas Teknik Universitas Indonesia
- [12] Dhiputra, I Made Kartika, Imanuel. 2012 *Kajian eksperimental flashback flame pada Bunsen burner bahan bakar LPG*. Paper No. 5 Proceeding Seminar Nasional Teknik Mesin XI UGM-Yogyakarta
- [13] I Made Kartika, Harinaldi, NK Caturwati ; Pengaruh Variasi Aliran Udara Terhadap Tinggi Lifted-Flame pada Pembakaran Difusi Propana, Prosiding seminar Nasional VI Rekayasa and Aplikasi Teknik Mesin di Industri, ITENAS – Bandung, 28 Januari 2008.
- [14] Mahandari, Cokorda Prapti. 2010. *Fenomena flame lift-up pada pembakaran premixed gas propana*. Disertasi Teknik Mesin Universitas Indonesia

## Plenary 5

# Low-Carbon Pretreatment Process of Iron Ores for Green Ironmaking

**Eiki Kasai**

*Graduate School of Environmental Studies, Tohoku University  
6-6-02, Aramaki, Aoba-ku, Sendai, 980-8759 Japan  
+81-22-795-4895  
kasai@material.tohoku.ac.jp*

Iron ore sintering process is a major supplier of the agglomerate burden to the blast furnace. The heat source of the process is mainly coke and therefore it emits a certain amount of CO<sub>2</sub>. Because of a large mass of the sinter production, the ratio of CO<sub>2</sub> emission in an integrated steelworks is nearly 20% and it occupies about 3% of the total emissions in Japan. Biomass will be an alternative energy source of the process since it is recognized as a carbon neutral fuel. Another possibility is metallic iron and lower oxides of iron contained in mill scales. Problems when using such fuels and their possible solutions are discussed. Further, updated technologies for the reduction of CO<sub>2</sub> emissions in the sintering process of iron ores are introduced.

**Keywords:**

*sintering of iron ores, sinter, production yield, fuel, combustion, oxidation, goethite, hematite, magnetite, coke, biomass char, reduction of CO<sub>2</sub> emission, metallurgical properties*

**This paper is not available from the author(s)**

## Viscous Deformation of Zn-Al-C-O Complexes with Excited Electron States of Zn Atoms

Kozo Obara<sup>a,b</sup>, Li Chen<sup>a</sup>, Shin-ichiro Yamashita<sup>a</sup>, Takashi Ikeda<sup>a</sup>, Masahiro Kuwayama<sup>a</sup>, Anne Zulfia<sup>b</sup> and Hirotsuka Manaka<sup>a</sup>

<sup>a</sup>Graduate School of Science and Engineering, Kagoshima University  
 Korimoto 1-21-40, Kagoshima 890-0065, Japan

<sup>b</sup>Faculty of Engineering, Universitas Indonesia  
 Gedung Dekanat 3rd. Floor, Kampus UI Depok 16424, Indonesia

### ABSTRACT

So far material science is promoted by mixing of different atoms as alloys, compounds, and composites. The basic mechanism of the processes of these materials is electronic interactions of outer-electron system of component elements and electronic information of elements is summarized as *Periodic table*. The electronic interactions in these materials are classified into ionic bonding, covalent bonding, and metallic bonding. The state of bonding between two atoms is evaluated by transfer integral of electron wave functions, if electronic picture is approximated by atomic like one.

Growth processes of practical multi component materials are dominated by *Energy*, which includes two pictures; dynamical picture includes potential energy and kinetic energy, and electromagnetic picture includes electronic energy and magnetic energy. Quantum dynamic theory (QD) unified these two contradictive pictures as Schrödinger equation. Thus, although QD is the most advanced tool to understand the fundamental process of materials, for understanding of processes and characteristics of materials we use a simplified picture of electronic structures. In the case of application of outer-core electron systems of component elements, the energy for growth or synthesis is *Thermal level*, less than 0.25 eV. On the other hand, in that of inner-core electron systems the energy is much higher than the thermal level, which will be higher than ~10 eV. The most apparent proof of the collision processes related to the inner-core electron system is that the reaction probabilities of inner-core electron systems depend on the discrete energies of the electron systems. Besides the transition probability of an electron between the initial state to the final state should obey the selection rule. From these reasons, the experimental results should clearly show discrete energy dependences.

For obtaining the apparent discrete energy dependences of the condensate, the production after the collision should be quenched and fixed the result of the reaction. We propose the surface ion recombination process on the insulative substrate for these requests. Following is the summary of the procedures and the result of condensation of inner-core electron excited zinc films

#### Boundary conditions for correlated condensation of excited zinc atoms.

In ion recombination process, Zn<sup>-</sup> ions are fixed on the Al<sub>2</sub>O<sub>3</sub> substrate with 6.5<sup>□</sup> diameter by using positive bias potential. The density of Zn<sup>-</sup> ions shows concentric distribution. The electric field generated by the negative charge is perpendicular to the surface, parallel component of the electric field is cancelled each other. Therefore, ion recombination on the substrate surface produces the oriented condensate perpendicular to the growth surface.

#### Energy dependence of the condensation processes.

Total energy of the ion recombination process is controlled by the bias potential of the substrate. The substrate surface is electrified by the incident electrons up to the same potential energy with the inverse potential. Electron configurations of Zn<sup>-</sup> and Zn<sup>+</sup> are (Ar)3d<sup>10</sup> 4s<sup>2</sup>4p and (Ar)3d<sup>10</sup>4s<sup>1</sup>, respectively. These electron states are the final states of inner-core electron states which are excited. Quantum dynamic selection rule,  $\Delta l = \pm 1$ , select transition path of an excited electron. We observed enhanced condensation processes at 10 eV, 90 eV, 100 eV, 140 eV, and 230 eV.

#### Crystal structures of the condensates.

Strong diffuse scattering of X-ray diffraction intensities were observed at the condensations with 10 eV, 90 eV, 100 eV and 230 eV. Enhanced Bragg diffraction intensities of X-ray were observed 10 eV, 100 eV, 140 eV and 230 eV. From analysis of these results, enhancements of diffuse scattering were induced by the transition from 3p (90 eV) state of Zn atom to 4s<sup>1</sup> in Zn<sup>+</sup>, and the enhancements of Bragg diffraction were induced by that to 4p state of Zn<sup>-</sup> from 3d (10eV) or 3s (140 eV), respectively.

#### Electronic structures of the condensates.

Unique energy dependences of X-ray diffraction intensity show single excitation process and double one. We confirmed the electronic structure of the condensates by using X-ray photoelectron spectroscopy (XPS). We confirmed inner-core excited states of zinc atom in the case of double excitations only. The lifetime of the excited state induced by the single excitation process is too short to confirm by XPS. Three excited states were found, 3d<sup>10</sup>L, 3d<sup>9</sup>, 3d<sup>8</sup>, which are the state of electron transfer

from the ligand to  $3d^9$ , one electron excited  $3d$  state, and two electron excited  $3d$  state, respectively. Excited states depend on the density of excited zinc atoms, carbon and oxygen as ligands.

#### **Morphology of the condensates.**

Morphologies of the condensates depend on the total energy of the ion recombination. Grain size of the condensates is roughly proportional to the total energy because the average charge density is proportional to the energy of incident electrons. The microcrystal condensed at off resonant conditions show hexagonal morphology, however, that at double excitation cases show modified edge structure like Wulff's pattern. The patterns of platelets strongly depend on the substrate temperature.

#### **Deformation of the condensates.**

X-ray diffraction intensities and XPS spectra show time dependence at room temperature. This is because of the existence of fluidity of the condensates. The condensation process includes high energy process and the products of ion recombination are quenched. The high internal energy state is easily speculated from the strong diffuse scattering of X-ray. Therefore as grown condensates at double excitation processes are in a high energy state and showed long-term relaxation process in diffuse scattering intensity of X-ray diffraction, whose lifetime was confirmed as around 44 weeks.

The condensate is not homogeneous because of the charge density distribution induced by bias potential and geometrical condition of the substrate. After one year from the deposition, the condensates showed decomposition into liquid like materials and thin solid plates. The shapes of liquid type materials are very similar to "highviscous oil" with disk type morphology. Solid thin plate showed unique characteristics, which deformed by electron irradiation with 5 keV and  $3 \times 10^{19} \text{ cm}^{-2}$  electron irradiation density. The penetration depth of electron with 5 keV is 6 nm. We estimated the Young's modulus of the thin plate with 1  $\mu\text{m}$  in thickness. The derived Young's modulus was the order of liquid level.

Recrystallized microcrystals,  $\sim 0.05 \times 2 \times 0.6 \mu\text{m}^3$ , showed unique behaviors by electron irradiation with 5 keV and electron irradiation density  $> 10^{19} / \text{cm}^2$ . As increasing the density of electron irradiation, the microcrystal slightly bent and vibrated slowly and then melted from the top of the microcrystal. This behavior is very similar to the melt of plastic stick or glass stick. After growth of the droplet, a new microcrystal with almost the same size regrew, finally this new crystal stopped the growth under the electron irradiation.

## Lead-Free Oxide Thin Films for Gas Detection

D. Fasquelle<sup>a</sup>, S. Députier<sup>b</sup>, M. Mascot<sup>a</sup>, N. Uschanoff<sup>c</sup>, V. Bouquet<sup>b</sup>, V. Demange<sup>b</sup>, M. Guilloux-Viry<sup>b</sup>, J.-C. Carru<sup>a</sup>.

<sup>a</sup>Unité de Dynamique et Structure des Matériaux Moléculaires (UDSMM)  
Université du Littoral Côte d'Opale, 50 rue F. Buisson, BP717, 62228 Calais, France  
Tel/fax : 00 33 21 46 57 78  
Email : didier.fasquelle@univ-littoral.fr

<sup>b</sup>Institut des Sciences Chimiques de Rennes (ISCR), UMR 6226 CNRS-Université de Rennes 1  
Campus de Beaulieu, 35042 RENNES Cedex, France,

<sup>c</sup>SIMTRONICS SAS, 792, Av. de la Fleuride, BP 11061  
13781 Aubagne Cedex, France

### ABSTRACT

In view to develop gas sensors, a first generation of lead-free thin films was deposited by different techniques on commercial Si and Al<sub>2</sub>O<sub>3</sub> substrates. During our research project, the correlation between the micro structure of films, the structure of the embedded sensors and the applied temperature range, is being studied. In the first year, doped and undoped BaTiO<sub>3</sub>, KNbO<sub>3</sub> and ZnO thin films have been deposited by sol-gel and PLD techniques. BT and BST films have shown a polycrystalline structure with very fine and regular grains, while disoriented grains with an average size ranging from 50 to 200 nm were observed on the KNbO<sub>3</sub> film surface, and ZnO films exhibited a columnar growth. All films were characterized and finally embedded to make semiconductor gas sensors which have been tested under different gases. In this first generation of sensors, ZnO sensors have shown encouraging preliminary results under CO and H<sub>2</sub>S gases.

### Keywords

*Thin films, lead-free oxide, sensor, gas.*

This Paper is Published in Advanced Materials Research Journal

## Crystallographic Properties of Aluminum-doped Barium Zirconium Titanate Thin Films by Sol Gel Process

Rachmat Andika and Muhammad Hikam

Department of Physics, Faculty of Mathematics and Sciences, University of Indonesia, Depok 16424  
E-mail: rachmat.andika11@ui.ac.id

### ABSTRACT

We studied the crystallographic of Barium Zirconium Titanate thin films with Aluminum doped (BZAT). These films were prepared by sol-gel process and followed by spin coating. The sintering temperature is taken from 800 °C to 900 °C. We found that the crystallographic system of BZAT thin films have tetragonal structure with the lattice parameter slightly changed by various Aluminum partial substitution. When 0.01 Al mole added, the grain size of the films is 29.42 nm at 800 °C. The sintering temperature 900 °C increased the grain size into 50.95 nm. We also calculated the spontaneous polarization theoretically and we found the optimum value of BZT thin film with 0.01 mole Al heated at 800 °C, is 0.143 C/m<sup>2</sup>. This way, we could predict that the film has ferroelectric phase.

### Keywords

BZT, ferroelectric, sol gel, grain size, tetragonality, spontaneous polarization

This Paper is Published in Advanced Materials Research Journal

## Quasi-solid State DSSC Performance Enhancement by Bilayer Mesoporous TiO<sub>2</sub> Structure Modification

R. A. Wahyuono, D. D. Risanti

*<sup>a</sup>Department of Engineering Physics, Faculty of Industrial Technology, Institut Teknologi Sepuluh Nopember (ITS), Kampus ITS keputih Sukolilo Surabaya 60111, Indonesia  
Email: r\_agung\_w@ep.its.ac.id, risanti@ep.its.ac.id*

### ABSTRACT

*Quasi-solid state dye-sensitized solar cells (DSSC) having bilayer structure were made by using nanocrystalline anatase-rutile TiO<sub>2</sub> to enhance the photovoltaic performance. The bilayer structures were coated to FTO glass using doctor blade technique with total active area of 0.4 cm<sup>2</sup>. Cyanidin dye extracted from mangosteen pericarp was used as photosensitizer. Bilayer anatase-anatase was formed with surface area of 99.9 m<sup>2</sup>/g and pore volume of 0.23 cc/g while anatase-rutile structure has surface area of 103.5 m<sup>2</sup>/g and pore volume of 0.21 cc/g. Overall energy conversion efficiencies under illumination of 10 mW/cm<sup>2</sup> of 0.461% and 0.1365% were achieved for DSSC employing anatase-anatase and anatase-rutile TiO<sub>2</sub> structure, respectively. Both efficiencies were higher than that of monolayer anatase and rutile TiO<sub>2</sub> structure whose efficiencies in the range of 0.02% to 0.037%. The photocurrent action spectra of bilayer structures performed high efficiency spectrum in the wavelength range of 420 – 480 nm owing to cyanidin effect of dye.*

### Keywords

*Quasi-solid state DSSC, bilayer TiO<sub>2</sub>, anatase, rutile, cyanidin, IPCE*

This Paper is Published in Advanced Materials Research Journal

## Atomic Layer Deposition of Inverse Opals for Solar Cell Applications

Siva Krishna Karuturi, Lijun Liu, Liap Tat Su, Wenbin Niu, Alfred Iing Yoong Tok\*

School of Materials Science and Engineering, Nanyang Technological University  
50 Nanyang Avenue Singapore 639798  
Email: MIYTok@ntu.edu.sg

### ABSTRACT

Atomic layer deposition (ALD) technique shows superior application in the fabrication of  $\text{TiO}_2$  inverse opals (IO), compared with conventional infiltration method. In the present report, the gradient and uniform  $\text{TiO}_2$  IO structures were infiltrated by ALD method in a continuous-flow and internally developed stop-flow process, respectively. The corresponding optical and optoelectrical properties of  $\text{TiO}_2$  IO structures were investigated. The prepared uniform IO structure of 288 nm was used as a photoanode for dye-sensitized solar cells. An efficiency of 2.22% was achieved, which was much higher than that of prepared by conventional solution-infiltration method. It is indicated that ALD method is an effective approach for fabricating  $\text{TiO}_2$  IO photoanode.

### Keywords

Atomic layer deposition,  $\text{TiO}_2$  inverse opal, solar cell

This Paper is Published in Advanced Materials Research Journal

## **Modifications of Multi-walled Carbon Nanotubes on Zinc Oxide Nanostructures for Carbon Monoxide (CO) Gas Sensitive Layer**

**Muhammad Iqbal, Brian Yulianto and Nugraha**

*Engineering Physics Department, Faculty of Industrial Technology, Institut Teknologi Bandung, Indonesia 40132  
Email: brian@tf.itb.ac.id*

### **ABSTRACT**

*A novel functional material has been synthesized by modification of multi-walled carbon nanotubes (MWNTs) with nanostructured zinc oxide (ZnO). Multi-walled carbon nanotubes have unique electronic and photonic properties, as well as nanostructured zinc oxide [1]. Both have advantages when combined as to provide a material with extremely high surface area-to-volume ratio, which is required for the sensor structure. So far, CNT-based gas sensors have been investigated for the detection of H<sub>2</sub>, N<sub>2</sub>, NO<sub>2</sub>, and NH<sub>3</sub> [2]. In this study, modification of multi-walled carbon nanotubes with nanostructured zinc oxide is conducted by simple screen printing and ultrasonic spray pyrolysis (USP) methods, which consists of the fabrication of MWNTs paste, the formation of ZnO sol, and calcination. The deposited thin films are then characterized using several characterization techniques, such as X-ray diffraction and SEM. The performance testing of the sample as a CO gas sensitive layer has also been investigated and the measurement results on 100 ppm CO gas exposure at 250°C showed the sample had a sensitivity of 85%, response time of 5 minutes and recovery time of 20 minutes.*

### **Keywords**

*Multi-walled carbon nanotubes, zinc oxide, nanostructure, gas sensor, carbon monoxide*

This Paper is Published in Advanced Materials Research Journal

## An investigation of structure and Complex Impedance Behavior of Composite $(1-x)\text{Ba}_{0.5}\text{Sr}_{0.5}\text{Fe}_{11.7}\text{Mn}_{0.15}\text{Ti}_{0.15} / x\text{La}_{0.7}\text{Ba}_{0.3}\text{MnO}_3$

V. Vekky R. Repi<sup>a,b</sup>, Azwar Manaf<sup>a</sup>

<sup>a</sup> Postgraduate Program of Materials Science, Faculty of Mathematics and Natural Science, Universitas Indonesia, Jalan Salemba Raya 4, Jakarta 10430, Indonesia

<sup>b</sup> Department of Engineering Physics, Universitas Nasional, Jakarta 12520  
E-mail : vekky\_repi@yahoo.com

### ABSTRACT

Has done an investigation on composite materials  $(1-x)\text{Ba}_{0.5}\text{Sr}_{0.5}\text{Fe}_{11.7}\text{Mn}_{0.15}\text{Ti}_{0.15} / x\text{La}_{0.7}\text{Ba}_{0.3}\text{MnO}_3$  with conventional ceramic method. Investigations carried out on the structure and the complex impedance of materials using X-ray diffraction patterns, SEM, and impedance spectroscopy. Data from XRD, SEM showed that the phase  $(1-x)\text{Ba}_{0.5}\text{Sr}_{0.5}\text{Fe}_{11.7}\text{Mn}_{0.15}\text{Ti}_{0.15} / x\text{La}_{0.7}\text{Ba}_{0.3}\text{MnO}_3$  contained in the composite material according to the ratio of material to move  $x = 0$ ,  $x = 0.3$ ,  $x = 0.5$ ,  $x = 0.7$ ,  $x = 1$ . From the pattern of impedance spectroscopy shows that  $x = 0.5$  and  $x = 0.7$  has a value of complex impedance and pattern forming semicircle in the frequency range between 1 kHz to 1MHz.

### Keywords

Composite material, complex impedance, barium hexaferrite, mechanical alloying, electrical charge transport, electromagnetic wave absorber.

This Paper is Published in Advanced Materials Research Journal

# 100W Sustainable Society Prospected from Electrical Power Consumptions between Indonesia and Japan

Ikunori Hiraishi<sup>a)</sup>, Mitsuomi Yamaguchi<sup>a)</sup>, Bondan T. Sofyan<sup>b)</sup>, Nyoman Suwartha<sup>b)</sup> Bambang Sugiarto<sup>b)</sup> and Kozo Obara<sup>a)b)</sup>

<sup>a)</sup> Graduate School of Science and Engineering, Kagoshima University  
Korimoto 1-21-40, Kagoshima 890-0065, Japan

E-mail : pass2515@tos.bbiq.jp, kozo@eee.kagoshima-u.ac.jp

<sup>b)</sup> Faculty of Engineering, University of Indonesia, Depok 16424

## ABSTRACT

*This paper presents the possibility of 100 W sustainable society. From the analysis of historical data of electrical power consumption in Japanese society, it is shown that 100 W society with adequate electrical products existed in 1970s. The most important key for realizing 100 W society is the life style which live together with family, total four persons. This model was confirmed by the present situation in Hioki city, which showed the similar electrical power consumption, 106 W for a home of four persons.*

## Keywords

*Sustainability, Electrical power consumption, Life style*

## 1. Introduction

Recently we can find the word “Sustainability” in many fields. The meaning of this word includes the warning or risk for our present society [1]. The developed countries are making the new program to answer the demands and requests for improving our environment [2]. Our societies notice the unsustainability of the Earth, which is accelerating environmental degradation, loss of biodiversity, shortage of energy, etc, for next generation.

In this report, we discuss the history of electrical energy consumption in Japanese society for discussing a model for sustainable society in near future. The reason why we pick up the electrical energy consumption as an index to analyze the sustainability is that the electrical power consumption is proportional to the industrial activity and related to the life style of a family.

Electrical power consumption indicates the economic growth condition of the society. We report the history of electrical power consumption of Japanese society from 1951 to 2011. In these period, Japanese society had five big economic crises; 1st oil shock[3], 2<sup>nd</sup> oil shock[4], collapse of bubble economy[5], Lehman Shock[6], and East Japan earthquake (FUKUSHIMA)[7].

Electrical power consumption (EPC) is separated into industrial use and home use. The total electrical power consumption of home use increases almost linearly year by year in Japan. On the other hand, that of industrial use directly reflects the economic conditions. Firstly we discuss on the correlation of the electrical power consumptions between Industrial use and home use in Japanese society, in which the most important change is the decrease of EPCs in both industry and home after FUKUSHIMA. The other past economic crises showed a linear model between industrial use and home use, in which the ration of EPCs between industry and home increased linearly.

We discuss one index related to EPC for the sustainable society, which is the electrical power consumption per person (EPCPP). The maximum EPCPP in Japan was 270W at 2010 just before FUKUSHIMA. On the other hand, EPCPP in Indonesia is 20 W. Now, recent economic growth rate in Indonesia suggests the same GDP level as Japan near 2050[8].

The shortage of fossil energies is very clear if we consume energy in the same rate. Especially energy consumption in Asia area is increasing rapidly because of economic growth. In this report we want to discuss our sustainable society for next generation and make clear what we should do in our daily life or how we can change our life style. This will be one duty for our next generation. Discussion points are followings;

- 1) Correlation between EPCPP and number of family in one home
- 2) Number of electrical products and essential electrical products
- 3) Electrical energy management and storage of electrical energy
- 4) Peak shift of electrical energy consumption

## 2. Electrical Power Consumption in Japan during 1951 to 2011

Electrical power consumption reflects the economic growth condition and life style of the nation because the electrical energy is easily transferred to the other usages with high conversion efficiency. Figure 1 shows EPCs of industrial use and home use during 1951 to 2011[9]. Home use and business use are classified by the maximum electrical current of the contact,

in home use  $I_{\text{home}} < 60$  A and in business use  $I_{\text{business}} > 60$  A. Industrial use is classified by input voltage, which is higher than 6000V.

Industrial use shows clearly the influences of economic crises. The 1<sup>st</sup> oil crisis due to the 4<sup>th</sup> Middle East War at 1973 induced the shortage of oil supply and the increase of the price of oil, which suppresses EPC in industry and business uses. The typical examples of suppresses of EPC are stop of escalators in departments, shortening of lighting time of street illuminations, closing gas station at Sunday, change of the schedule of the last train, shortening of the time of broadcasts, etc. However, EPC of home use increased gradually even though industrial use showed the very sharp decrease.

The 2<sup>nd</sup> oil crisis due to Islamic Revolution in Iran at 1979 showed a similar dependence in industrial use as the 1<sup>st</sup> oil crisis. This is the effect of training of the 1<sup>st</sup> oil crisis and the start of the movements of saving energy, development of high efficiency products including the low cost items. In this second economic crisis EPC of home use showed small change which correlated to the industrial use more strongly, which suggests the expansion of the movement of saving energy in home use. After the decrease of economic depression of USA, the EPC of industrial use increased with almost the same rate before the 1<sup>st</sup> oil crisis until the disintegration of the bubble economy of Japan. This is an important index for the sustainability of the society which suggests that the high growth rate of EPC will induce an economic crisis.

The EPC of home use decreased the growth rate fifty percent. After three years from the end of bubble economy, EPC of industrial use increased gradually until Lehman shock at 2008. The EPC of industrial use after Lehman shock showed negative growth rate with -350 million kWh per year, which is the biggest decrease of EPC. On the other hand EPC of home use increased with almost the same rate before Lehman shock. The correlation of EPCs between industrial use and home use suggests the change of the society. The characteristic of EPCs in recent three years shows clear positive correlation. This feature is very unique which has never seen before.

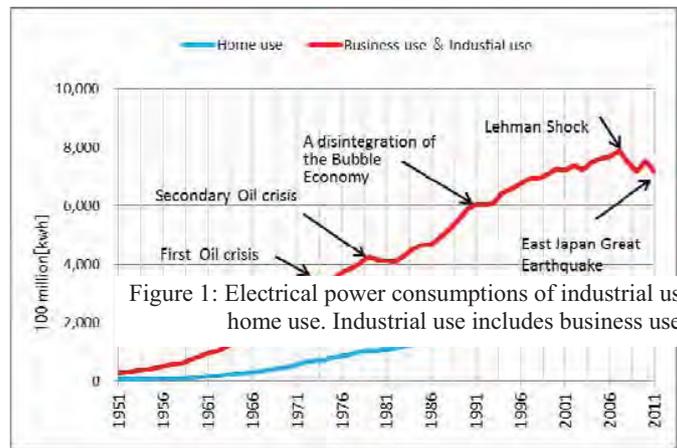


Figure 1: Electrical power consumptions of industrial use and home use. Industrial use includes business use.

### 3. Correlation of EPCs in Industrial Use and Home Use

The simplest method to show the correlation between two quantities is to use the ration between them. Figure 2a shows the ratio of EPCs of industrial use and home use.  $W_r$  is the ration of  $W_i/W_h$ , in which  $W_h$  and  $W_i$  indicate the EPCs of home use and industrial use, respectively. The EPC ratio  $W_r$  shows the minimum at 1960, indicated by Y1, and increased rapidly until Y2 at 1966 and decreased gradually until Y3 at 1970. These relations are impossible to see from Fig.1 directly. The structure after Y3 is almost linear except for A1, which is after Lehman shock.

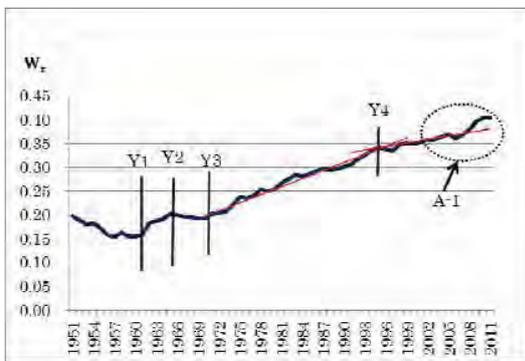


Figure 2a: Ration of EPCs of home use and industrial use,  $W_r = W_i/W_h$ , where  $W_h$ ,  $W_i$  are EPCs of home use and industrial use, respectively.

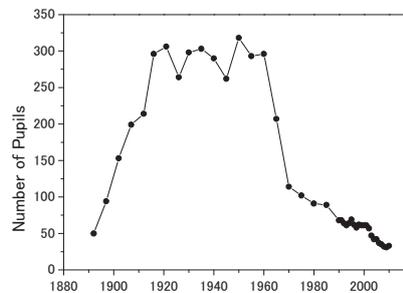


Figure 2b: Change of number of pupils at Sumiyoshi elementary school.

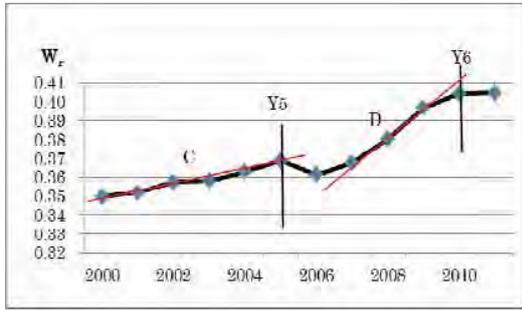


Figure 3: Expanded view of the EPC ratio  $W_r$  of A-1 in Fig. 2a. This area suggests recent unique changes due to different factors.

The first decrease of  $W_r$  is due to the growth of EPC of industrial use relative to that of home use. The rapid increase of  $W_r$  during Y1 to Y2 suggests a big change in Japanese society. Figure 2b show the change of number of the pupils at Sumiyoshi elementary school in Kagoshima, Japan during 1890-2010. Approximately the number of pupils was constant in 1920-1960. Then the number of pupils rapidly decreased to 60 % in the period of 1960 and 1970. The increase of  $W_r$  and the decrease of number of pupils are correlated with each other. The decrease of number of pupils is due to the immigration of peoples who live in rural communities to cities. The gradual increase of  $W_r$  from 1970 suggests the relation with the gradual linear decrease of population in rural side. Although Figure 2b is an example of one elementary school, this example is a typical one which shows that there was a large immigration of people from rural side to urban side for supporting the labors of newly constructed companies in 1960-1970.

From these correlations between EPCs and the immigration from rural area to urban area we propose a model to explain a main factor dominating EPC. The minimum unit for EPC is "Home" and the number of persons per home dominates the practical EPC. The immigration to urban side from rural one induces the increase of the number of minimum home of one person. This model is applicable to the developing period of the society.

A-1 area in Fig. 2a is slightly different from the other area in it because, although the population of Japan is almost constant the ratio  $W_r$  of EPCs shows relatively large change. Figure 3 shows expanded view of A-1 area in Fig. 2a. The kink at Y5, 2005, is due to the decrease of EPC of home use because there is no kink in EPC of industrial use. This curve is classified into two area indicated by lines C and D.

The line C suggests the weak correlation between EPCs of industry and home in spite of individual small each changings. One reason of the kink at Y5 may be the start of ecological movement in the society. The steep increase of  $W_r$  in the line D is related to Lehman crisis, in which EPC of industrial use decreased suddenly. The EPC of home use in the line D was almost constant. The transition area between the line C and D suggests the mind of the society for constructing new stage in their daily life. The last two years in Fig. 3 is very unique. The EPC of home use became the maximum at 2010. In 2011 March, East Japan Great Earthquake occurred. The EPC ratios in these two years were the same magnitude. This is due to the same time dependence of each EPCs. The same dynamic characteristic is the result of a common factor. Although these two years are very short period to get important conclusion, its meaning is very important because of the stable balance of Japanese society.

#### 4. EPCPPs in the Present World

We think the history of EPC in Japan is a model for developing countries in near future. The EPCPPs in different countries were summarized in Fig. 4 as a histogram. EPCPPs distribute in the range of 1W to 1688 W. The countries of high energy consumption are the countries with rich energy resources like water power or oil [11].

The global average of EPCPP is 90 W and the peak of the histogram located at 101-200 W. The present EPCPPs of Japan and Indonesia are 265 W and 20 W, respectively. The EPCPP of Indonesia is the same level of Japan at early stage of 1960s. We can speculate the EPCPP of home use in Indonesia in near future by using the present model if we can get the change of the number of persons of individual home. For sustainable society in really near future we propose the target EPCPP as 100W. The reason is very clear because 100 W is the middle of the global average rate and the peak of the histogram of EPCPP, that is, it is easy to shift the value of global average to 100 W in a meaning of statistics.

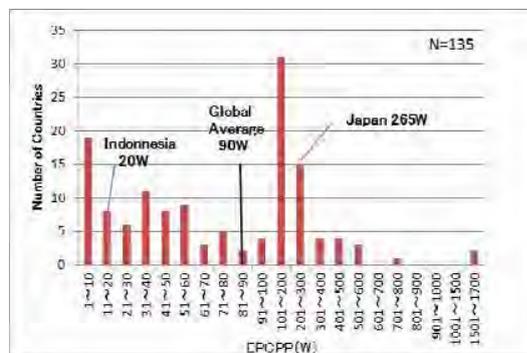


Figure 4: Electrical power consumption per person (EPCPP) in countries at 2010.[11]

### 5. 100 W Sustainable Society

Another reason of 100 W is a practical meaning of life style of Japan. For Japanese society, EPCPP of 100 W was achieved at 1978. This era was the time with high growth rate of economy, which is very similar to the present Indonesian economy; problems of waste material managements and shortage of future energy. The table 1 is the saturation level of electrical products for home uses at 1978 and 2010. The electrical products of high diffusion rates higher than 95 % were refrigerator, washing machine, color TV, and vacuum cleaner. These electrical machines are symbolic electrical products of the modern electrified society. Recent energy saving techniques suppress the electrical power consumption more than 50 % as shown in Table 1. These new techniques assist the possibility for the uses of new electrical products for next generation.

Product	Diffusion Rate (%) 1978	Diffusion Rate (%) 2010	Energy-saving
Rice Cooker	56	89	——
Refrigerator	99	99	2001⇒2010 ▲65%
Washing Machine	98	99	1995⇒2005 ▲75%
Color Television	98	99	1997⇒2012 ▲70%
Vacuum-cleaner	95	99	——
Air-conditioning	30	89	2001⇒2011 ▲14%
Microwave Oven	28	97	——
Electric Hot-water System	0	8	——

Table 1: Electrical power consumption per person (EPCPP) in many countries at 2010. Diffusion rate of products and information about electrical energy saving. [10,12,13]

The main reason of the increase of EPCPP from 100 W to 265 W is the increase of the electrical products related to heat loads; electric hot-water system, microwave oven, air-conditioner, rice cooker, etc. especially EPC of electrical hot-water system is very high, which is introduced to improve the electrical power supply from the power plant. For future life we have to improve the system for hot water supply by using solar heat energy.

The products using heat energy have another effect which means the function to store the energy. The hot water system keep hot water without the power supply for several hours and refrigerator keep the foods cool for a few hours. This function is the same as a capacitor for electrical system. The present data on thermal insulation are not adequate for future sustainable society, which should be improved by ourselves.

Persons in Home	EPCPP in Hioki 2012 (W)	EPCPP in Indonesia 2012 (W)
1	212	
2	180	
3	129	
4	106	* 10
5	75	
6	67	

Table 2: EPCPP and number of persons in a home in Hioki, Japan and Depok in Indonesia.

EPCPP depends on the number of persons in the home. Table 2 shows the data of EPCPP of Hioki city in Japan. Hioki city is located in rural area 25 km from the capital of Kagoshima prefecture. EPCPP linearly decreases almost linearly. If we apply linear model, we obtain the model EPCPP (W) as follows,

$$EPCPP = 234.5 - 30.4N \quad (1),$$

where N is the number of persons who live in one home and the error is 10 %. This result shows the real energy consumption of one person in the home is 30.4 W. At the present time although the average EPCPP in Japan is 265 W, if four persons live in one home EPCPP decreases to 105 W. The EPCPP at 1978 in Japan was 100 W and the number of persons in one home was 3.5 persons. If we admit 15% error for the model, 100 W sustainable society will be possible by the home where four persons live together. EPCPP in Indonesia is relatively lower than Japanese case. Average value of EPCPP is 20 W. The denoted data of Indonesia in the table is average of very small resources. We need data more for making plan for future sustainable society in Indonesia.

## 6. Conclusion

We analyzed the historical time dependence of EPC of Japanese society. The industrial use, which include business use, was strongly reflected by the economic situation, however, that of home use was insensitive to economic crises except for the case in 2010-2011. In the first stage of economic growth, the immigration of laborers from rural area to urban area makes EPCPP increase rapidly. This is the first point which we have to think the change of life style and energy consumption. The second point is the ration of EPCs between home use and industrial use. EPC ratio,  $W_r$ , clearly indicated the difference of time dependence of both EPCs. This measure quantity suggests the correlation of EPCs between industrial use and home use. From the result of  $W_r$  we can obtain a model with constant EPCs ratio, which means the balanced society between home and industry.

The reason of 100 W is the relation of life style which was expressed by the high diffusion rate of main electrical products. In 1978, Japanese society achieved to the first stage of improvement of the life style by the electrification. The average number of persons in a home was 3.5 and the electrical power consumption at that time was 100 W. We confirmed the relation between EPCPP and number of persons in one home as life style of Japanese society at 2012. Surprisingly, EPCPP of the home with four persons was 106 W. These results exactly suggest that 100 W sustainable society is possible.

## Acknowledgements

We thank for the cooperation of Mr. Bambang Rijadi, the first Indonesian citizen who opened our mind in Indonesian society, and Hioki city and Depok city on the inspection of electrical power consumption and also for the practices of energy saving activities and collaborative works as Solidarity with students of University of Indonesia and communities in Depok working with JICA project for the improvements of waste materials management.

## REFERENCES

- [1] *Valenti Rull*, "Sustainability, capitalism and evolution", *EMBO reports*, vol.12, pp. 103-106, 2011.
- [1] *Amanda Mascarelli*, "Sustainability: Environmental puzzle solvers", *Nature*, vol. 494, pp. 507-509, 2013.
- [3] 1st oil shock: At 1973 October the 4<sup>th</sup> Middle East War occurred. OPEC declared 70 % up of the cost of oil as an economic sanction for the countries which supported Israel.
- [4] 2<sup>nd</sup> oil shock: At 1979 Islamic revolution occurred. The oil supply from Iraqi was stopped. Since Japanese industries depended on the supply from Iraqi, the balance of oil in Japan was crashed. The effect of OPEC is included it, too.
- [5] Collapse of bubble economy: Bubble economy means the increases of value of assets and economic activity in Japanese society during 1988-1991. This economic situation collapsed at 1991 February.
- [6] Lehman Shock: At 2008 September 15, an investment bank , Lehman Brothers Holdings Inc. went bankrupt which induced global economic panic.
- [7] East Japan earthquake: At 2011 march 11, Great earthquake with M 9.0 attacked east Japan, Ibaragi, Fukushima, Iwate. By the damage of earthquake and Tsunami, four atomic power plants were destroyed. This biggest disaster changed the mind of Japanese people to the sustainable society.
- [8] Goldman Sachs, Global Economics Paper No. 66
- [9] The Federation of Electric Power Companies - Homepage Electric-power environmental data - Statistics for electrical-utility 60 years - An operating power quantities
- [10] Japanese government statistics(e-Stat) A population and a household - National census A long-term statistical series of Japan - Chapter 2 Population and Household 1872-2009 A long-term statistical series of Japan - Chapter 20 Household Economy-Consumers' Durables 1959-2004
- [11] GLOBAL NOTE Homepage A resource and energy - Power consumption - (Source origin - World Bank) 1998-2010 A population and labor - Population - (Source origin - United Nations) 1998-2011
- [12] Energy-saving performance catalog The summer version of 2012 - Agency of Natural Resources and Energy Air-conditioner pp.10, TV pp.21, refrigerator pp.35
- [13] <http://secca.net/> Eco-life Q&A - Energy-saving Q&A (Source origin) Energy Conservation Center homepage Washing machine

## SKD 61 Material Surface Treatment With Electric Discharge Machining Using Cu, CuCr & Graphite Electrodes and Dielectric Fluid Jatropa Curcas

Triyono<sup>a</sup>, DediPriadi<sup>b</sup>, Eddy S Siradj<sup>b</sup>, Winarto<sup>b</sup>

<sup>a</sup> Department of Mechanical Engineering, Universitas Trisakti, Jakarta, Indonesia  
E-mail: triyono@trisakti.ac.id

<sup>a, b</sup> Department of Materials and Metallurgy, Faculty of Engineering  
Universitas Indonesia  
E-mail: dedi@eng.ui.ac.id

### ABSTRACT

The emergence of white layer in each process of Electric Discharge Machining (EDM) became the focus of attention of the experts. It's harder than the base metal would be advantageous to withstand friction engine components, such as the plastic molding industry. From various studies it has been reported that the increase in the value of hardness of white layer either due to migration of the electrode material and dielectric fluid to the white layer. This paper discusses the influence of electrodes Cu, CuCr and graphite as well as jatrophacurcas dielectric fluid to the surface of the material SKD 61, microhardness of the white layer, Tool Wear Rate (TWR) of Material Removal Rate (MRR), Surface roughness (Ra) and the microstructure. Initial studies conducted are the transesterification and characterization of jatrophacurcas to determine the dielectric strength and the content of metal elements. Furthermore, the EDM testing is done to dies steel of SKD 61 using the electrodes of Cu, CuCr and Graphite. The use of jatrophacurcas yield the best MRR when using Graphite electrodes followed Cu last CuCr. While the smallest TWR produced by Cu electrode, CuCr and then the highest is Graphite. The relative wear which is the ratio TWR with MRR, for the three types of electrodes are always great at small current then decreases and then tends to be stable with the increase of electric current. Jatrophacurcas for the three types of electrodes provide higher TWR than kerosene. This means that migration of materials is beneficial because larger material, but in terms of the geometric accuracy of the product can lead to decreasing of dimensional tolerances. Vickers hardness values of white layer is achieved by CuCr electrodes, Graphite lowest. Microstructural observation results of EDM white layer using graphite electrodes produce a more uniform thickness than the white layer using Cu and CuCr electrodes. The conclusion of this study that jatrophacurcas can be used as a dielectric fluid in EDM process, because electrode wear during EDM process is relatively high compared to kerosene that is mean more profitable in the surface treatment process of dies steel of SKD 61.

### Keywords

EDM, metal removal rate, tool wear rate, jatrophacurcas, SKD 61

This Paper is Published in Advanced Materials Research Journal

# Application of Shot Peening and Shot Blasting to Increase Hardness and Depth of Nitride Hardened Layer to the Modified H13 Steel as Die Casting Die Materials

Myrna Ariati, Rizki Aldila

*<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : myrna@metal.ui.ac.id, rizki.aldilla@ui.ac.id*

## ABSTRACT

In metal forming process by die casting method, nitriding plays an important role in increasing the life of dies and good quality product. Innovation surface treatment processes performed before nitriding aims to improve the efficiency and depth of nitride layer on Modified H13 Steel. Nitriding has done in a gas vacuum furnace, at temperature of 510°C for 5 hours. Shot peening has done by using steel balls with a pressure of 461 kPa. Shot blasting has done as a method of cleaning the material surface using SiC particles. Characterization of the sample surface before and after the variation process is focused on changing the microstructure, micro hardness distribution, and depth and composition nitriding layer. Of the process that preceded nitriding shot peening, obtained maximum hardness 1196 HV with effective depth of diffusion layer of 72  $\mu\text{m}$ . This value is greater than the nitriding without any prior surface treatment, which produces a maximum hardness HV 1101.4 with effective depth of diffusion layer of 54  $\mu\text{m}$ . Variation nitriding by shot peening process produces white layer thickness 4.1  $\mu\text{m}$ ; thicker than nitriding without shot peening process 3.7  $\mu\text{m}$ . While on nitriding that are not preceded treatment did not reveal any white surface layer.

### Keywords:

*Nitriding, shot peening, shot blasting, AISI H13, white layer, diffusion layer.*

This Paper is Published in Advanced Materials Research Journal

## Optimization of Multiple Performance Characteristics in the Wire EDM Process of AISI D2 Tool Steel using Taguchi and Fuzzy Logic

Bobby O.P. Soepangkat<sup>1</sup>, Bambang Pramujati<sup>2</sup>, Nuraini Lusi<sup>3</sup>

<sup>1,2</sup> Mech. Eng. Dept., Institut Teknologi Sepuluh Nopember (ITS), Surabaya 60111, Indonesia.

<sup>3</sup> Mech. Eng. Dept., Universitas Negeri Malang (UM), Malang 65145, Indonesia.

<sup>1</sup> bops\_1994@me.its.ac.id, <sup>2</sup> pramujati@me.its.ac.id, <sup>3</sup> lusi\_nuraini@yahoo.co.id

### ABSTRACT.

In this study, the optimization of material removal rate (MRR) and surface roughness (SR) simultaneously in a WEDM process by using Taguchi method with fuzzy logic has been applied. The Wire EDM process parameters (flushing pressure, on time, open voltage, off time and servo voltage) were optimized with considerations of multiple performance characteristics, i.e., MRR and SR. Based on the Taguchi method, an  $L_{18}$  mixed-orthogonal array table was chosen for the experiments. Fuzzy reasoning of the multiple performance characteristics has been developed based on fuzzy logic, which then converted into a fuzzy reasoning grade or FRG. As a result, the optimization of complicated multiple performance characteristics was transformed into the optimization of single response performance index. Experimental results have shown that machining performance characteristics of Wire EDM process can be improved effectively through the combination of Taguchi method and fuzzy logic.

### Keywords:

Taguchi, fuzzy logic, wire EDM, material removal rate, surface roughness, AISI D2

This Paper is Published in Advanced Materials Research Journal

## Characterization of Al-7Si-Mg-Cu Turbine Impeller Produced by Investment Casting

Muhammad Syahid<sup>a,b</sup>, Bondan T. Sofyan<sup>a</sup>, Singgih G. Basuki<sup>a</sup>,  
Bayu Adam<sup>a</sup>

<sup>a</sup>Department of Metallurgy and Materials, University of Indonesia, Indonesia

<sup>b</sup>Department of Mechanical Engineering, Hasanuddin University, Indonesia  
Email: chaid\_ar@yahoo.com, bondan@eng.ui.ac.id

### ABSTRACT

Application of a light-weight material, such as an aluminum alloy, on a turbine impeller can enhance the efficiency of an Organic Rankine Cycle power plant that operates at temperatures below 150 °C. The density of an aluminum alloy only one-third that of steel. However, increased strength of aluminum alloys is needed for turbine impeller qualification. Investment casting was chosen to produce radial inflow turbine impeller due to their complex geometry and precision. It can replace machining process, which is time-consuming and less efficient because of material removal. This study describes the investment casting process used to produce a radial inflow impeller turbine. The study also identifies defects, microstructures and properties of radial inflow turbine impeller. The turbine impeller were produced from Al-7Si-4Mg alloy with 0.38, 3.82, and 6.0 wt. % Cu. Visual examination showed that the turbine impeller was free of macro defects and misruns. Microstructures were characterized by Optical Microscopy and SEM. The structures consisted of  $\alpha$ -Al, Si eutectic, AlMgSi, AlMgFeSi (Chinese script) and CuAl<sub>2</sub>. The higher hardness value of 54HRB was affected by Cu content due to the good mechanical properties of fasa CuAl<sub>2</sub>

### Keywords

*Investment casting, aluminum alloys, turbine impeller, organic rankine cycle*

This Paper is Published in Advanced Materials Research Journal

## Research on the Manufacturing of Steam Turbine Blade by Using Investment Casting Technology

Hafid<sup>a,b</sup>

<sup>a</sup>Metal Industries Development Centre (MIDC) - Ministry of Industry Indonesia, Jl. Sangkuriang 12 Bandung 40135  
also at <sup>b</sup>Pasundan University of Program Doctorate Management, Bandung  
E-mail : hafidochan@yahoo.com

### ABSTRACT

*This paper presents the results of research on the manufacturing of steam turbine blade by using investment casting technology. Metal forming technology with precision casting process or investment casting is the right technology for the manufacture of turbine blades, because it can produce casting products that has advantages in size and shape accuracy, surface finish and the ability to produce thin casting, which the usually foundry can not be done. The purpose of this research is to produce a good quality of the casting products as an effort to reduce import dependency of steam turbine blade and to be the alternative way of making steam turbine blades in Indonesia, in addition to the machining process. Based on the experimentation trial implemented on casting products of stainless steel 304, the result indicates that the injection temperature for the wax NF-411 and optimal nozzle in hydraulic injection machine are 64°C and 30°C, injection pressure 1.75 MPa and injection time 9 seconds. The best casting induction furnace achieved at temperature 1.620°C as for to the number of ceramic mould coat which is good to be obtained at 7 layers. The testing results show that: (1) chemical composition meet the existing standard, (2) hardness 160 HB, (3) shrinkage 2.83%.*

### Keywords

*Investment casting, steam turbine blade, stainless steel 304*

This Paper is Published in Advanced Materials Research Journal

## Comparison of Commercially Pure Titanium Surface Hardness Improvement by Plasma Nitrocarburizing and Ion Implantation

Agung Setyo Darmawan<sup>a</sup>, Waluyo Adi Siswanto<sup>b</sup>, Tjipto Sujitno<sup>c</sup>

<sup>a</sup>Department of Mechanical Engineering, Faculty of Engineering,  
Universitas Muhammadiyah Surakarta, Pabelan, Surakarta 57102, Indonesia.

<sup>b</sup>Department of Engineering Mechanics,  
Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia.

<sup>c</sup>National Nuclear Energy Agency (BATAN), Yogyakarta 55281, Indonesia.

Email: agungsetyod@gmail.com, waluyo@uthm.edu.my, tjiptosujitno@batan.go.id

### ABSTRACT

Application of a light-weight material, such as an aluminum alloy, on a turbine impeller can enhance the efficiency of an Organic Rankine Cycle power plant that operates at temperatures below 150 °C. The density of an aluminum alloy only one-third that of steel. However, increased strength of aluminum alloys is needed for turbine impeller qualification. Investment casting was chosen to produce radial inflow turbine impeller due to their complex geometry and precision. It can replace machining process, which is time-consuming and less efficient because of material removal. This study describes the investment casting process used to produce a radial inflow impeller turbine. The study also identifies defects, microstructures and properties of radial inflow turbine impeller. The turbine impeller were produced from Al-7Si-4Mg alloy with 0.38, 3.82, and 6.0 wt. % Cu. Visual examination showed that the turbine impeller was free of macro defects and misruns. Microstructures were characterized by Optical Microscopy and SEM. The structures consisted of  $\alpha$ -Al, Si eutectic, AlMgSi, AlMgFeSi (Chinese script) and  $\text{CuAl}_2$ . The higher hardness value of 54HRB was affected by Cu content due to the good mechanical properties of phase  $\text{CuAl}_2$ .

### Keywords

Investment casting, aluminum alloys, turbine impeller, organic rankine cycle

This Paper is Published in Advanced Materials Research Journal

## Preparation of Uranium Nitride from Uranium Metal through by Hydriding and Nitriding Process

Hadi Suwarno

*Center for Technology of Nuclear Fuel, National Nuclear Energy Agency,  
Gedung 20, Kawasan Puspiptek-Serpong, Tangerang Selatan 15314, Indonesia  
Email: hadis@batan.go.id*

### ABSTRACT

The RERTR Program (Reduced Enrichment in Research and Test Reactors) is an attempt to utilize uranium fuel enriched below 20% for nuclear research reactors. Since the program was launched by the United States in 1978, the International Atomic Energy Agency (IAEA) has recommended that  $U_xSi_y$  alloys, particularly  $U_3Si_2$  and  $U_3Si$  compounds, be used to fuel nuclear research reactors with uranium loading rate up to 4.8 gU/cm<sup>3</sup>. Unfortunately, there are difficulties in reprocessing  $U_3Si_2$  and  $U_3Si$  compounds due to the Si content. To overcome this problem, the IAEA initiated international cooperation to find the best solution in the development of new nuclear fuels to substitute the  $U_xSi_y$  alloys. In order to synthesize nuclear fuel containing high loading of uranium, research in developing uranium nitride (UN) from uranium metal has been conducted by reacting the massive uranium metal with hydrogen gas at a temperature of 573 K followed by dehydriding at a temperature of 773 K under vacuum pressure and nitriding at a temperature of 1073 K by introducing nitrogen gas in the reaction chamber. The X-ray diffraction analysis results showed that the hydriding process caused the uranium metal to turn into a stable compound,  $UH_3$ , which was identified by the changes of the massive shapes into fine metal powders. Dehydriding process at a temperature of 773 K caused the  $UH_3$  compound to decompose into U metal powders, and when the metal powders were reacted with  $N_2$  gas at 1073 K a stable phase identified as UN was formed. The results showed that it is possible to produce UN powders by hydriding, dehydriding, and nitriding process, although special handling of  $UH_3$  and UN powders is required due to their pyrophoric nature.

### Keywords

*UN,  $UH_3$ , hydriding, dehydriding, gas nitriding*

This Paper is Published in Advanced Materials Research Journal

## Materials Selection in Appropriate Technology: Four Focuses in Design Thinking

Corinthias P.M. Sianipar<sup>a,d,e</sup>, Husein Taufiq<sup>b</sup>, Heny R. Estiningtyas<sup>c</sup>, Kiyoshi Dowaki<sup>d</sup>, Akbar Adhiutama<sup>a</sup>, and Gatot Yudoko<sup>a</sup>

<sup>a</sup>Institut Teknologi Bandung (ITB), Jl. Ganesha 10, Bandung 40132, Indonesia

<sup>b</sup>Metal Industry Development Center (MIDC), Jl. Sangkuriang 12, Bandung 40135, Indonesia

<sup>c</sup>Gadjah Mada University (UGM), Bulaksumur, Yogyakarta 55281, Indonesia

<sup>d</sup>Tokyo University of Science (TUS), 2641 Yamazaki, Noda-shi, Chiba-ken 278-8510, Japan

<sup>e</sup>Triple Helix Association (THA), Corso Giulio Cesare 4 bis/B, Torino 10152, Italy

Email: [morgana.sianipar@sbm-itb.ac.id](mailto:morgana.sianipar@sbm-itb.ac.id)

### ABSTRACT

Appropriate technology is widely recognized as a good solution in providing alternative technology for underdeveloped people who live in a very limited circumstance. However, it is often seen as an idea without clear explanation from engineering perspective. One of critical process in appropriate technology design process is materials selection. This study aims to provide applied logic for selecting materials in the design process. The logic is constructed by surveying previous notions from researchers. Reasoning techniques are explored by using design thinking. This study reveals that there are four focuses which must be applied to find sufficient materials for an appropriate technology. This study also concludes that, unlike pure engineering efforts which tend to substitute materials given in a technology design with locally available ones, appropriate technology start from existing resources to produce its design. It requires soft selection by involving local people in exploring any potential materials which already available in their own area. By looking at previous studies which tended to ignore the contribution from local people in exploring potential materials, this study embraces their involvement and then encourages insights for further research around it.

### Keywords

*Materials selection, appropriate technology, design thinking, four focuses*

This Paper is Published in Advanced Materials Research Journal

## Optimizing the Nanostructural Characteristics of Chemical Bath Deposition derived ZnO Nanorods by Post-Hydrothermal Treatments

Akhmad Herman Yuwono<sup>a</sup>, Amalia Sholehah<sup>a,b</sup>, Sri Harjanto<sup>a</sup>, Donanta Dhaneswara<sup>a</sup>, Fajrika Maulidiah<sup>b</sup>

<sup>a</sup>Department of Metallurgical and Materials Engineering, Universitas Indonesia, Indonesia  
[ahyuwono@metal.ui.ac.id](mailto:ahyuwono@metal.ui.ac.id)

<sup>b</sup>Department of Metallurgical Engineering, Universitas Sultan Ageng Tirtayasa, Indonesia  
[amalia.sholehah@ft-untirta.ac.id](mailto:amalia.sholehah@ft-untirta.ac.id)

### ABSTRACT

Zinc oxide (ZnO) is an inorganic semiconductor material which has been widely studied due to its various potential applications. Over the past decades, one-dimensional (1-D) nanostructures such as nanowires and nanorods have stimulated significant scientific interests because of their unique properties in comparison to bulk materials. For the application of dye sensitized solar cell (DSSC), 1-D ZnO nanostructures are more desired than the spherical nanoparticles since the former provides ballistic effect leading to faster electron transfer which in turn can increase the device performance. Motivated by this consideration, in the current study ZnO nanorods were deposited on ITO glass substrate via chemical bath deposition (CBD) process where the seeding solution was prepared at 0°C. In order to increase their crystallinity and optical properties, the as-deposited ZnO nanorods were subjected to post-hydrothermal treatment at 150°C for 3, 6 and 9 hours. The scanning electron microscope (SEM) analysis revealed that the ZnO nanorods were successfully grown as vertically-aligned hexagonal structure, while the X-ray diffraction (XRD) study showed that the intensity of (002) crystal plane is the highest peak for all nanorod samples. The optical study by UV-Vis spectroscopy showed that the absorption edge of the as-deposited sample was slightly red-shifted to visible region after post-hydrothermal treatment. The ZnO nanorods sample derived from post-hydrothermal treatment for 6 hours provided the optimum nanostructural characteristics with an average diameter of 228 nm, crystallite size of 27.97 nm and the band gap energy,  $E_g$ , of 3.12 eV.

### Keywords

ZnO nanorods, low temperature seeding solution, chemical bath deposition, post-hydrothermal treatment

This Paper is Published in Advanced Materials Research Journal

## High Coverage ZnO Nanorods on ITO Substrates via Modified Chemical Bath Deposition (CBD) Method at Low Temperature

Amalia Sholehah<sup>a,b</sup>, Akhmad Herman Yuwono<sup>b</sup>, Nji Raden Poespawati<sup>c</sup>, Adithya Trenggono<sup>a</sup>,  
Fajrika Maulidiah<sup>a</sup>

<sup>a</sup>Department of Metallurgical Engineering, Universitas Sultan Ageng Tirtayasa, Indonesia  
amalia.sholehah@ft-untirta.ac.id

<sup>b</sup>Department of Metallurgical and Materials Engineering, Universitas Indonesia, Indonesia  
ahyuwono@metal.ui.ac.id

<sup>c</sup>Department of Electrical Engineering, Faculty of Engineering Universitas Indonesia, Indonesia

### ABSTRACT

In the present work, ZnO nanorods array were successfully grown on ITO substrate via chemical bath deposition method (CBD). The seeding solution was prepared at low temperature (0°C) using zinc nitrate tetrahydrate and hexamethylenetetramine. The as-deposited ZnO nanorods were hexagonal wurtzite structure growing vertically on the substrate. Various reaction times from 3 to 5 hours were applied upon the CBD process at 90°C. The results showed that the duration of reaction time has affected the nanorods array properties. With the increase of reaction time from 3 to 5 hours has increased the diameter and crystallite size of nanorods from 325 to 583 nm, and from 22.68 to 34.28 nm. As a result, the band gap energy,  $E_g$  of ZnO nanorods decreased from 3.63 to 3.13 eV.

### Keywords

ZnO nanorods, high coverage, chemical bath deposition, growing solution, low temperature

This Paper is Published in Advanced Materials Research Journal

## Influence of Intermetallic Inclusion to Brittle Fracture of Electric Motor Shaft AISI 1045 under Torsion Loading

Suryadi<sup>1,a</sup>, Ahmad I. Karayan<sup>2,b</sup>, Adidjaya C. Nugraha<sup>3,c</sup> and Badrul Munir<sup>4,d</sup>

<sup>1,2,3</sup>Center for Materials Processing and Failure Analysis (CMPFA)  
Department of Metallurgy and Materials Engineering, Faculty of Engineering  
Universitas Indonesia, Indonesia

<sup>4</sup>Department of Metallurgy and Materials Engineering, Faculty of Engineering  
Universitas Indonesia, Indonesia

<sup>a</sup>suryadi@metal.ui.ac.id, <sup>b</sup>ivan@metal.ui.ac.id, <sup>c</sup>chandra@metal.ui.ac.id, <sup>d</sup>bmunir@metal.ui.ac.id

### ABSTRACT

A shaft of electric motor fin-fan cooler failed after two years operation. The inspection revealed that the v-belt attached on the electric motor loosed before the failure occurred. Visual investigation results showed the brittle fracture with less plastic deformation. Multiple crack origins observed on the edge of the shaft indicates that the more than one stress concentration generated within the shaft. Microstructure observation revealed fine grain on the edge and become coarse into the center of the shaft. The hardness test results were in good agreement to the microstructure observation where the edge are is harder than the center. Fractography using SEM revealed inclusions located within the shaft and some inclusions are clustered on the area where the cracks initiate to propagate. The presence of intermetallic inclusions was identified by microanalysis using EDS. Inclusions that are brittle in nature become stress concentrations for the operating load since its properties is close to ceramic. The presence of fine grain and inclusions on the edge of the shaft become detrimental to the shaft properties and the presence of fine grain aggravate the failure for its effect according to Hall-Petch theory.

### Keywords:

*Failure analysis, electric motor shaft, brittle, intermetallic, stress concentration, fatigue.*

This Paper is Published in Advanced Materials Research Journal

# Performance of Natural Carotenoids from *Musa aromatica* and *Citrus medica* var Lemon as Photosensitizers for Dye-Sensitized Solar Cells with TiO<sub>2</sub> Nanoparticle

Eka Cahya Prima, Brian Yulianto, and Suyatman

*Advanced Functional Material Laboratory, Department of Engineering Physics  
Faculty of Industrial Technology, Institut Teknologi Bandung, Indonesia*

[brian@tf.itb.ac.id](mailto:brian@tf.itb.ac.id)

## ABSTRACT

Several natural dyes have been extracted from tropical fruit shells such as *Musa aromatica* and *Citrus medica* var Lemon fruit shells. The resulting dyes have been used as sensitizer at dye sensitized solar cell (DSSC). The main pigments, which are carotenoids, was obtained by extraction and purification at dark room. Ethanol and water are used as solvents. The dyes have been characterized through UV-Vis spectrophotometer. The thin film of TiO<sub>2</sub> anatase has been sintered at 450°C to enhance film compactness. According to the experimental results, the DSSC conversion efficiency which has been prepared by carotenoid dye from *Musa aromatica* fruit shell extract is 0.21%, 0.614 V of open-circuit voltage ( $V_{OC}$ ), 0.280 of short-circuit current density ( $J_{SC}$ ) mA/cm<sup>2</sup>, 56  $\mu$ W of maximum power ( $P_{max}$ ) and 0.43 of fill factor (FF). Then, the DSSC conversion efficiency which has been prepared by carotenoid dye from *Citrus medica* var Lemon fruit shell extract is 0.05%, 0.460 V of  $V_{OC}$ , 0.093 mA/cm<sup>2</sup> of  $J_{SC}$ , 14  $\mu$ W of  $P_{max}$  and 0.44 of FF. The measurement of I-V curve demonstrated that carotenoid was potential component as sensitizer for DSSC.

## Keywords

*Dye Sensitized Solar Cell, photosensitizer, natural carotenoid, purification*

This Paper is Published in Advanced Materials Research Journal

## Magnetic Behaviors of BaTiO<sub>3</sub>-BaFe<sub>12</sub>O<sub>19</sub> Nanocomposite Prepared by Sol-Gel Process Based on Differences in Volume Fraction

Dwita Suastiyanti<sup>a</sup>, Bambang Soegijono<sup>b</sup>, Muh.Hikam<sup>c</sup>

<sup>a</sup>Graduate Program of Material Science, Department of Physics  
University of Indonesia, Depok 16424

<sup>a</sup>Mechanical Department of Indonesia Institute of Technology  
Puspiptek-Serpong

<sup>b,c</sup>Multiferroic Laboratory, Department of Physics  
University of Indonesia, Depok 16424

<sup>a</sup>dwita\_suastiyanti@yahoo.com, <sup>b</sup>bambangsg11@yahoo.com, <sup>c</sup>m.hikam@gmail.com

### ABSTRACT

Barium titanate BaTiO<sub>3</sub> (BTO) - barium hexaferrite BaFe<sub>12</sub>O<sub>19</sub> (BHF) nanocomposite could be as a raw material of multiferroic. Multiferroic is a class of materials with coupled electric, magnetic and structural order parameters that yield simultaneous effects of ferroelectric, ferromagnetism and ferroelasticity in the same material. This material has potential applications in such as spintronic devices and sensors. This work was an earlier research towards formation of multiferroic material. Knowing magnetic properties that will lead to a better understanding of magnetoelectric coupling in multiferroic material is the objective of this research. The samples were BTO and BHF prepared by sol-gel and then were mixed in bulk system by a conventional techniques in various of volume fraction between BTO : BHF = 1:1 ; 1:2 and 2:1, then samples were sintered at 925°C for 5, 10 and 15 hours. Composite phase study was carried out using X-Ray Diffraction (XRD). MPS Magnet – Physik EP3 – Permagraph L was used to characterize magnetic properties. XRD results confirm that composite with volume fraction of BTO : BHF = 1:1 with sintering at 925°C for 5 hours consists only of 2 phases BTO and BHF. There is impurity phase BaFe<sub>2</sub>O<sub>4</sub> beside BTO and BHF phases at samples with volume fraction BTO:BHF = 1:2 and 2:1 for longer sintering. Composite with volume fraction of BTO:BHF = 1:1 for 5 hours sintering has a high value of remanent magnetization 0.081 T and the lowest value of intrinsic coercive 333.6 kA/m leading to good characteristics of multiferroic materials.

### Keywords :

*Sol-gel, nanocomposite, magnetic properties, multiferroic material, volume fraction.*

This Paper is Published in Advanced Materials Research Journal

## Fabrication of Polymer Solar Cells on Flexible Substrate

**Erlyta Septa Rosa, Shobih**

*Research Center for Electronics and Telecommunication  
Indonesian Institute of Sciences (PPEI-LIPI)  
Kampus LIPI Gd. 20 Jl. Sangkuriang Bandung 40135*

*[erlyta@ppet.lipi.go.id](mailto:erlyta@ppet.lipi.go.id) Email: [shobih@ppet.lipi.go.id](mailto:shobih@ppet.lipi.go.id)*

### ABSTRACT

Polymer blends are potential candidates for solar-energy conversion, due to their flexibility, ease of processing, and low costs. We report herein 2.6 cm<sup>2</sup> active area of flexible polymer solar cells based on blends of polymeric semiconductor [poly(2-methoxy-5-(3,7-dimethyloctyloxy)-(para-phenylene vinylene)] (MDMO-PPV) and the soluble fullerene C60 derivative [6,6-phenyl C61-butyric acid methyl ester] (PCBM). Devices were prepared by etching an electrode pattern of Indium Tin Oxide (ITO) covered on poly[ethylene terephthalate] (PET) substrate. A layer of conducting poly(3,4-ethylenedioxythiophene):poly(styrene sulphonate) (PEDOT:PSS) were screen printed on top of the ITO. Followed by spin coated a polymer blends of MDMO-PPV/PCBM in chlorobenzene onto PEDOT:PSS layer. Finally, evaporation of a silver electrode and PET film lamination completed the devices. The typical overall power efficiency of the prototype devices in an active area of 2.6 cm<sup>2</sup> was 0.004 % with open circuit voltage of 1.473 Volt, short circuit current of 5.84 x 10<sup>-06</sup> Ampere, and maximum power of 2.12 x 10<sup>-06</sup> Watt.

### Keywords

*Polymer, blends, flexible, solar cells, efficiency*

This Paper is Published in Advanced Materials Research Journal

## The Effect of Vertical Step Block Casting to Microstructure and Mechanical Properties in Producing Thin Wall Ductile Iron

Rianti Dewi Sulamet-Ariobimo<sup>a</sup>, Johny Wahyuadi Soedarsono<sup>b,c</sup>,  
Is Prima Nanda<sup>d</sup>

<sup>a</sup>Mechanical Engineering Department, Faculty of Industrial Technology, Universitas Trisakti, Jakarta, Indonesia  
[riantiaribimo@yahoo.com](mailto:riantiaribimo@yahoo.com)

<sup>b</sup>Department of Metallurgy and Materials, Faculty of Engineering, Universitas Indonesia, Depok, Indonesia

<sup>c</sup>Politeknik Negeri Jakarta, Depok, Indonesia  
[jwsono@metal.ui.ac.id](mailto:jwsono@metal.ui.ac.id)

<sup>d</sup>Department of Mechanical Engineering, Faculty of Engineering, Universitas Andalas, Padang, Indonesia

### ABSTRACT

Thin wall ductile iron (TWDI) is introduced to fulfill the needs of lighter material in automotive parts that will reduce fuel consumption. Problem occurs during the production of TWDI due to the casting thickness. TWDI casting thickness classified to below 5 mm. Many designs have been made to answer the problem in producing thin wall ductile iron. Soedarsono et al established vertical step block casting design. This design based on Y-block principle that allows direct pouring of liquid metal to the mold without passing any gating system. This design will increase casting yield. The parameter of this research is pouring basin placement to study the effect of plate arrangement to filling and solidification. This research is conducted to see the effect of pouring basin placement to microstructure and mechanical properties of TWDI. The Design is made to produce 5 plates with different thickness that is 1, 2, 3, 4, and 5 mm. All of the plates arranged parallel in line. Pouring basin located in 2 ways. The first type located pouring basin above the plate of 5 mm thickness while the second one located it above the plate with 1 mm thickness. The first type coded as T4 while the second coded as T5. The moulds made from furan sand. The result shows although cold shut occurred in both pouring basin placements due to pouring discontinuity but shrinkage only formed in T5 on its plate with 1 mm thickness. Microstructure of all the plates presented nodule graphite in pearlite matrix. Carbide and skin effects also detected. Average nodularity is above 80% while the nodule count is between 614 to 1269 nodule/mm<sup>2</sup>. Most of the Brinell hardness number exceeded maximum limit given by JIS G5502 but the UTS is below the minimum limit except for 3 mm plate thickness of T5. All elongation values below the minimum standard. The results confirm that pouring basin location is important in casting design following Y-Block principle.

### Keywords

*Casting design, TWDI; vertical step block, Y-block principle, pouring basin position*

This Paper is Published in Advanced Materials Research Journal

## Characteristics of Heat Treated Al7Si-Mg-Zn - SiC 5 wt.% Squeeze Casted Composite with Variation of Mg Content for Tactical Vehicle Application

**Sigma R. Sigit, Bondan T. Sofyan**

*Department of Metallurgy and Materials Engineering, Faculty of Engineering, Universitas Indonesia, Depok, Indonesia  
sigmardi@gmail.com, [bondan@eng.ui.ac.id](mailto:bondan@eng.ui.ac.id)*

### ABSTRACT

Composite as main materials for ballistic applications has been developed in order to reduce density which leads to lower fuel consumption and faster mobilization. Composite is required to own high hardness and high impact strength for good ballistic performance. Particulate composites Al-7Si-Mg-Zn reinforced by SiC is designed for ballistic applications due to its light weight and high hardness. Whilst the high hardness showed brittle properties, heat treatment process is applied to this composite to reduce it. This research aims to study the effect of magnesium as alloying element to composite Al-7Si-Mg-Zn reinforced by SiC particulate which applied to precipitation hardening. Composites Al-7Si-Mg-Zn-SiC with 2, 4 and 6 wt. % Mg is solution treated at 500 oC for 1 hour, followed by ageing at 200 oC. The characterization was carried out by hardness testing, microstructure observations, SEM and EDX observations, impact testing and fractographic observations. Results showed that Mg does not affect hardness of composite by precipitation hardening. Composite with 2, 4, 6 wt. % Mg had 63.83, 62.27, 62.48 HRB on its peak hardness. Mg did not become precipitate in matrix Al-7Si-Mg-Zn because of its low diffusivity in aluminium. Mg worked as wetting agent that reduces interface tension between aluminium matrix and SiC particles in order for composite to own better interface bonding. Therefore impact testing showed significant increase of impact strength with the increase of Mg content. Composite with 2, 4, 6 wt. % Mg had 2075, 3006, 3257 J/mm<sup>2</sup> impact strength respectively.

### Keywords

*Aluminum composite, lightweight, ballistic, precipitation hardening, magnesium, wetting agent interface*

This Paper is Published in Advanced Materials Research Journal

# Controlled Process in Producing 490 MPa Class High Strength Low Alloys Steel for Shipbuilding Applications

Cahyo Antarikso<sup>a</sup>, Ahmad Desrianto<sup>b</sup>, Himawan Sutanto<sup>c</sup>

<sup>a</sup>Quality Control Manager, Krakatau Steel, Indonesia  
E-mail: [cahyo.antarikso@krakatausteel.com](mailto:cahyo.antarikso@krakatausteel.com)

<sup>b</sup>Quality Control Senior Engineer, Krakatau Steel, Indonesia  
E-mail: [ahmad.desrianto@krakatausteel.com](mailto:ahmad.desrianto@krakatausteel.com)

<sup>c</sup>Quality Control Engineer, Krakatau Steel, Indonesia  
E-mail: [himawan.sutanto@krakatausteel.com](mailto:himawan.sutanto@krakatausteel.com)

## ABSTRACT

Energy saving is one of popular topic in environmental issue in recent years. In the field of transportation, energy savings can be done either by reducing the weight of the vehicle. Therefore the usage of lighter raw materials plays an important role. Steel is commonly used as one of structural and hull materials for shipbuilding application. The usage of higher strength steel materials can reduce weight of vessels itself.

This paper concerns to the controlled process in producing higher strength steel materials for shipbuilding applications. Krakatau Steel has been successfully producing 490 MPa Class high strength steels materials for this application, with standard class of ABS-AH36 and NK-KA36. The addition of solid solution strengthening elements up to 0.3% Ni, 0.3% Cu and grain refinements strengthening elements up to 0.06% Nb, 0.08% V into steel containing 0.07% C and 1.2% Mn, combined with controlled rolling process resulted in high yield strength of 450-570 MPa, tensile strength of 510-630 MPa, and fine ferrite grain size of 5-9  $\mu\text{m}$ . This steel has excellent charpy impact properties up to 270 Joule at 0 °C and very low Drop Weight Test (DWT) transition temperature of -40 °C and also good weldability.

### Keywords:

Hull, structural steel, high strength, HSLA, micro alloy, weldability

## 1. INTRODUCTION

Steel is commonly used as raw material for structural in several applications. In the shipbuilding application, steel materials can be directly used as hull and structural materials or can be manufactured into several forms such as boiler, pressure vessels, pipe and other forms which are used in the vessels.

Energy cost becomes higher and higher in the recent few years. In the field of transportation, energy cost is one of important factor which have big impact for transporter companies. Energy saving in term of reducing operating cost of transportation can be done by reducing the weight of the vehicle. Therefore usage of lighter weight steel material with higher level strength can reduce weight of the vessels itself.

Since early 1980's, Krakatau Steel has been producing 400 MPa class steel for shipbuilding application with Lloyd's Register Class Certification. And furthermore, in the early 1990's until the early 2000's Krakatau Steel has also produced the same material with other Class Certification such as BKI, GL, NV, DNV, ABS and NK. In 2007 Krakatau Steel has been successfully developing higher strength 490 MPa class steel for this application with NK and ABS Class Certifications.

This paper briefly describes the experience of the company in producing 490 MPa Class High Strength Low Alloys Steel (HSLA Steel) product for hull and structure of shipbuilding application.

## 2. PRODUCT REQUIREMENTS AND DESIGN

The chemical requirements of NK and ABS Class for KA36 and AH36 grade compare to typical of chemical composition of the products and target mechanical properties of the product are shown in Table 1 and Table 2, respectively. The steel material design considered both the uniformity of the targeted mechanical properties and its microstructure.

*Table 1 Chemical Requirements and Typical of Chemical Composition of the Products*

Element (%)	NK Standard	ABS Standard	Typical
C	0.18 max		0.05 – 0.09
Mn	0.90 – 1.60		1.00 – 1.40
Si	0.50 max	0.10 – 0.50	0.15 – 0.40
P	0.035 max		0.020 max
S	0.035 max		0.010 max
Al	0.020 min	0.015 min	0.025 – 0.050
Nb	0.02 – 0.05		0.030 – 0.040
V	0.05 – 0.10		0.060 – 0.080
Ti	0.02 max		0.020 max
Cu	0.35 max		0.10 – 0.20
Ni	0.40 max		0.10 – 0.20
Cr	0.20 max		0.10 max
Mo	0.08 max		0.02 max
Nb+ V+Ti	0.12 max	-	0.12 max
CE	0.36 max	0.38 max	0.34 max
Pcm	-	-	0.17 max

*Table 2 Target of Mechanical Properties of the Products*

Properties	NK KA36 Standard	ABS AH36 Standard	Typical
Yield Strength (Trans)	355 min		450 – 550
Tensile Strength (Trans)	490 – 620		510 – 600
Elongation	16 min		17 – 26
Charpy, 0°C (J)	34 min (Long) 24 min (Trans)		> 100 J
Drop Weight Test (DWT) 0°C	No Break		No Break

In general, steel raw material for hull structural steel of shipbuilding application should have following characteristics such as: *High Ductility, Good Toughness, Excellent Weldability, Good Corrosion Resistance Properties and also should have Higher Strength*. To obtain these characteristics, the quality of hot rolled steel plate products that must met the following requirements:

- Good surface condition (free from surface defects),
- Good internal quality (lower micro inclusion, lower segregation), and
- Homogenous microstructure (fine grain structure of fine ferrite and fine lamellar pearlite, no banded structure).

### **3. CONTROLLED PROCESS IN PRODUCING HOT ROLLED STEEL PLATE FOR HULL STRUCTURAL STEEL OF SHIPBUILDING APPLICATION**

The production of steel for hull structural steel of shipbuilding application is carried out in the existing slab steel plant and hot strip mill with processing route as generally shown in Figure 1. In the Electric Arc Furnace, the raw materials which consist of 20% scrap and 80% of sponge iron are melted. This melted steel is then further processed in the Ladle Furnace to reduce the sulphur content of the steel and to adjust the chemical composition of the steel by addition of alloying elements. Subsequently, the steel is continuously cast in the continuous casting machine to produce steel slab.

The steel making and casting practices adopted for NK – KA36 and ABS – AH36 grade can be summarized as follows:

- Hot metal desulphurization
- Calcium treatment by CaSi wire injection for inclusion shape control
- Casting into tundish with argon gas purging and extended shroud to minimize re-oxidation during set up
- Controlling the cooling intensity, superheat, and casting speed
- Metal retention in ladle at ladle change

This practice is developed not only to achieve the required chemical composition but also to obtain steel with high cleanliness, free from internal and surface defect.

In the hot strip mill, the steel slabs which come from the slab steel plant are subsequently hot rolled to the specified thickness. The Thermo-Mechanical Control Process is applied during rolling to get fine grain microstructures of HRC and to achieve the required mechanical properties. Figure 2 shows the basic principle of Thermo-Mechanical Control Process during rolling applied in the hot strip mill. Slab is reheated up to about 1200 °C and soaked at that temperature in the reheating furnace. The slab is then control-rolled with high reduction at above the non-recrystallization temperature in the roughing mill in order to achieve fine austenite grain size. This steel is then rolled at a temperature between non-recrystallization and  $A_{r3}$  transformation temperature in the finishing mill. This process will introduce the deformation bands within the austenite grains which promote the nucleation sites for ferrite grains. It consequently results in the formation of finer ferrite grain after austenite – ferrite transformation. The steel strip is finally coiled at about 600 °C.

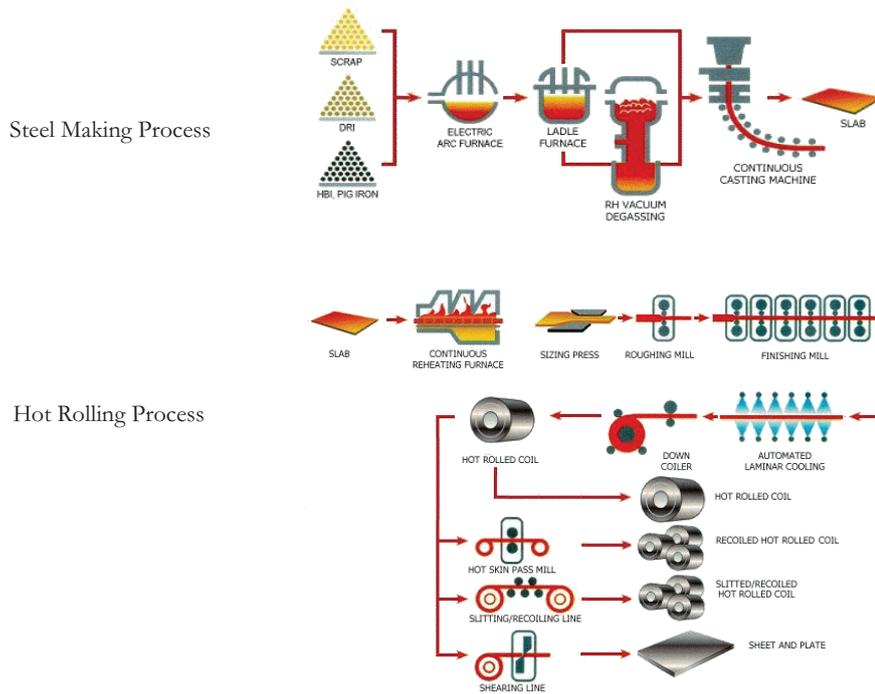


Figure 1 The Production Process Line in Steel Making and Hot Rolling

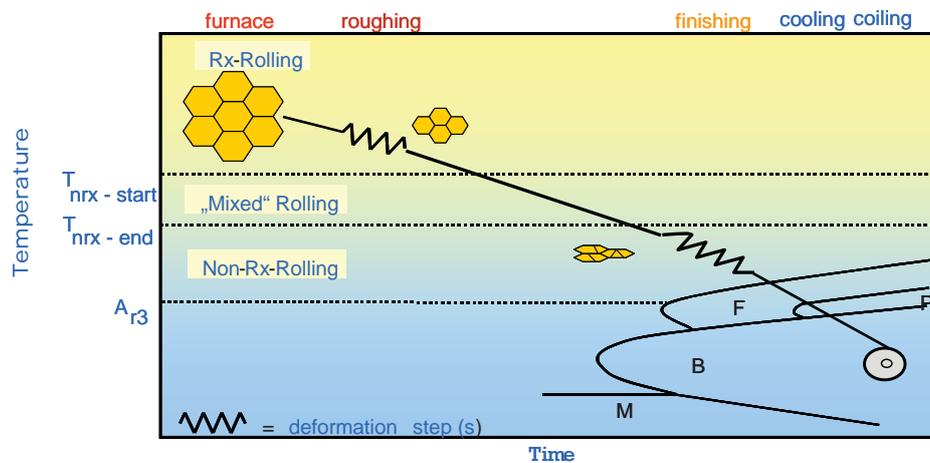


Figure 2 A schematic of Thermo-Mechanical Control Process during Control Rolling

## 4. RESULT AND DISCUSSION

### 4.1 Mechanical Test Results

#### 4.1.1 Tensile Test Result

The results of tensile test which were taken from production data of hot rolled steel plate in transversal direction are presented at Table 3. The yield strength and tensile strength of the steel with thickness range of 4 - 22 mm are 460 to 560 MPa and 510 to 610 MPa, respectively. The elongation of the steel is 16% to 25% in transversal direction. The value of yield strength, tensile strength and elongation in transversal direction are within the range of the specified values for the NK – KA36 and ABS – AH36 specification and achieve the targeted values.

Table 3 Tensile Test Result of Hot Rolled Steel Plate

Thickness Range (mm)	Yield Strength (Mpa)	Tensile Strength (Mpa)	Elongation (%)	Testing Direction
4 - 6	520 – 560	550 – 610	16 – 21	Transversal
8 - 16	470 – 540	520 – 600	17 – 22	
18 - 22	460 – 540	510 – 580	18 – 25	
NK and ABS Class Standard	355 min	490 – 620	13 min ( $t < 5$ mm) 15 min ( $5 \leq t < 10$ mm) 16 min ( $10 \leq t < 15$ mm) 17 min ( $15 \leq t < 20$ mm) 18 min ( $20 \leq t < 25$ mm)	Transversal

#### 4.1.2 Charpy Test Result

The results of Charpy Impact Test conducted at temperature range of -40 °C to 25 °C are presented in Figure 3. As can be seen in this figure, charpy values in longitudinal and transversal direction within that temperature range are 150 – 300 J and 100 – 280 J respectively. Until test temperature as low as -40 °C, transition temperature phenomenon is not observed. These charpy values indicate that the material has a very good toughness even at very low temperature.

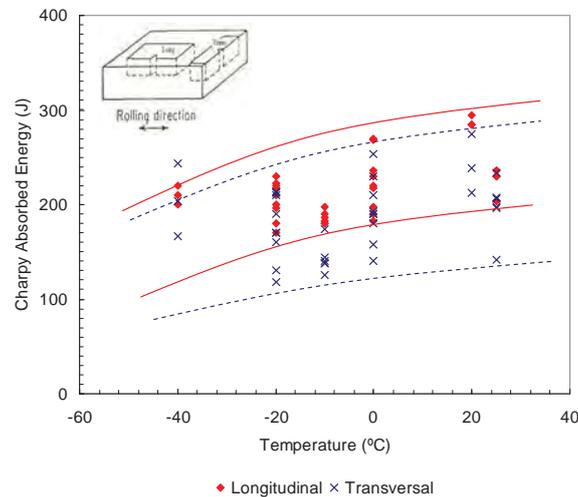


Figure 3 Charpy Test Result of Hot Rolled Coil

In order to simulate the usage in a prolonged period, charpy impact test is conducted on strain aged samples. Comparison of charpy values on longitudinal direction for as rolled and strain aged samples are shown in Figure 4. Strain aged samples are achieved by heating samples at 250 °C for 60 minutes after they are previously subjected to 5% strain. As presented in the figure, charpy values of strain aged samples until temperature of 0 °C are high enough i.e. more than 90 J, and then tend to decrease at temperature below 0 °C.

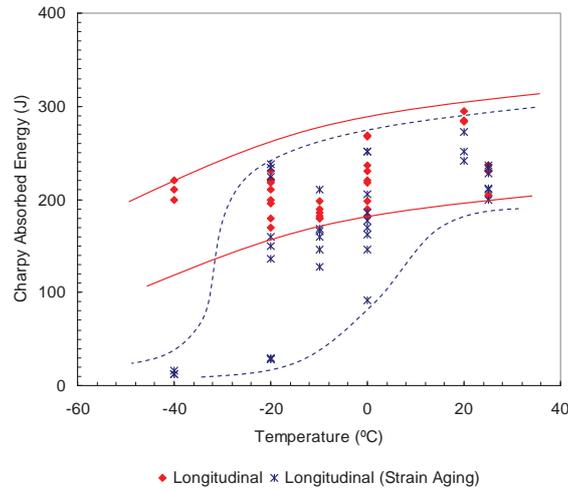


Figure 4 Charpy test results for strain aged and non strain aged samples

Lateral expansion values at temperature of -40 °C, -20 °C, 0 °C, and 20 °C are shown in Figure 5. A slight decreasing on lateral expansion values is observed at a test temperature of -40 °C.

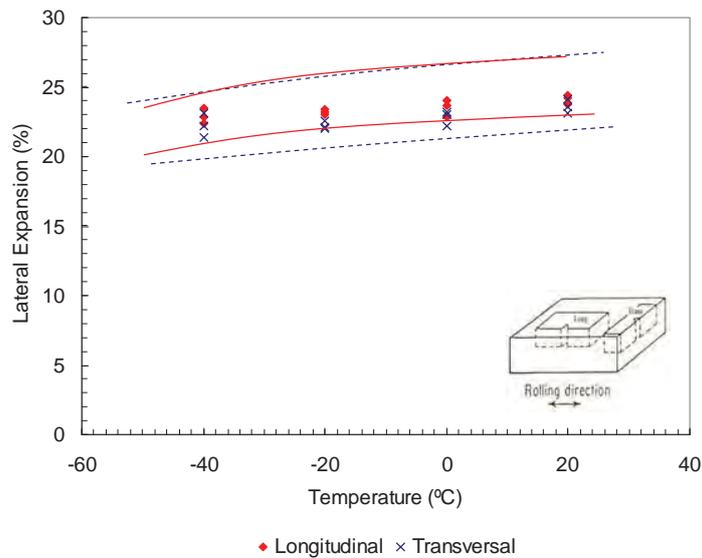


Figure 5 Lateral expansion value

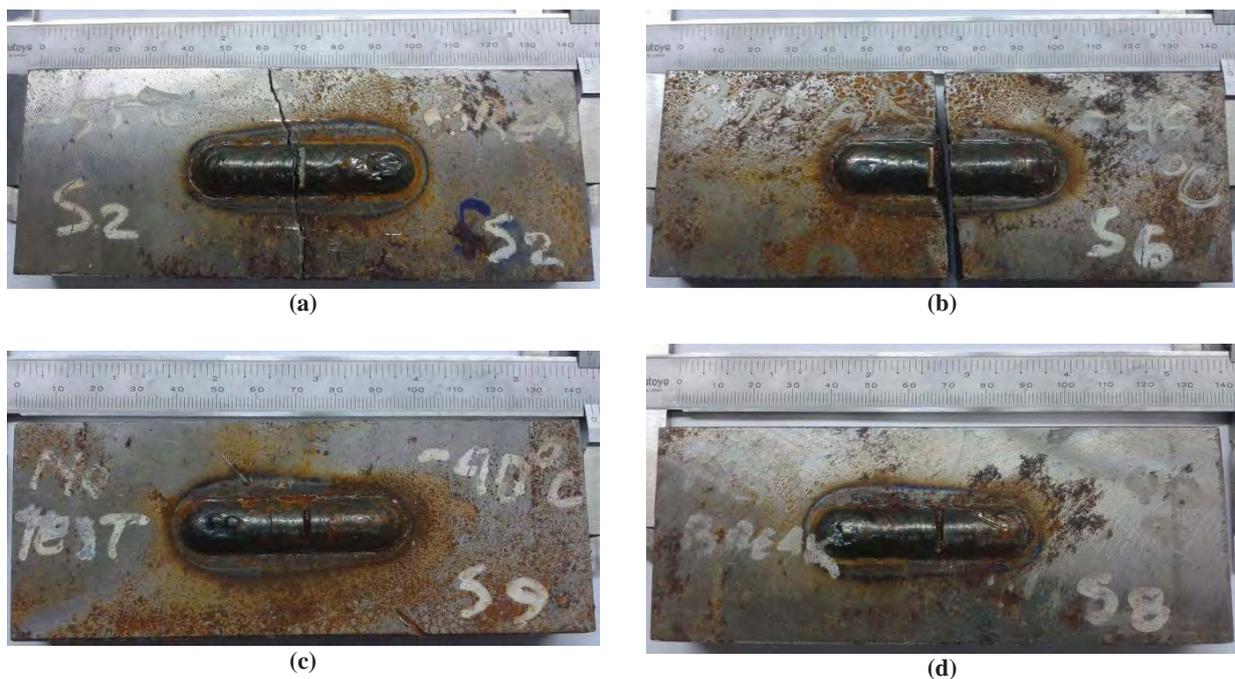
#### 4.1.3 Drop Weight Test Result

Drop Weight Test (DWT) referring to ASTM E208 is conducted to determine the nil-ductility transition temperature (NDTT). The NDTT is the temperature above which a steel will fracture in a ductile mode and exhibit plastic deformation at nominal stresses beyond its yield strength. Below this temperature, steel will fracture in a brittle mode when loaded to its yield strength. The NDTT is determined when one specimen at a lower temperature results in a “break” condition, while two tests at the same temperature show “no-break” results. DWT results summary and photograph of three different test results are presented in Table 4 and Figure 6 respectively. Based on the results, temperature of -40 °C is considered as NDTT.

**Tabel 4** Drop Weight Test result

No.	Heat No	Coil No	Temperature (°C)	Result <sup>*)</sup>
1	57790P	475701	-35	No Break
2	57790P	475701	-35	No Test
3	57790P	475701	-40	No Break
4	57790P	475701	-40	No Test
5	57790P	475701	-40	Break
6	57790P	475701	-40	No Test
7	57790P	475701	-45	No Test
8	57790P	475701	-45	Break
9	57790P	475701	-45	Not Break
10	57790P	475701	-45	No Test
11	57790P	475701	-50	No Test
12	57790P	475701	-50	Break

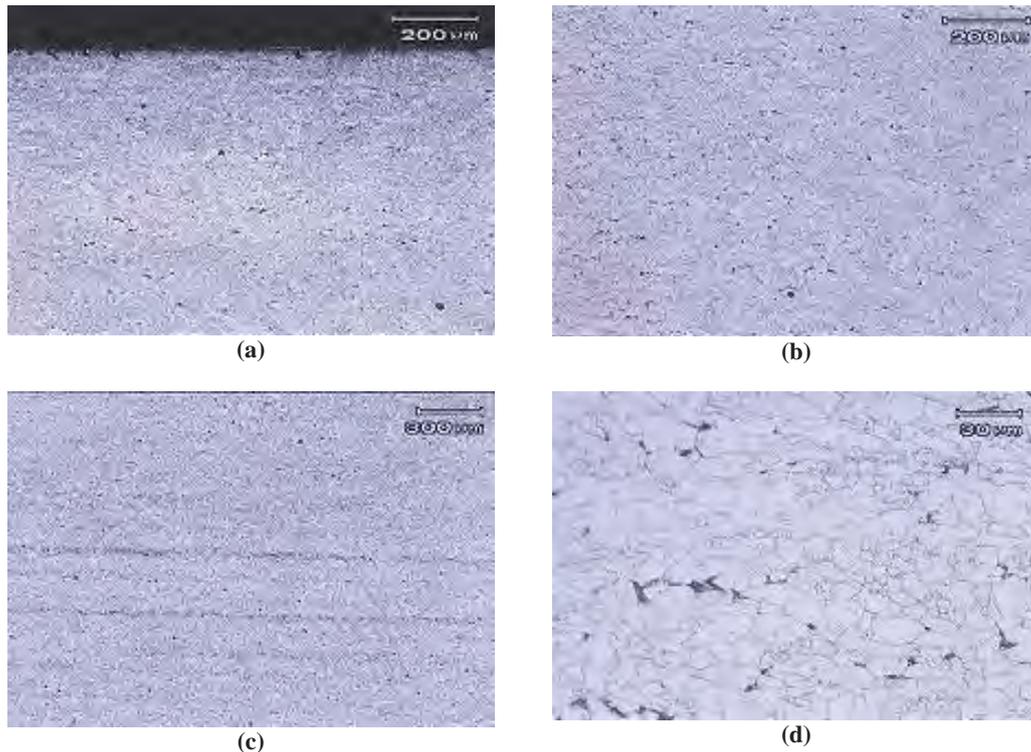
\*) *No Test* : crack propagations on welding area and base metal are not observed  
*No Break* : specimen develops a visible crack in the crack-starter weld bead that is not propagated to either edge of the tension surface  
*Break* : specimen is fractured to one or both edges of tension surface



**Figure 6** Drop weight test results at various temperature tests: (a) break condition at -55 °C, (b) break condition at -45 °C, (c) no test condition at -40 °C, and (d) no break condition at -40 °C

## 4.2 Metallographic Observation

Microstructure of the hot rolled steel plate is shown in Figure 7. Fine ferrite with grain size of 5.0 – 9.0 μm (ASTM no 12.3 – 10.7) and fine lamellar pearlite were observed by means of optical microscopy. Banded pearlite structure is not observed at surface, quarter thickness, and half thickness of the samples.



**Figure 7** Microstructure of the hot rolled steel plate in surface position (a), quarter thickness (b) and (d), and half thickness (c)

## 5. SUMMARY

The appropriate properties of hot rolled steel plates NK – KA36 and ABS – AH36 specification for shipbuilding application could be obtained by strictly chemical composition control during slab steel making process combined with reduction and temperature control during hot rolling process.

## 6. REFFERENCES

- [1] Max Haneke et al. *Low Temperature Steels (Steels with Good Toughness at Low Temperatures)*. eds. Verein Deutscher Eisenhüttenleute, STEEL A Handbook for Materials Research and Engineering Vol. 2. 1993.
- [2] C W K Hyland, W G Ferguson, and J W Butterworth. *The Effect Of Pre-Strain And Aging On The Fracture Toughness Of Australasian Constructional Mild Steel*. Structurel Integrity and Fracture. 2004.
- [3] Regis Geisler. *Relevance Of Drop-Weight Testing In The Determination Of The Reference Nil-Ductility Temperature*. <http://www.fabricatingandmetalworking.com/2012/02/relevance-of-drop-weight-testing-in-the-determination-of-the-reference-nil-ductility-temperature/>. 2013.
- [4] John M Holt. *Charpy Impact Test: Factors and Variables*. ASTM International. 2002.
- [5] Ship Structure Committee. *Fracture Toughness Characterization of Shipbuilding Steels*. 1975.

## The Influence of Coal Ratio in Reduction Process of Producing Iron Nugget

Johny Wahyuadi Soedarsono<sup>1, a, b</sup>, Adji Kawigraha<sup>2, a, c</sup>, Rianti Dewi Sulamet-Ariobimo<sup>3, d</sup>, M. Amryl Asy'ari<sup>4, e</sup>, Andre Yosi<sup>a</sup>, and Eko Mulia Putra<sup>a</sup>

<sup>a</sup> Department of Metallurgy and Material, Faculty of Engineering, Universitas Indonesia  
Depok 16424 – Indonesia  
Tel: +62217863510 Fax: +62217872350

<sup>b</sup> Politeknik Negeri Jakarta  
Depok 16424 – Indonesia

<sup>c</sup> Center of Mineral Resources Technology,  
Agency for Assessment and Application of Technology, Jakarta, Indonesia  
Tel: +62213169659 Fax: +62213169668

<sup>e</sup> Mechanical Engineering Department, Faculty of Industrial Technology, Universitas Trisakti  
Jakarta 11440 – Indonesia  
Tel: +62215663232 ext 8430 Fax: +62215605841

<sup>d</sup> Politeknik Negeri Banjarmasin  
Martapura – Indonesia  
Tel: +62817260856

<sup>1</sup> [jwsono@metal.ui.ac.id](mailto:jwsono@metal.ui.ac.id), <sup>2</sup> [akawigraha@gmail.com](mailto:akawigraha@gmail.com), <sup>3</sup> [riantiaribimo@yahoo.com](mailto:riantiaribimo@yahoo.com) - [riantiaribimo@trisakti.ac.id](mailto:riantiaribimo@trisakti.ac.id), <sup>4</sup> [amril\\_18arie@yahoo.com](mailto:amril_18arie@yahoo.com)

### ABSTRACT

Limitation of iron ore reserve having high quality ore and of energy has enhanced development in iron and steel producing technology and method. The ITmk3 process is one of iron making technology that can cope with the problems. It uses composite pellet as feeding material. In this process the ratio between iron and carbon are very important. Carbon holds an important role in the reduction process of iron. The transformation from iron oxides to iron metal will complete if composite pellet contains enough carbon. This paper discusses the influence of carbon ratio in iron reduction process. Nickel saprolite and coal are used as iron and carbon source. They are grinded, crushed, sieved, mixed and formed in cylinders. The weight ratios of ores to coal are 1:1 and 2:1. The reduction held in a furnace at 1100°C for 60 minutes and 1250°C for 120 minutes. The results show that the reduction could not complete. Weak peak of FeNi is due to reduction process do not immediately follow the dehydroxylation process.

### Keywords

Composite pellet, saprolite, carbon ratio, iron reduction, weight ratio

This Paper is Published in Advanced Materials Research Journal

## Sulfuric Acid Leaching of Bangka Indonesia Ilmenite Ore and Ilmenite Decomposed by NaOH

Latifa Hanum Lalasari<sup>a,b</sup>, Rudi Subagja<sup>a</sup>, F. Firdiyono<sup>a</sup>, Akhmad Herman Yuwono<sup>b</sup>, Sri Harjanto<sup>b</sup>, Bambang Suharno<sup>b</sup>

<sup>a</sup>Research Centre for Metallurgy, Indonesian Institute of Sciences (LIPI), Kawasan Puspiptek Serpong, Tangerang Selatan 15314, Indonesia  
E-mail: ifa\_sari@yahoo.com, lati003@lipi.go.id

<sup>b</sup>Department of Metallurgy and Materials Engineering, Faculty of Engineering, University of Indonesia, Jawa Barat 16424, Indonesia  
E-mail: ahyuwono@metal.ui.ac.id,

### ABSTRACT

Ilmenite (FeO.TiO<sub>2</sub>) ore from Bangka island-Indonesia is a potential raw material for synthesizing titanium dioxide (TiO<sub>2</sub>) to be used as pigmen and photocatalyst. The manufacture of TiO<sub>2</sub> particles from ilmenite can be done through the process of solvent extraction using sulfuric acid route. Therefore, the solubility of this ilmenite ore in sulfuric acid environment is one of key factors to obtain the desired TiO<sub>2</sub> particles. The current research is aimed at comparing the solubility of pristine Bangka ilmenite ore with that of precedingly decomposed by sodium hidroxide (NaOH) in both pressurized reactor/autoclave and atmospheric reflux reactor. The dissolution of both precursors was carried out in a pressurized reactor and an atmospheric reflux reactor with various temperatures of 75, 100, 125, 150 and 175 °C. The results showed that the optimum dilution was achieved at 150 °C in a pressurized reactor and an atmospheric reflux reactor. The obtained recovery of ilmenite was 88.8 % for a pressurized reactor and 75.5 % for an atmospheric reflux reactor. The solubility of titanium increased steadily to reach a recovery of 68 % at f 150 °C and decreased significantly afterwards. It was also found that the increase of iron solubility was proportional to the rise of processing temperatures.

### Keywords

*Ilmenite, sulfuric acid, sodium hidroxide, ionic titanium, ionic iron*

This Paper is Published in Advanced Materials Research Journal

## Anatase TiO<sub>2</sub> Enrichment from Bangka Ilmenite (FeTiO<sub>3</sub>) and Its Photocatalytic Test on Degradation of Congo Red

Sariman<sup>a</sup>, Yuni K. Krisnandi<sup>b</sup>, Budi Setiawan<sup>c</sup>

<sup>a</sup>Center for Coal and Mineral Technology (Puslitbang TekMira)  
Jl. Jendral Sudirman No. 623, Bandung 40211  
Tel : (022) 6030483. Fax : (022) 6003373  
E-mail : sariman@tekmira.esdm.go.id

<sup>b</sup>Department of Chemistry, FMIPA  
Universitas Indonesia, Depok 16424  
Tel : (021) 7270027 Fax : (021) 7863432  
E-mail : yuni.krisnandi@sci.ui.ac.id, budisetiawan1326@gmail.com

### ABSTRACT

Anatase TiO<sub>2</sub> enrichment from Bangka ilmenite (FeTiO<sub>3</sub>) has been conducted. First, ilmenite was mechanically activated using a planetary ballmill to obtain sub-micron sized particle followed by magnetic separation. Chemical treatment, dissolution of iron using hydrochloric solution, was performed to obtain titania rich residue. EDX data shows that the iron content was reduced in the titania residue. Ammonium hydroxide (NH<sub>4</sub>OH) solution was added to the washed precipitate, before adding H<sub>2</sub>O<sub>2</sub> solution (10%) that acted as a coordination agent to leach titanium from the residue in the form of ammonium peroxy titanate solution. The peroxy titanate powder was obtained by evaporating the ammonium peroxy titanate solution. XRD data show that TiO<sub>2</sub> anatase was formed after peroxy titanate powder was calcined at the temperature of 600°C. EDX data also shows that the obtained anatase TiO<sub>2</sub> still has impurities, such as silicon (0.98%) and iron (2.75%). Its photocatalytic activity was studied on photodegradation of Congo Red and compared with the photocatalytic activity of commercial TiO<sub>2</sub>, Degussa P-25. The photoreactivity test on degradation of Congo Red solution with the as-prepared Anatase gave 20% degradation which is still inferior compared to the results given by Degussa P25 (92%). This indicates that the impurities in as-prepared Anatase may cover the titania surface hindering the contact between Congo Red as well as UV-light and the active titania species.

### Keywords

*Ilmenite, leaching, powder peroxy titanate, TiO<sub>2</sub> anatase, photoreactivity*

This Paper is Published in Advanced Materials Research Journal

## Reduction of Nickel Ion Release on a TiO<sub>2</sub> Coated onto an Orthodontic Wire

Sungging Pintowantoro and Yuli Setiyorini

*Department of Material and Metalurgical, Institut Teknologi Sepuluh Nopember, Surabaya 60111  
Email: sunggingp@yahoo.com, yulisetiyorini@yahoo.com*

### ABSTRACT

NiTi is alloy that has unique properties include shape memory dan superelasticity. However, it has disadvantages which cause allergic and toxicity to the body from the Ni release. In order to reduce Ni release and increase corrosion resistance an Electropolishing Pretreatment- Photoelectrocatalytic Oxidation (EP-PEO) and Advanced Oxidation Process (AOP) coating were synthesized in order to produce TiO<sub>2</sub>. Scanning Electron Microscope (SEM) was depicted various morphologies of NiTi orthodontic wire surface. Ni release experiment in various saliva by using Inductively Coupled Plasma (ICP) was shown reducing Ni release significantly both in saliva pH 3 dan pH 6.25 in AOP coating for 2 months monitoring. This results confirmed that the Ni release was evidently decreased and the corrosion resistance significantly improved after coated with AOP.

### Keywords

*Electropolishing pretreatment-photoelectrocatalytic oxidation (EP-PEO), advanced oxidation process (AOP), TiO<sub>2</sub>, Ni release*

This Paper is Published in Advanced Materials Research Journal

## Synthesis and Characterization of Bacterial Cellulose-based Carbon Nanotube by Catalytic Graphitization

Elsy Rahimi Chaldun<sup>a</sup>, Myrtha Karina<sup>a</sup>, Bambang Sunendar Purwasasmita<sup>b</sup>

<sup>a</sup>Research Center for Physics, Indonesian Institute of Sciences, Sangkuriang Kompleks LIPI Gedung 60,  
Bandung 40135, West Java, Indonesia  
Email: elsyrahimi@gmail.com

<sup>b</sup>Laboratory of Material Processing, Engineering Physics Department, Bandung Institute of Technology,  
Ganesa 10, Bandung, West Java, Indonesia  
E-mail: purwa@tf.itb.ac.id

### ABSTRACT

Bacterial cellulose-based carbon nanotube has been synthesized by catalytic graphitization method. Bacterial cellulose (BS) is a source of cellulose produced from fermentation of medium by *Acetobacter xylinum*. Since it contains unbranch polymer linked by  $\beta$ -1,4 glucopyranose with hydroxyl groups, BS is able to use as precursor in synthesis of carbon nanotube. Due to catalytic graphitization, chitosan served as coupling agent and dispersant of catalyst and various concentration of catalyst  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  also were used. Graphitization was conducted in furnace with inert nitrogen gas atmosphere at  $800^\circ\text{C}$  for 2 hours. SEM-EDS were used to evaluate the morphology and semi-quantitative analysis of sample. TEM was used to determine the microstructures and crystallographic. When the chitosan was added 0.5%, its served as coupling agent and dispersant of catalyst with BS. Chitosan improved physical properties, relieved its brittleness, and caused the optical properties of BS. Catalyst of  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  was used to assist the formation and growth of carbon nanotube. The amount of carbon was not affected by time aging. 0.1 M  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$  was the optimum concentration to produce carbon nanotube with 81, 58% the mass of carbon, plane orientation (002) (100) and the diameter of carbon nanotube is 25 nm.

### Keywords

*Bacterial cellulosa (BS), Chitosan,  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ , catalytic graphitization, graphite*

This Paper is Published in Advanced Materials Research Journal

## Submerged Ultrafiltration for Minimizing Energy Process of Refinery Wastewater Treatment

Erna Yuliwati<sup>a,b</sup>, Ahmad Fauzi Ismail<sup>a,c</sup>

<sup>a</sup>Advanced Membrane Technology Research Centre (AMTEC)

<sup>b</sup> Department of Industrial Engineering, Faculty of Engineering,  
Universitas Bina Darma, 30251 Palembang, Indonesia,  
Tel. +62 (711) 515-679; Fax: +62 (711) 518-000

<sup>c</sup>Faculty of Petroleum and Renewable Energy Engineering,  
Universiti Teknologi Malaysia, 81310 UTM, Skudai Johor, Malaysia  
Tel. +60 (7) 553-5592; Fax: +60 (7) 558-1463  
Email: [erna\\_yuliwati@mail.binadarma.ac.id](mailto:erna_yuliwati@mail.binadarma.ac.id)

### ABSTRACT

Refinery wastewater treatment is needed especially in the oil-producing arid regions such as oil refineries due to water scarcity. One of potentially applicable process to treat refinery wastewater is a submerged membrane technology. However, the application of submerged membrane systems for industrial wastewater treatment is still in its infancy due to the significant variety in wastewater composition and high operational costs. The aim of this study was to investigate ultrafiltration (UF) membrane morphology and performance for refinery produced wastewater treatment. Submerged UF bundle was equipped using polyvinylidene fluoride (PVDF) hollow fibers. Hydrophilic PVDF membranes were prepared via the phase inversion method by dispersing lithium chloride monohydrate (LiCl.H<sub>2</sub>O) and titanium dioxide (TiO<sub>2</sub>) nanoparticles in the spinning dope. The comparison of morphological and performance tests was conducted on prepared PVDF ultrafiltration membranes. Distinctive changes were observed in membrane characteristics in term of ionizable functional groups, membrane wettability, tensile testing and roughness measurement. Mean pore size and surface porosity were calculated based on permeate flux. The experiment was conducted using refinery wastewater as influent and an experimental set-up comprised mainly of submerged membrane UF reservoir, circulation pump, and aerator were used throughout investigation, which operated at vacuum pressure. Fouling characteristics for hydrophilic PVDF hollow fibers fouled with suspended solid matter was also investigated. Mixed liquor suspended solid (MLSS) of 3 g/L and 4.5 g/L were assessed by using submerged PVDF membrane with varied air bubble flow rates. Results showed that effect of air bubbles flow rate of 2.4 ml/min increased the flux, total suspended solids (TSS) and sulfide removal of 148.82 L/m<sup>2</sup>h, 99.82 % and 89.2%, respectively due to increase of turbulence around fibers, which exerts shear stress to minimize particles deposited on membrane surface. It was concluded that submerged ultrafiltration membrane is an available option to minimize energy process for treating such wastewater solution.

### Keywords

*Submerged membrane ultrafiltration, refinery wastewater, economic evaluation, scale-lab model*

This Paper is Published in Advanced Materials Research Journal

## **Influence of Processing Method of ECAP on High-Strain-Rate Deformation Behavior of Ultra Fine Grained Al Alloy**

**Yang Gon Kim<sup>1</sup>, Ji Hyun Sung<sup>1</sup>, Sang-Kon Lee<sup>1</sup>, Myeong-Sik Jeong<sup>1</sup>, Kang-Eun Kim<sup>1</sup>, Da Hye Kim<sup>1</sup>, Yong-Jae Cho<sup>1</sup>, Young Gun Ko<sup>2</sup> and Sunghak Lee<sup>3</sup>**

<sup>1</sup> Green Transformation Technology Center, Korea Institute of Industrial Technology, Daegu, Republic of Korea, 711-880

<sup>2</sup> School of Materials Science and Engineering, Yeungnam University, Gyeongsan, Republic of KOREA, 712-749

<sup>3</sup> Center for Advanced Aerospace Materials, Pohang University of Science and Technology, Pohang, Republic of KOREA, 790-784

kimyg@kitech.re.kr, TEL: +82-53-580-0135, FAX: +82-53-580-0130

### **ABSTRACT**

The effect of ECAP(equal-channel angular pressing) route on the high-strain-rate deformation behavior of ultra-fine-grained aluminum alloy was investigated. The 8-pass ECAPed specimens deformed via three different routes consisted of ultra-fine grains 0.5  $\mu\text{m}$  in size, and contained a considerable amount of second-phase particles, which were fragmented and distributed in the matrix. In the torsion tests, the maximum shear stress significantly increased with increasing number of ECAP passes, while the maximum shear stress and fracture shear strain were lowest in the specimen deformed via route A among the three 8-pass ECAPed specimens. Observation of the deformed area beneath the fractured surface revealed the adiabatic shear bands of 100  $\mu\text{m}$  in width in the specimen deformed via route A, which minimized the maximum shear stress and fracture shear strain, whereas they were hardly formed in the specimens deformed via route B or C. The formation of adiabatic shear bands was explained in terms of critical shear strain, deformation energy required for void initiation, and microstructural homogeneity related to ECAP routes.

This Paper is Not Available

## Resolving Individual Solute Levels of AA6061 Through Multiple Sub-Ambient Temperatures Thermoelectric Power Measurements

D.D. Risanti<sup>a</sup> and S. van der Zwaag<sup>b</sup>

<sup>a</sup>Dept. of Engineering Physics, Fac. Industrial Tech., Institut Teknologi Sepuluh Nopember, Kampus ITS Keputih Sukolilo, Surabaya 60111, Indonesia

<sup>b</sup>NOVAM Group, Faculty of Aerospace Engineering TU Delft, Kluyverweg 1, 2629HS Delft, Netherlands  
Email: risanti@ep.its.ac.id, bs.vanderzwaag@tudelft.nl

### ABSTRACT

This work concentrates on assessment of the TEP change of AA6061 during isothermal aging at 177 °C and the following interrupted aging at 65 °C. The results show that the TEP is sensitive to follow the microstructural changes undergone during all aging stages. Multiple sub-ambient temperature dependences TEP of binary Al-X alloys as well as the AA6061 subjected to the above mentioned heat treatments were undertaken. The solute level of individual element of the alloy, particularly those contributing to the clustering/precipitation, can be extracted and evaluated

### Keywords

*Al-Mg-Si alloys, interrupted ageing, thermoelectric power, sub-ambient temperature*

This Paper is Published in Advanced Materials Research Journal

## Springback Prediction Compensation and Optimization for Front Side Member in Sheet Metal Forming using FEM Simulation

Agus Dwi Anggono<sup>a</sup>, Waluyo Adi Siswanto<sup>b</sup>, Badrul Omar<sup>b</sup>

<sup>a</sup> Department of Mechanical Engineering, Universitas Muhammadiyah Surakarta  
PO.BOX 1 Pabelan, Surakarta 57162, Indonesia  
E-mail : agusdwianggono@gmail.com

<sup>b</sup> Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia  
86400 Parit Raja, Batu Pahat, Johor, Malaysia  
E-mail : waluyo@uthm.edu.my

### ABSTRACT

Numerical simulation by finite element method has become a powerful tool in predicting and preventing the unwanted effects of sheet metals technological processing. One of the most important problems in sheet metal forming is the compensation of springback. To improve the accuracy of the formed parts, the die surfaces are required to be optimized so that after springback the geometry falls at the expected shape. This paper presents and discusses numerical simulation procedure of die compensation by using the methods of Simplified Displacement Adjustment (SDA). This analysis use Benchmark 3 models of Numisheet 2011. Sensitivity analysis was done by using finite element method (FEM) show that the springback values are influenced by element size, integration points and material properties.

### Keywords

*Sheet metal forming, springback, compensation, optimization*

This Paper is Published in Advanced Materials Research Journal

## Effect of Rolling Direction to The Strength of A Thin-Walled Steel SHS Beam under Concentrated-Compressive Load and Bending Moment

Andi M. Kadir<sup>a</sup>, Dedi Priadi<sup>a</sup>, Eddy S. Siradj<sup>a</sup>, Harkali Setiyono<sup>b</sup>

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok, Indonesia 16424  
E-mail : amkadir66@yahoo.com, dedi@metal.ui.ac.id, siradj@metal.ui.ac.id

<sup>b</sup>B2TKS- BPPT PUSPIPTEK, Tangerang Selatan-Banten, Indonesia 15314  
E-mail : harkali\_setiyono@yahoo.co.id

### ABSTRACT

In this research, it has been carried out the development of a strength analytical method of a thin-walled steel square pipe (Square Hollow Section/SHS) affected by the interaction of concentrated-compressive load and bending moment then it verified by experimental approach. The experimental approach was consisted of measuring a basic material property and the strength of the investigated SHS pipe. The basic material property identified parallel to rolling direction ( $0^\circ$ ) and perpendicular to rolling direction ( $90^\circ$ ). The analytical data obtained from cut-off strength method is generally scattered within the acceptable limits of  $\pm 20\%$  and tends to be in unconservative region. The actual data measured from experiments shows that SHS beam with  $t = 0.6$  mm and longitudinal axis parallel to the rolling direction of base material has higher strength compared to the one of the SHS beam with  $t = 0.6$  mm and longitudinal axis perpendicular to the rolling direction, meanwhile the SHS beam with  $t = 1.2$  mm is tends to be equal. This means that the rolling direction of base material can be considered to be a parameter in the strength design of a thin-walled SHS beam.

### Keywords

Rolling direction, strength analytical, SHS beam, cut-off strength, plastic mechanisms, a thin-walled steel

This Paper is Published in Advanced Materials Research Journal

# Mechanical Properties and Micro Structure of Aluminum Alloys [Al-Mg-Si] as Results of Variation Time in Friction Welding

Mahros Darsin<sup>a</sup>, Hary Sutjahjono<sup>a</sup>, Amri Hadi<sup>a</sup>

<sup>a</sup>Faculty of Engineering, the University of Jember, Jember 68131  
E-mail : mahros.azzahra@yahoo.co.id, hary\_uj@yahoo.com, zoneamri89@yahoo.co.id

## ABSTRACT

Friction welding is one solution to solve the problems joining of metals which are difficult to be welded by fusion welding such as aluminum. The process was run by rotating a rod upon another metal and force was applied. Consequently, heat arose below the melting point and made the metals molten joined together as force continuously applied. In this research aluminum 6xxx series were used as this metal have good corrosion resistance, good machinability but not ease to weld. Among important parameters in linear welding are friction time, friction pressure and rotation speed; we only concern in the first one. The friction time variations were 20, 45, 80, and 120 seconds respectively. Whereas the pressure and the rotation speed were kept constantly. The joined aluminum then tensile strength tested using universal testing machine, hardness tested using Electrical Brinell hardness Tester Hauser Henry SA and also observed under optical microscope. The highest tensile strength of 61.07 MPa was gained from friction time of 45 seconds, while the least of only 28.81 MPa when using friction time of 20 seconds. Hardness in the welding areas was almost the same as that of base metal, whereas in the heat affected zone tend to little bit decreased. Friction time of 20 seconds gave the hardest in the welding are almost the same as base metals, whereas the softest as result of 120 friction time. Optical microscope observations show that there were porosities in the welding areas. It probably caused by some trapped gas which formed inter-dendritic porous.

## Keywords

*Friction Welding, Friction Time, Porosity, Tensile strength, Micro structure*

## 1. INTRODUCTION

Aluminum is kind material, which has some advantages, i.e. it is light, soft and easy to be machined [1]. In order to be able to used as material for construction aluminum should be alloyed. However, both pure and alloyed aluminum are not easy to be joined by fusion welding. The reason is it has high heat factor, oxidation easy and form aluminum oxide  $Al_2O_3$  which high melting point. Alternatively, aluminum alloy could be joined by friction welding. In the previous research, we have successfully applied friction stir welding for joining plate of aluminum alloy AA 1100 by varying speed and feed [2, 3]. The results were not significantly different from another researcher [4, 5]. This series of aluminum alloy, however, have limited application as material construction. Whereas, aluminum alloy (Al-Mg-Si) serial number 6061 have been applied for high-strength structural members, vehicles, rolling stock, marine applications, architectural applications [1]. This aluminum alloy is able to be heat treated, good machine ability, good weld ability and corrosion resist.

Friction welding is a solid state welding process [4] in which the heat for welding is produced by the relative motion of the two pieces being joined. Friction welding achieves 100 per cent metal-to-metal joints, giving parent metal properties. It is the only joining process to do this. No addition material or fillers are required and there are no emissions from the process. The process involves making welds in which one component is moved relative to, and in pressure contact, with the mating component to produce heat at the faying surfaces. Softened material begins to extrude in response to the applied pressure, creating an annular upset. Heat is conducted away from the interfacial area for forging to take place. The weld is completed by the application of a forge force during or after the cessation of relative motion. The joint undergoes hot working to form a homogenous, full surface, high-integrity weld.

Apart from speed and feed rate, other parameters influence the quality of welding such as time and force applied during the process [5]. The quality of weld and mechanical properties of weld depend on the correct choice of these parameters. In this research we were developing the use of aluminum alloy (Al-Mg-Si) to be joined by rotary friction welding by devoting on attempt to find the best mechanical properties and micro structure of the welded area by varying the time of friction.

## 2. EXPERIMENTAL PROCEDURE

A simple set up of a rotary friction welding machine are shown in Fig. 1. This machine was modified from ordinary lathe adapted from [6]. Ideally, the machine should be equipped with a braking system to stop the machine when the process completed. However, in this research the chuck in the movable head was modified to make the welded parts rotating together until the machine stop.

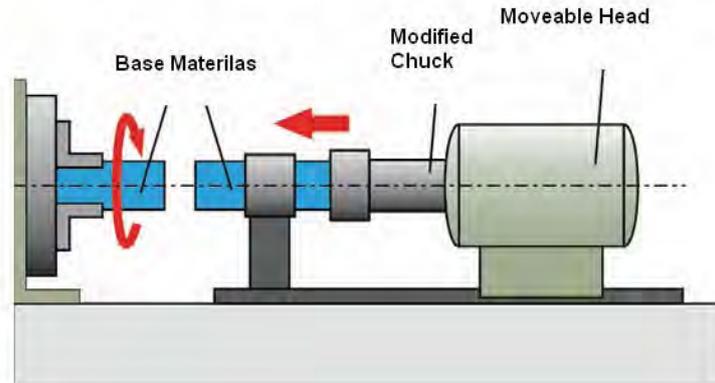
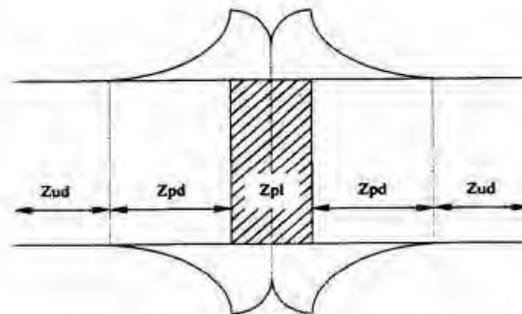


Figure 1: Equipment of rotary friction welding.

The parts to be welded were solid rods of diameter 20mm. Initial preheating was developed by giving friction about 10 seconds. The friction time for welding process were varied as 20s, 45s, 80s and 120s, whereas, the spindle rotation was kept constantly at 1600 rpm. After the friction time was achieved, the rod in the modified chuck was released to let the welded rods turn together.

The welded rods then prepared for tested its tensile strength using ASTM A370-speciment 3 using Universal Testing Machine of 3000kg capacity and 13mm maximum stroke. They were also observed their hardness using Electric Hardness Hauser Henry SA in three areas i.e. fully plasticized ( $Z_{pl}$ ), partially deformed ( $Z_{pd}$ ) and undeformed ( $Z_{ud}$ ) areas as shown in Fig.2. Penetration given was 1kg for about 15 seconds. Furthermore, the welded rods were also observed its microstructure using optical microscope Olympus BX41. The observation areas were the same as hardness tests. Some procedures for preparing the observations were carried out carefully to maximize the results.



fully plasticized ( $Z_{pl}$ ), partially deformed ( $Z_{pd}$ ) and undeformed ( $Z_{ud}$ ) regions

Figure 2: Three regions of observation for hardness and micro structures of welded rods.

### 3. RESULTS AND DISCUSSION

#### 3.1 Results

A sample result of successfully welded rods was presented at Fig. 3. The rods developed like an anchor as they were joined. There are some marks at left and right rods caused of clamping force of chucks. These samples then sawn longitudinally. Before they were observed under microscope, they were etched and some macro photos were taken to check the quality of bond.



Figure 3: A pair of successfully welded rod

Macro photos of each region observed were shown at Fig.4. It is clear that there are porosities in each welded areas. The porosity is one of disadvantages of aluminum alloy when they are welded. High difference of solubility of Hydrogen between in solid and liquid phase lead to this gas tend to trapped and make smooth porosities when it was heated and then quenched as in welding process [7]. Some porosity was long caused by shrinkage when the welded zone cooling down [8].

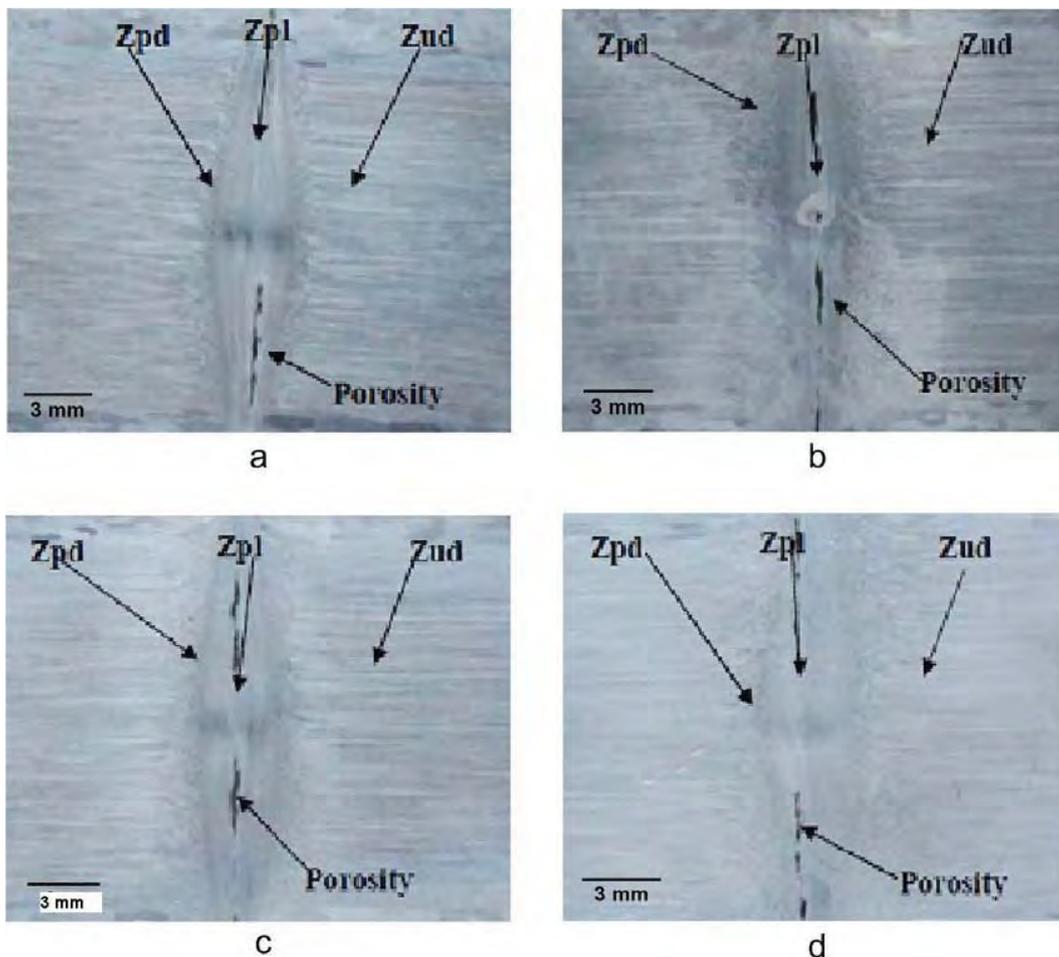


Figure 4: Macro photos of welded rods with variation in friction time (a) 20 seconds, (b) 45 seconds, (c) 80 seconds, and (d) 120 second. All of photos shown that many porosities in the fully plasticized zone.

### 3.2 Microstructure observation

Microstructure observation was carried out to know changing of microstructure after friction welding. The micrographic photo was compared to the one in the literature [7]. The spots shown at Fig 5 which are well dispersed in the aluminum Al-Mg-Si matrices are  $Mg_2Si$  (black) and  $Fe_3Si Al_{12}$  (grey). The later was come out because in the aluminum alloy there are 0.677% Fe and 0.65% Si.

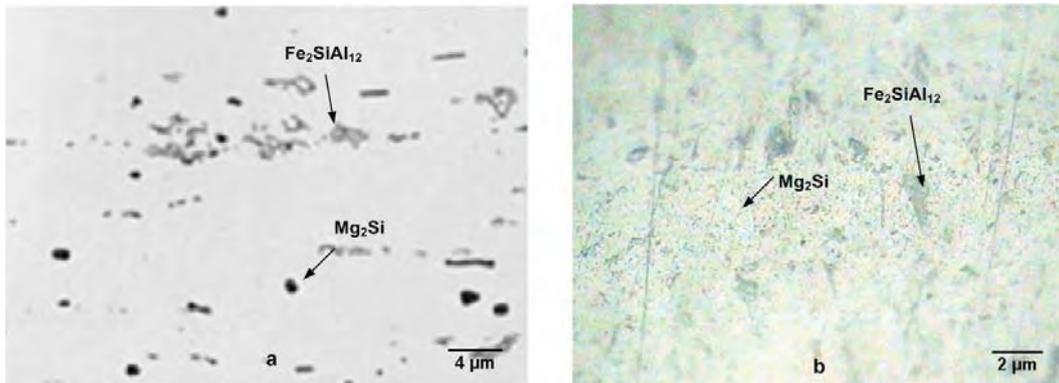


Figure 5: Microstructure at base metal as observed under microscope (right) and compared that of in the ASM Hand Book Metallography and Microstructures (left) [2].

Other observations at different zones were presented at Fig 6. To make it brief only observation in the plasticized zone is presented.

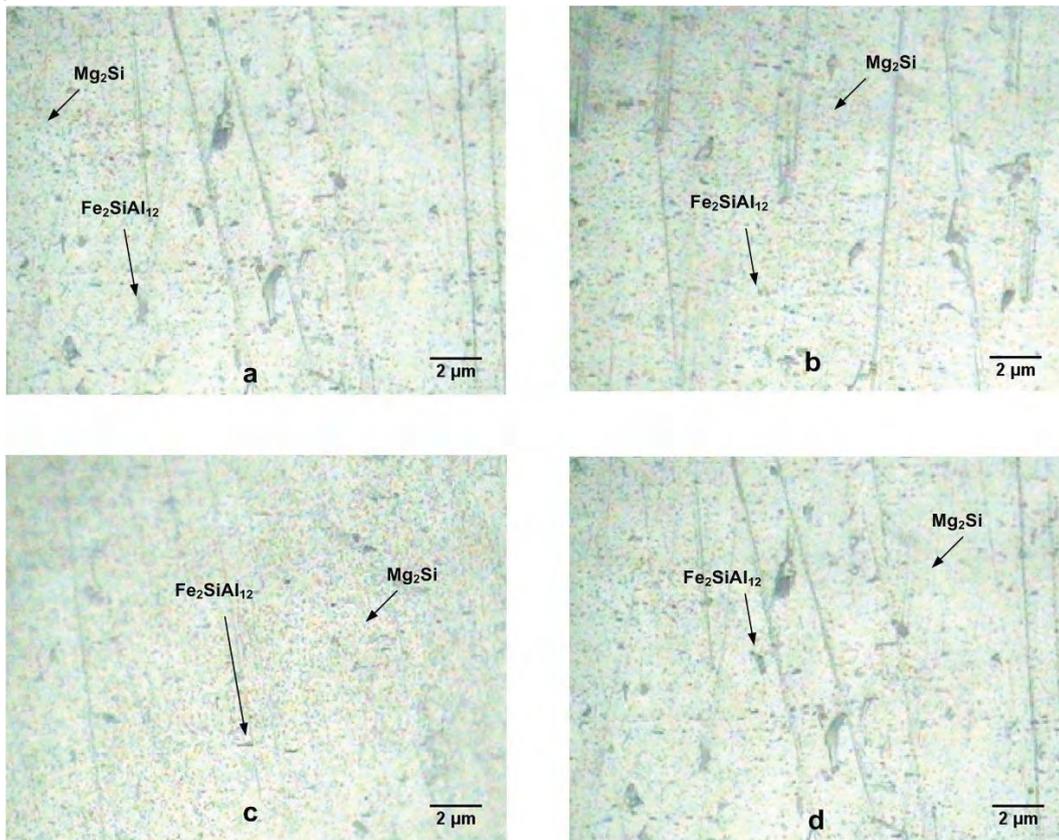


Figure 6: Microstructure of plasticized deformation zone (Zpl) as friction time varied (a) 20 seconds, (b) 45 seconds, (c) 80 seconds and (d) 120 seconds.

According to observation in the Zpl zone, particles of  $Mg_2Si$  were spread and smooth. It is because in this zone the direct friction during welding. Among different friction time there were no such significant differences in their microstructure. However, when it is compared with base metal, the particles of  $Mg_2Si$  in this zone are smaller and smoother.

### 3.3 Tensile Test

Tensile test was carried out to know average tensile strength of the joined rods. Each variation parameter was conducted three times to ensure the result, and graphically presented as in Fig 7. It is clear that there is big difference between tensile strength between base metal and the welded specimens. It is because the structures of the welded rods were changed as effect of deformation. The highest tensile strength of 61.07 MPa was achieved when using friction time of 45 seconds. It can be described that the porosity in this parameter was smallest among others. The wider the porosity the weaker the tensile strength is.

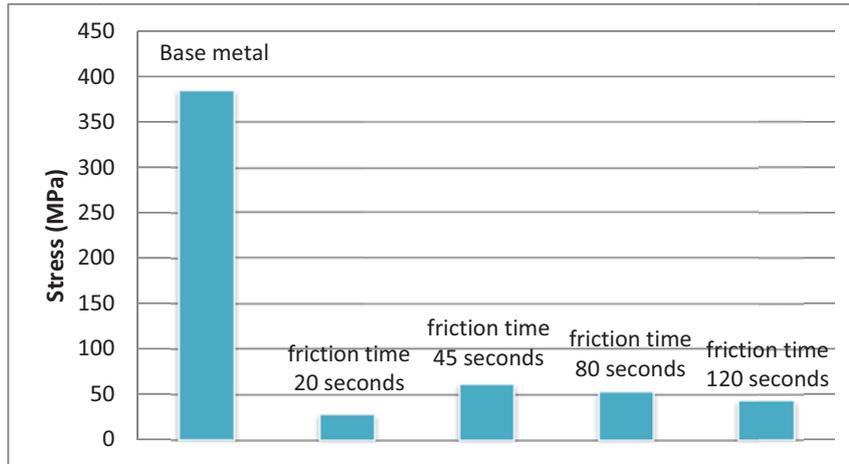


Figure 7. Tensile strength as variation of friction time compared to that of base metal.

The weakest tensile strength achieved when friction time was 20 seconds. Short time of friction would generate not enough heat so cooling time is also shorter. Consequently, the grains are bigger. The smaller the grain size the more grain boundary formed. The more grain boundary the more difficult is the dislocation movement. Finally, it will strengthen the materials.

### 3.4 Hardness Test

Hardness test was also carried out in three different zones as shown at Fig.8.



Figure 8: Hardness average as variation of friction time

From the figure 8 above it is clear that hardness of plasticized zone (Zpl) and base metal (Zud) are insignificantly different, or it can be said that hardness of the welded area is similar to that of base metal. It is effect of friction welding where there was no inserted metal as filler. Nevertheless, hardness in the welded zone would not higher than in the base one, as hardening will not occur during welding [6]. The highest hardness of 68 BHN was achieved when applied friction time of 45 seconds. In this parameter, the grain of  $Mg_2Si$  is smoother and well spread and biggest in number. The smoother grain its structure more densely and bond between atoms is stronger.

### 4. CONCLUSION

From result and discussion it can be concluded that:

1. The strength of welded rods by friction welding was lower compare that of base metal as effect of macro porosities.
2. Micro structure of  $Mg_2Si$  in the welded area (plasticized zone) was smoother and well dispersed than that of partially deformed zone. Consequently, this area is harder and stronger than the later.
3. Friction time of 45 seconds results in highest strength as well hardness than others.

### 5. FUTURE WORKS

Some attempt should be done to reduce the porosities in the welded area such as increasing time of preheating. The machine for this friction welding should be designed that the machine should be stopped as the welding completed.

## REFERENCES

- [1] Fundamentals of Friction Welding, ASM Handbook, Welding, Brazing and Soldering, vol. 6, ASM International, 1994.
- [2] Pamungkas, A.F., Sumarji, and Darsin, M., 2012. "Analysis of Mechanical Properties of Welded AA1100 by Friction Stir Welding". *Journal Techno*, vol. 16 No.2 pp. 15 -22.
- [3] Permana, M.I, Darsin, M., Sumarji, 2011. "Mechanical Properties and Microstructure of AA1100 by Friction Stir Welding with Feed Rate Variation". *Journal of Rotor*, vol 5 No 1 pp 15 -22
- [4] Alves, E.P., Neto, F.P., Chen Ying An, C.Y., 2010. "Welding of AA1050 aluminum with AISI 304 stainless steel by rotary friction welding process". *J. Aerosp.Technol. Manag.*, São José dos Campos, Vol.2, No.3, pp. 301-306.
- [5] Moarrefzadeh, A., 2012." Study of Heat Affected Zone (HAZ) in Friction Welding Process". *Journal of Mechanical Engineering*. Vol. 1, No. 1, pp.11-17.
- [6] A. Kurt, I. Uygur, And U. Paylasan, 2011. "Effect of Friction Welding Parameters on Mechanical and Microstructural Properties of Dissimilar AISI 1010-ASTM B22 Joints". *Welding Journal*. Vol.90. pp 102-109.
- [7] Mathers, G. 2002. *The Welding of Aluminium and its Alloys*. England: Woodhead
- [8] ASM Handbook vol 9, 1996. Metallography and Microstructures.

## Two-Dimensional Ferroelectric Polymer Films and Its Application for Resistive Switching Memories

Damar Yoga Kusuma<sup>a</sup>, Pooi See Lee<sup>b\*</sup>

<sup>b</sup>School of Materials Science and Engineering  
Nanyang Technological University, Singapore 639798  
Tel : (+65) 67906661. Fax : (+65) 67909081  
Presenter: dkusuma@ntu.edu.sg

\*Corresponding author : pslee@ntu.edu.sg

### Introduction

Nanometer-thick ferroelectric films are of interest due to its distinct ferroelectric properties from the bulk as well as its applicability for resistive switching memory applications. To date, resistive switching behavior of ferroelectric ultrathin films only observable locally via scanning tunneling microscopy (STM) or conducting atomic force microscopy (AFM). This is due to enormous challenge of fabricating nanometer-thick ferroelectric films, continuous over large area. In this work, we present two dimensional ferroelectric films realized via Langmuir-Schaeffer monolayers transfer.

### Results and Discussion

X-ray diffraction (XRD) and AFM analysis of nanometer-thick oligomeric vinylidene fluoride OVDF and P(VDF-TrFE) films reveals the presence of ferroelectric phase and continuous film morphology over millimeters scale. Ferroelectric characterization reveals remanent polarization and coercive voltage of  $0.4 - 1.8 \mu\text{C}\cdot\text{cm}^{-1}$  and  $\pm 0.5 \text{ V}$  respectively. Current-voltage (I-V) and capacitance-voltage (C-V) measurements indicate resistive switching behavior of up to 3 orders of magnitude. The resistive switching behavior is proven to be reproducible through multiple switching for single device and switching of multiple memory cells. Further memory characterization shows stable ON/OFF ratio after switched for  $10^4$  cycles and retains more than 80% its initial ON/OFF current ratio extrapolated to  $10^6$  s. In addition, the memory elements can be reversibly switched between ON and OFF state by voltage pulse as short as  $250 \mu\text{s}$  at  $\pm 1.0 \text{ V}$ . Detailed I-V characterizations confirm the charge tunneling mechanism. On the other hand, the dependence of ON/OFF current ratio on remanent polarization and the cease of resistive switching behavior above the ferroelectric critical temperature verified that the resistance switching is of ferroelectric origin. The robust and continuous ferroelectric films over large area enable fabrication of ferroelectric resistive switching devices at the macroscopic level, representing the first realization of organic ferroelectric switching memory devices by solution processing.

### Conclusion

Resistive switching memory devices based on organic ferroelectric materials has been demonstrated. Formation of robust, continuous, nanometer-thick ferroelectric films can be realized by Langmuir-Schaeffer monolayers transfer. The resistive switching behavior can be implemented for instance as building block for 2D and 3D memory arrays based on crossbar structure as well as hardware basis for memristors' neuromorphic computing.

### Keywords

*Ferroelectric polymer, Langmuir monolayer, resistive switching, memory device, memristors*

# The Development of 550 MPa Class High Strength Low Alloy Steel for Atmospheric Corrosion Resistant Applications

Agung Baskoro<sup>a</sup>, Beno Supriyadi<sup>b</sup>, Sumadi<sup>c</sup>

<sup>a</sup>Product Development Engineer, Krakatau Steel, Indonesia  
 Email : [agung.baskoro@krakatausteel.com](mailto:agung.baskoro@krakatausteel.com)

<sup>b</sup>Material & Product Development Division Head, Krakatau Steel, Indonesia  
 Email : [beno.supriyadi@krakatausteel.com](mailto:beno.supriyadi@krakatausteel.com)

<sup>c</sup>Product Development Senior Engineer, Krakatau Steel, Indonesia  
 Email : [sumadi.6434@krakatausteel.com](mailto:sumadi.6434@krakatausteel.com)

## ABSTRACT

Atmospheric corrosion resistant High-Strength Low-Alloy (HSLA) steel is intended for structural applications where a combination of high strength and enhanced atmospheric corrosion resistance are desired. It has approximately 4 times the atmospheric corrosion resistance of structural carbon steel, good formability and weldability. The extra strength of HSLA steel makes it more durable and offers a longer useful life span for chimney, bridge, tubular bridge, container and tank.

This work is concerned with the development of 550 MPa Class High Strength Low Alloy (HSLA) steel strips for atmospheric corrosion resistant applications. The addition of corrosion resistant elements up to 0.40% Cu, 0.50% Cr and 0.50% Ni into steel containing 0.16% C and 1.2% Mn, combined with controlled rolling process resulted in high yield strength of 425 ~ 500 MPa and tensile strength of 570 ~ 600 MPa with good formability and weldability.

## Keywords

Atmospheric Corrosion Resistance, HSLA, Corrosion Resistant Elements, Structural Steel

## 1. INTRODUCTION

Atmospheric corrosion resistant High-Strength Low-Alloy (HSLA) steel is intended for structural applications where a combination of high strength and enhanced atmospheric corrosion resistance are desired. It has approximately 4 times the atmospheric corrosion resistance of structural carbon steel, good formability and weldability. Thus atmospheric corrosion resistant steel have strength 35 – 40% higher than carbon steel (effect of vanadium addition). The extra strength of HSLA steel makes it more durable and offers a longer useful life span for chimney, bridge, tubular bridge, container and tank.

Since early 1930s with discovering weathering steels by US Steel Corporation many kind of atmospheric corrosion resistant steels is become widely used in structural and construction application. The steels are born to fulfil increasing demand of bridges and vehicles with higher strength, lower weight, lower maintenance cost and good corrosion resistance properties. In corrosive atmosphere with higher pollutant content of marine and industrial environment, appropriate material selection is become one important factor for longer life time materials. Compare to an ordinary plain carbon steels for structural, atmospheric corrosion resistant steel which is used in this application has better corrosion resisting properties. By adding certain amount of chromium, nickel, copper or phosphorus shows better corrosion resistance due to formation of protective oxide layer in several years of exposure.

This paper briefly describes the experience of Krakatau Steel in developing 550 MPa Class High Strength Low Alloy (HSLA) steel strips for atmospheric corrosion resistance applications. The development has been carried out by addition of corrosion resistant elements combined with controlled rolling process resulted in high strength product with good formability, weldability and corrosion resistant.

## 2. PRODUCT DESIGN

The requirements of the developed steel are in accordance to Baja Tahan Korosi Cuaca (BTKC) grade C standard, that equivalent to USS COR-TEN C standard. The requirements, which comprise chemical composition and mechanical properties, compare to typical of chemical composition and target mechanical properties as summarised in table 1 and table 2.

Table 1: Standard and Design of Chemical Composition (wt, %)

	C	Mn	Si	P	S	Cu	Cr	Ni	V
Design KS	0.16 max	0.90-1.20	0.30-0.60	0.020 max	0.020 max	0.30-0.40	0.40-0.60	0.30 max	0.05-0.08
Standard	0.19 max	0.80-1.35	0.30-0.60	0.040 max	0.050 max	0.25-0.40	0.40-0.70	0.40 max	0.04-0.10

Table 2: Mechanical properties

	YS (N/mm <sup>2</sup> )	TS (N/mm <sup>2</sup> )	A (%)
Design KS	425 - 500	570 - 600	22 - 28
Standard	415 min	550 min	21 min

The addition of corrosion resistant elements up to 0.40% Cu, 0.50% Cr and 0.50% Ni into steel containing 0.16% C and 1.2% Mn, combined with controlled rolling process resulted in high yield strength of 425 ~ 500 MPa and tensile strength of 570 ~ 600 MPa with good formability, weldability and corrosion resistant.

### 3. PRODUCTION PROCESS

The production of steel for atmospheric corrosion resistant applications is carried out in the slab steel plant and hot strip mill with processing route as generally shown in Figure 1. In the slab steel plant, there are three main stages of the process such as melting process, secondary treatment and casting. Melting process in the electric Arc Furnace uses the raw material which consists of 20% scrap and 80% of sponge iron is melted. This melted steel is then further processed for secondary treatment in the Ladle Furnace to reduce the sulphur content and to adjust the chemical composition by adding some alloying elements. Subsequently, the steel is continuously cast in the continuous casting machine to produce steel slab.

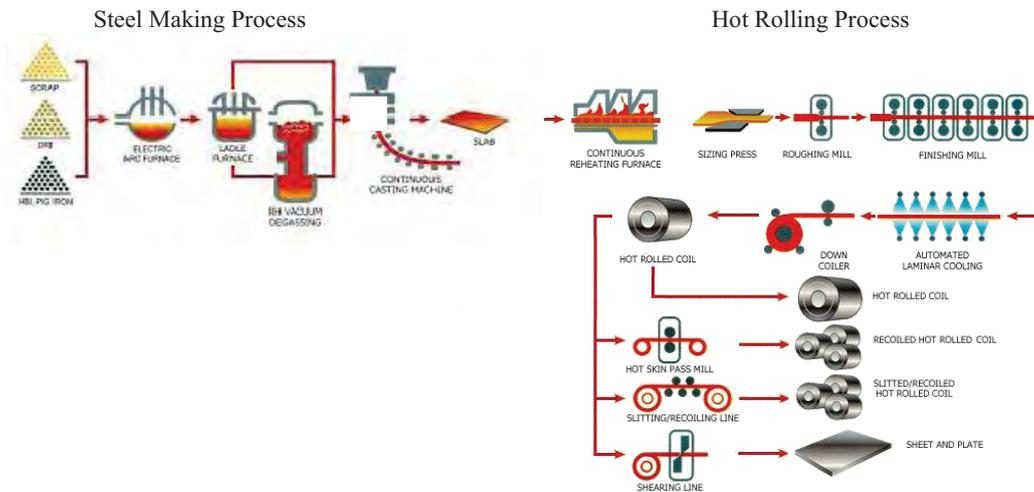


Figure 1: The Production Process Line in Steel Making and Hot Rolling

The steel making and casting practices adopted for this grades can be summarized as follows:

- Hot metal desulphurization
- Calcium treatment by CaSi wire injection for inclusion shape control
- Casting into tundish with dam and weir to float up the inclusions
- Argon gas purging and extended shroud to minimize re-oxidation during set up
- Controlling the cooling intensity, superheat and casting speed
- Metal retention in ladle at ladle change

These practices are developed not only to achieve the required chemical composition but also to obtain steel with high cleanliness, free from internal and surface defect.

In the hot strip mill, the slabs which come from the slab steel plant are subsequently hot rolled to the specified thickness. The Thermo-Mechanical Control Process is applied during rolling to get fine grain microstructures of HRC and to achieve the required mechanical properties.

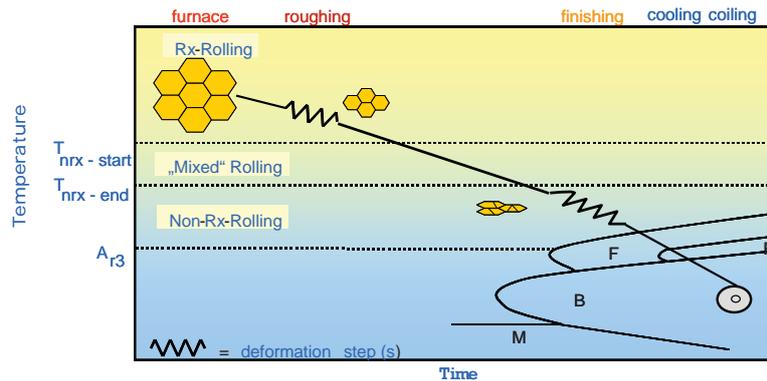


Figure 2: A schematic of Thermo-Mechanical Control Process during Control Rolling

Figure 2 shows the basic principle of Thermo-Mechanical Control Process during rolling applied in the hot strip mill. Slab is reheated up to about 1200°C and soaked at that temperature in the reheating furnace then control-rolled with high reduction at above the non-recrystallization temperature in the roughing mill in order to achieve fine austenite grain size. This steel is then rolled at a temperature between non-recrystallization and  $A_{r3}$  transformation temperature in the finishing mill. This process will introduce the deformation bands within the austenite grains which promote the nucleation sites for ferrite grains. It consequently results in the formation of finer ferrite grain after austenite – ferrite transformation. The steel strip is finally coiled at about 600°C.

#### 4. RESULT AND DISCUSSION

##### 4.1 Mechanical Test of Hot Rolled Coil

The results of tensile test which were taken from production data of hot rolled coil are presented at table 3. The tensile strength values of hot rolled coil with 14.0 and 16.0 mm in thickness are 585 – 600 MPa and 570 – 590 MPa, respectively. The yield ratio of the developed steels is around 75 – 83 %, indicate that material have higher stiffness properties. All the tensile values are within the range of specified values for the BTKC Grade C specification and achieve the targeted values.

Table 3: Tensile Test Result of Hot Rolled Coil

Thickness (mm)	Yield Strength (MPa)	Tensile Strength (MPa)	Elongation (%)	Yield Ratio (%)	Direction
14.0	440 - 500	585 - 600	24 - 28	77 - 83	Transversal
16.0	425 - 460	570 - 590	22 - 26	75 - 79	Transversal

##### 4.2 Corrosion Rate

Figure 3 and Table 4 shows the weight loss profile and corrosion rate of weathering resistance steel and carbon steel after 6 years exposed at marine and industrial area. As can be seen in the figure 3, after 6 years exposed in marine and industrial area the average weight loss for plain carbon steel were 0.097g/mm<sup>2</sup> and 0.105g/mm<sup>2</sup>, almost 2 times higher than weight loss for weathering steel where the average were 0.056 g/mm<sup>2</sup> and 0.062g/mm<sup>2</sup>, respectively. Weight loss for weathering steel were sharply increased in the first year and became slightly decreased after 3 years of exposure, while plain carbon steel were sharply increased until 6 years of exposure. This weight loss value indicates that weathering steel has better atmospheric corrosion resistant properties than ordinary plain carbon steel.

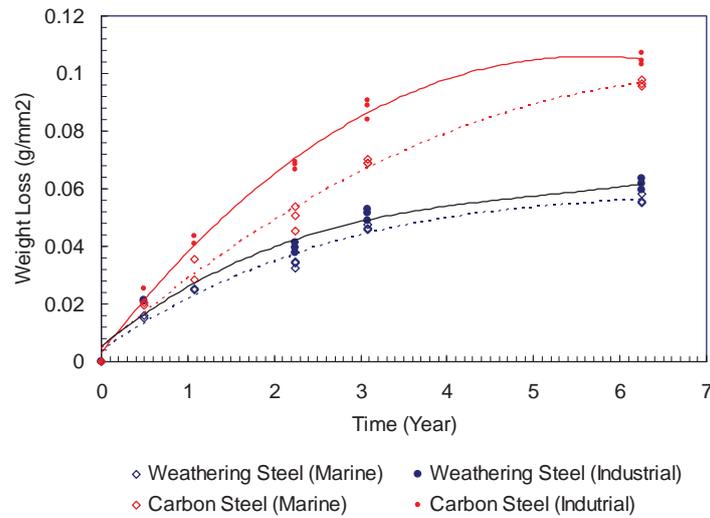


Figure 3: Variations of weight loss of steels in marine and industrial area

Table 4. Corrosion Rate after 6 years of exposure

Exposed Area	Steel Grade	Corrosion Rate (mpy)
Industrial	Carbon Steel	1.699
	Atmospheric Corrosion Resistant Steel	0.996
Marine	Carbon Steel	1.560
	Atmospheric Corrosion Resistant Steel	0.907

## 5. SUMMARY

Product design by addition some elements up to 0.40% Cu, 0.50% Cr and 0.50% Ni into steel containing 0.16% C and 1.2% Mn, combined with controlled rolling process in producing 550 MPa Class High Strength Low Alloy (HSLA) steel strips for atmospheric corrosion resistant applications has ensured the mechanical properties with good formability, weldability and corrosion resistant.

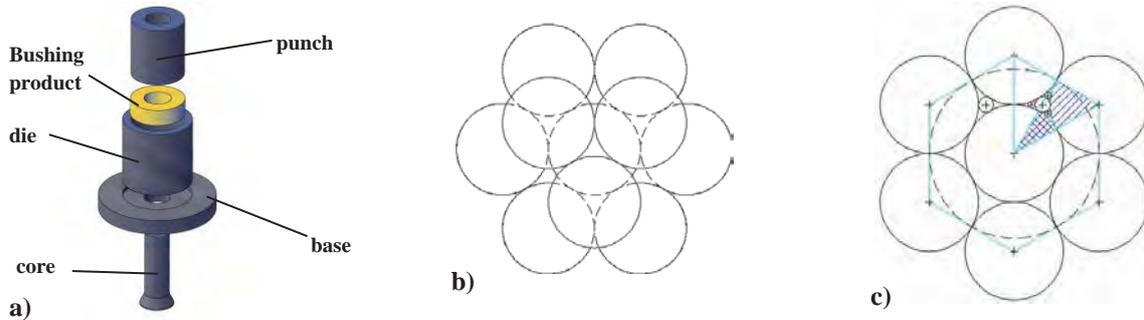
## 6. REFERENCES

- [1] C.P. Larrabee and S.K. Coburn, "Proc. 1<sup>st</sup> Int. Cong. Corrosion", Butterworth, London, (1962), 276.
- [2] Desrianto Ahmad et al. "Corrosion Characteristic of Weathering Resistant and Plain Carbon Steel in Marine and Industrial Atmospheric Condition in Indonesia", Krakatau Steel, Cilegon, 2005.

## 2. Analytical and Experimental Setup

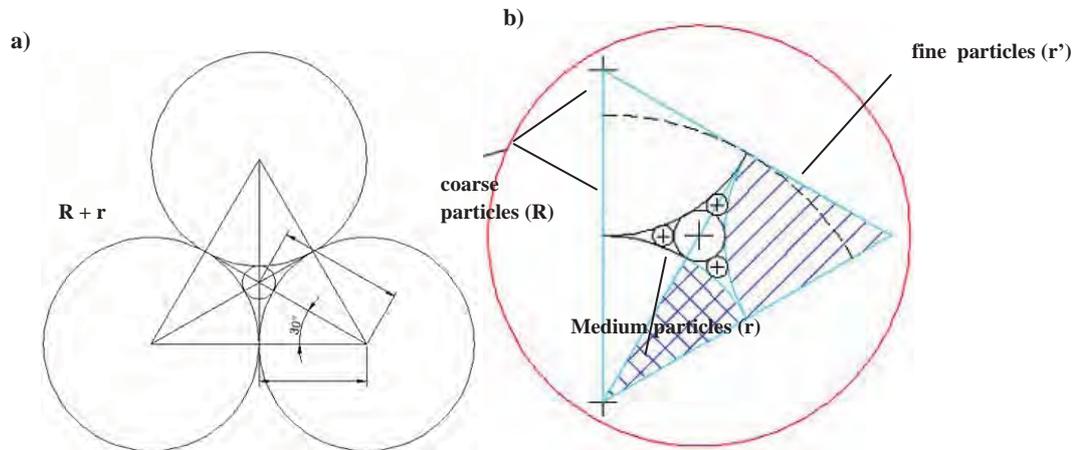
### A. Analytical of Geometric

The experimental began by preparing the mold bushing P/M (Fig. 1a), which consists of 4 components such as carbon steel shell (die), solid carbon steel rod (core), flange (base), and hollow carbon steel rod (punch). Prepare powder duralumin size by large (412 μm), medium (107 μm), fine (20 μm), and graphite as a lubricant P/M. Then made two analytical and experimental research design. The network mode is ordered of the particles forming the mold space also called discrete element models, have been used previously to study two-dimensional particle as in Fig. 1b, and detail of particles distribution in Fig. 1c.



**Figure 1.** Tools and ordered of P/M particles

a). Components of P/M process, b). Coordination of coarse particles, c). Particles coordination of P/M system



**Figure 2.** Geometry of powder in P/M

a). Radius correlation of particles, b). Filler interstitial of ordered particles

Powder radius (average) that can be inserted in triangle gap between powder grains (coarse powder). If the powder grains are considered the uniform, it can be shown in Fig. 2a, it can be searched by the equation;  $\frac{Base}{Hypotenusa} = \cos 30^0$  (1)

Result of operated equation 1 is  $\frac{R}{R+r} = \frac{\sqrt{3}}{2}$  and the final is  $r = 0.26 R$

While the triangular gap (the gap) formed between the particle grains themselves extent can be calculated as follows:

The gap area =  $2 \times (\frac{1}{2} \text{ blue triangle area} - (\text{Area of pie} + \text{small area of pie}))$  (2)

and  $\frac{1}{2} \text{ blue triangle area} = \frac{1}{2} a \times t = \frac{1}{2} R \times \sqrt{(2R)^2 - R^2} = 1.73 R^2$

Area of big pie (AoBP) =  $\frac{\pi R^2}{6} = \frac{3.14 R^2}{6} = 0.523 R^2$  and Area of small pie =  $\frac{AoBP}{2} = \frac{0.523 R^2}{2} = 0.2616 R^2$

Area of big gap =  $2 \times (1.73 R^2 - (0.523 R^2 + 0.2616 R^2)) = 1.8908 R^2$

Powders finer (fine powder) can be inserted between the slit powder with medium powder. To find the radius of a small powder, widely sought large gap formed powder with a small powder first (small gap), in the following way:

$$\text{Area of small gap (AoSG)} = \frac{\text{AoBG} - \text{Area of medium grains}}{3} \quad (3)$$

$$\text{AoSG} = \frac{1.8908 R^2 - \pi r^2}{3} = \frac{1.8908 R^2 - 3.14 \times (0.26 R)^2}{3} = \frac{1.04944 R^2}{3} = 0.3498 R^2$$

To find the radius ( $r'$ ) of a fine particles in Fig. 2b, used the ratio of the large gap with a small gap.

$$\frac{\text{AoBG}}{\text{radius of medium grains}} = \frac{\text{AoSG}}{\text{radius of fine grains}} \quad \text{where} \quad \frac{1.8908 R^2}{0.26 R} = \frac{0.3498 R^2}{r'} \quad \text{finally } r' = 0.048R$$

## B. Quantity of Powder

The coarse particles number are powder forming ( $N_p$ ), formulated:  $N_p = \frac{V_{die\ cavity} - V_{core\ rod}}{V_{particle\ sphere}} = \frac{\pi l R_d^2 - \pi l R_c^2}{\frac{4}{3} \pi r_p^3}$  (4)

$$N_p = \frac{l (R_d^2 - R_c^2)}{\frac{4}{3} r_p^3} = \frac{3 l (R_d^2 - R_c^2)}{4 r_p^3}$$

The medium particles number are first filler powder ( $N_{f1}$ ), calculated based on the fraction of particles in the mold cavity formed by the particles forming the powder, formulated:

$$N_{f1} = 3 N_p = \frac{9 l (R_d^2 - R_c^2)}{4 r_p^3}$$

The fine particles number are second filler powder ( $N_{f2}$ ), calculated based on the fraction of particles in the mold cavity formed by the powder particles forming and powder filler first, formulated:

$$N_{f2} = 3 N_{f1} = \frac{27 l (R_d^2 - R_c^2)}{4 r_p^3}$$

Volume particle powder bushing ( $V_b$ ), formulated particles mixture fraction, coarse : medium : fine is 12 : 3x12 : 3x3x12 or 1 : 3 : 9. In the experiment the mixture fraction weight fraction of particles is more practical than a mixture of grains, which is the volume of grain ( $V$ ) =  $\frac{4}{3} \pi R^3 \gamma_{dul}$  so the weight of the mixture of particles included in the printed P / M for fraction of weight [ in g ] coarse : medium : fine is 10247 : 185 : 1

## C. Experimental

In this experimental duralumin filling powder into a mold bushing is determined on the basis of volume. And bushing the P/M were used as specimens grouped by similar sized powder particles and the variation (fraction size is coarse : medium : fine).

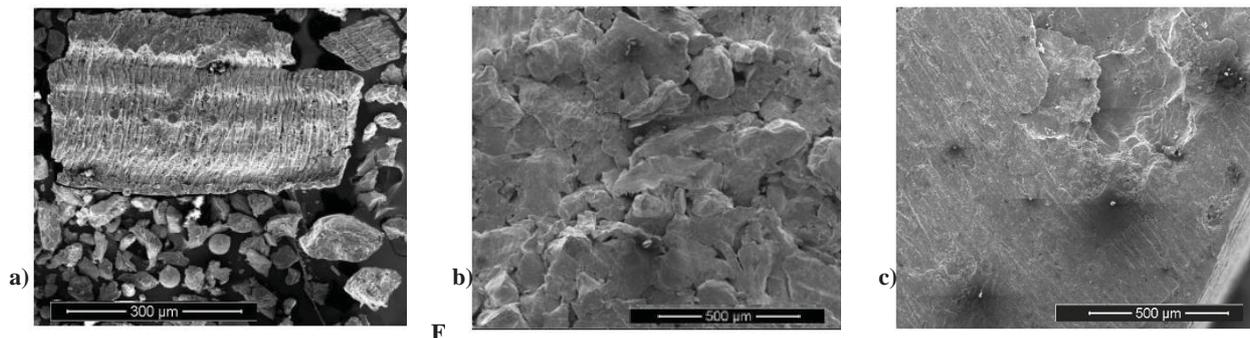
### Preparation of Specimens

Lubricate bushing with graphite mold components, mold components are stacking the electric furnace and did preheating to a temperature of 350°C. Lift the punch by lowering the hydraulic pressure and input duralumin powder particles that have been weighed or stirred into molds and lower punch until the hydraulic pressure machine indicated number Zero. Thermoregulation set at 450°C temperature after the temperature reaches the lower mold punch until the manometer indicates the pressure 400 bar and maintain the pressure for 15 minutes. Lower hydraulic pressure to zero bars so punch lifted up, take molds of the furnace and remove the specimen from the mold.

### Test of Specimen

The optical emission spectrometry (OES) test to see the major alloying element in powder duralumin. Two important considerations OES tests performed, namely: 1). for determining the ideal density specimen, 2). the hot compacting process (a combination of pressure and sinter) diffusion occurs between base metals and master alloys. Picnometry test to measure the physical properties (density and porosity) specimen. Picnometry test is done by weighing the specimen in air and in water, to operate the press. Picnometry actual density values obtained and the porosity of the specimen P/M. Tested scanning electron microscopy (SEM) to obtain images porosity (qualitative and quantitative) and the length of contact (neck) between powder particles. In this research, surface hardness P / M in the test using Vickers micro hardness ( $H_V$ ) with a load of 100g. Besides, SEM porosity test done as validation (method of calculation).

## 3. Result and Discussion



a). Powder particles, b). Sphere geometry of disordered particles, c). Sphere geometry of ordered particles

Generally the quality of near net shape manufacturing processes such as metal forging, metal casting, and powder metallurgy are determined by optimizing the arrangement of the micro-spatial variation in the control of the compression, vibration, and fine particles inserts. Method of fine particles inserts results of randomized trials and control the number of particles in the mold as in Fig. 3b and 3c, respectively. Fig. 3b shows the amount of porosity greater than Fig. 3c, this is due to P/M with disorganized grain constituent particles during the hot press process locked up, causing a permanent gap until the agglomeration process is complete. While the P / M with items ordered (Fig. 3c) during the hot press slide between the particle filler occupy particle gaps and reduce the cavity space between the grains of the agglomeration process to complete. According to Božić et al. [4], the microstructural analysis of ordered of dislocations within the boundaries created sub-grains resulting in higher grain density around Al<sub>2</sub>O<sub>3</sub> particles. The statement was supported by result of research as in [5], the addition of small amounts of lead and zinc to the composite increases the hardness and wear resistance.

**Table 1.** Nomonal composition of duralumin in experiment

Duralumin [wt%Cu]	Weight of elements [%]								Theoretical mass density [g.cm <sup>-3</sup> ]
	Cu*	Mn	Si*	Mg*	Zn	Fe*	Sn	Al*	
	<b>8.38</b>	<b>7.20</b>	<b>2.52</b>	<b>1.59</b>	<b>7.14</b>	<b>7.26</b>	<b>7.17</b>	<b>2.55</b>	
95.5Al4.5Cu	4.49	0.07	0.70	0.22	0.27	1.32	0.01	Res	2.89

**Description.** Bold numbers, italic, and regular each shows the element of theoretical density, the percentage of elements OES test results, and the elements density of the material in duralumin (partial).

Effect of content elements (Table 1) in the experimental determine the theoretical density of material (duralumin). According Wahyono et.al [6], duralumin mass density values can be determined analytically based on the equilibrium system is

formulated:

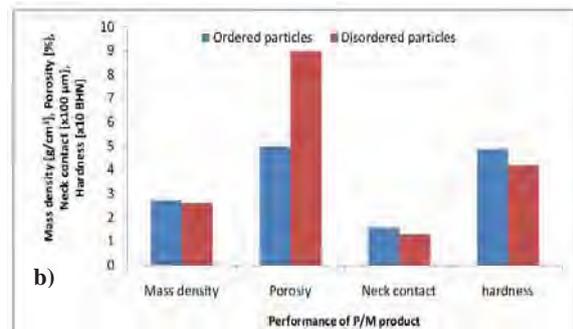
$$\gamma_{dural} = \frac{\sum \%u_i \cdot \rho_{u_i}}{100} = \frac{\%u_1 \cdot \rho_{u1} + \%u_2 \cdot \rho_{u2} + \dots + \%u_n \cdot \rho_{un}}{100} \quad (5)$$

where %, u respectively show the percentage, the chemical elements. And the use of Archimedes' principle which application

in Pycnometry apparatus refers to the ASTM standard D3800 is formulated;

$$\gamma_{P/M} = \frac{W_A \times \gamma_W}{W_A - W_W} \quad (6)$$

where W<sub>A</sub>, W<sub>W</sub>, and γ<sub>W</sub> each specimen showed heavy in the air and in water, and the mass density of water. Quantity of porosity P/M products were analyzed by Saltykov refers to the standard ASTM B311-93 and ASTM C948. Possible reduction in the amount of porosity in particles ordered is caused by mass density effects. It is caused by a large cavity insulation inserts gap filler particles. Generally, a lower mass density of casting product shows a higher porosity level, and a higher mass density of casting product shows a low porosity. Reference [7], the void are filled by the medium and small particles and these particles will melt in hot compacting so wet as a result of large particles contact neck between the particles increases to produced good wetting.



a). Bushing product of experiment, b). Chart of experiment results

Sample (bushing product of P/M) surface in Fig. 4a, the disordered has a lower hardness than ordered particles as in Fig. 4b. Hardness tests were carried out with Vickers micro hardness (Hv) and hardness test results are converted into Brinell hardness (BHN) in accordance with Approximate Hardness Conversion Numbers for Wrought Aluminum Products of ASTM E140-02 and hardness values obtained in Fig. 4b. Increased P/M hardness on the ordered particles not only due to higher density of grain but the hot compaction process also contributed. Rationally porosity lowered number of strength elements of solid material and the strength of P/M to the disordered lower than ordered particles. The porosity of a powder metallurgy component is greatly depends on the sintering temperature and in order to optimize the wear resistance it is important to keep porosity down to a minimum, Gaál [8] and Goutam [9]. According to Huang [10], Voids in sintered powder compacts exert a detrimental effect on the mechanical properties and total change of the void volume fraction in the porous metals during deformation arises partly from the growth of existing voids and partly from the nucleation of new voids.

Particle P / M were prepared by direct mixing weight fraction forming a more homogeny. Analysis of the microstructure (SEM) on the adhesion between the contact points between the grains showed coarse, medium, and fine particles. The length of the

contact point of contact between the particles can be measured and a comparison with a circumference of primary particles (coarse). Further contacts neck P/M disordered and ordered compared. In this study, neck contact 155 to 160  $\mu\text{m}$  and 165 to 173  $\mu\text{m}$  for disordered and ordered particles, respectively. The presence of pressure and temperature combination in hot pressing is caused by the high melting rate of filler, a consequence of sufficiently correct necking or wetting process control in P/M. The bulk of the powder contained numerous agglomerations of the smallest particles is porousless and characterized by the presence of prior particle boundaries, Dhokey et al.[11].

#### 4. Conclusion

- The inclusion of medium and fine particles in coarse particle gaps are able to increase mass density and micro hardness, and decrease porosity, and in bushing product of P/M significantly.
- The results of analytical and metallographic examination indicate the type of porosity in arrangement system of the P/M process of powder duralumin is a type of micro porosity. Explicitly neck of contact between particles in the arrangement has positive influence on increasing the density so that porosity decreases of the P/M.
- Inserts fine and medium particles in large grain gaps were enlarging contact line or neck of particles affecting linearly to hexagonal networking.

#### Acknowledgements

The authors wish to acknowledge the support of  $\alpha\beta\gamma$  Material Lab. in the preparation of this paper. They are particularly grateful to Andik Budi Prasetyo for his assistance with all aspects of testing, Martha Zainuddin Zuhri Marsus and Ika Listiawati who were instrumental in performing all the necessary drawing and SEM image who prepared all that were used for this study.

#### References

- [1]. Ademeso Odunyemi Anthony, Adekoya John Adeyinka, Olaleye Boluwaji Muraina, The Inter-relationship of Bulk Density and Porosity of Some Crystalline Basement Complex Rocks: A Case Study of Some Rock Types In Southwestern Nigeria, IOSR Journal of Engineering, Apr. 2012, Vol. 2(4) pp: 555-562.
- [2]. K. Travis Holman, Molecule-Constructed Microporous Materials: Long under Our Noses, Increasingly on Our Tongues, and Now in Our Bellies, Metal–Organic Frameworks, *Angew. Chem. Int. Ed.* 2011, 50, 1228 – 1230, doi: 10.1002/anie.201006783.
- [3]. Won-Chun Oh, Properties of Metal Supported Porous Carbon and Bactericidal Effects, *J. Ind.Eng. Chem*, Vol. 9, No. 2, (2003) 117-124.
- [4]. D. Božić, J. Stašić, V. Rajković, Microstructures and Mechanical Properties of ZA27-Al<sub>2</sub>O<sub>3</sub> Composites Obtained by Powder Metallurgy Process, *Science of Sintering*, 43(2011) 63-70, doi:10.2298/SOS1101063B.
- [5]. Montasser Dewidar, G.T. Abdel-Jaber, Mahmoud Bakrey, and Hussien Badry, Effect of Processing Parameters and amount of additives on the Mechanical Properties and Wear Resistance of Copper-based Composite, *International Journal of Mechanical & Mechatronics IJMME-IJENS* 2010, Vol: 10 No: 03
- [6]. Wahyono Suprpto, Bambang Suharno, Johnny Wahyuadi Soedarsono, Dedi Priadi, Analytical and Experimental Models of Porosity Formation of Duralumin Cast in Vacuum Casting System, *Advanced Materials Research* Vol. 277 (2011) pp 76-83, Online available since 2011/Jul/04 at [www.scientific.net](http://www.scientific.net), © (2011) Trans Tech Publications, Switzerland, doi:10.4028/www.scientific.net/AMR.277.76.
- [7]. Leander Pease, A Quick Tour of Powder Metallurgy, *Advanced Material & Processes* /March 2005.
- [8]. I. Gaál, A. L. Tóth, L. Uray, Effect of Process Parameters on The Low Temperature Electrical Resistivity of P/M Materials, *Powder Metallurgy Progress*, Vol.11 (2011), No 3-4, pp. 210-221.
- [9]. Goutam Dutta, Dipankar Bose, Effect of Sintering Temperature on Density, Porosity and Hardness of a Powder Metallurgy Component, *International Journal of Emerging Technology and Advanced Engineering*, Website: [www.ijetae.com](http://www.ijetae.com) (ISSN 2250-2459, Volume 2, Issue 8, August 2012).
- [10]. Cheng-Chao Huang, Jung-Ho Cheng, An investigation into the forming limits of sintered porous materials under different operational conditions, *Journal of Materials Processing Technology* 148 (2004) 382–393, Elsevier.
- [11]. N.B. Dhokey, V.A. Athavale, N. Narkhede, M. Kamble, Effect of processing conditions on transient liquid phase sintering of premixed aluminium alloy powders, *Advanced Materials Letters*, Copyright © 2012 VBRI Press.

## **Novel Technique for Conceptual Design Selection of Manufacturing Process and Material of Metal Matrix Composite Brake Disc**

**N. Fatchurrohman, S. Sulaiman, S.M. Sapuan, M.K.A. Ariffin, B.T.H.T. Baharuddin**

*Department of Mechanical and Manufacturing Engineering, Faculty of Engineering,  
Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia  
Email: n.fatchurrohman@gmail.com, suddin@eng.upm.edu.my,  
sapuan@eng.upm.edu.my, khairol@eng.upm.edu.my, tuah@eng.upm.edu.my*

### **ABSTRACT**

This article introduced a novel technique which involved Concurrent Engineering (CE) strategy and Analytical Network Process (ANP) technique to form a ranking methodology as a part of the Conceptual Design Selection (CDS). The proposed method is referred as Concurrent Network (CN). The objective of this study is to simultaneously consider of all features of product elements by implementing CE strategy. Furthermore, CN enables interdependence and interrelationship analysis between product elements by application of ANP. In this study, CN is utilized for a conceptual design of metal matrix composite (MMC) brake disc. The results show that by using CN, all important product parameters can be considered simultaneously during the CDS and the importance weights of manufacturing process parameters and material parameters which are related to MMC brake disc performance are attained.

### **Keywords**

*Concurrent engineering, analytical network process, conceptual design selection, manufacturing process, material, metal matrix composite, brake disc*

This Paper is Published in Advanced Materials Research Journal

## Physics and Chemistry Test on Aluminum-Based Composite Materials an Alternative Material for The Manufacture of Drum Brake

Prantasi Harmi Tjahjanti <sup>a</sup>, Wibowo Harso Nugroho <sup>b</sup>, Hana Catur Wahyuni <sup>c</sup>

<sup>a</sup>Faculty of Mechanical Engineering, University of Muhammadiyah Sidoarjo 61271  
E-mail : pran\_tasi@yahoo.com, prantasi@gmail.com

<sup>b</sup>UPT BPPH, BPPT Surabaya, Sukolilo, Surabaya (60111)  
E-mail : bowo02@yahoo.com

<sup>c</sup>Faculty of Industry Engineering, University of Muhammadiyah Sidoarjo 61271  
E-mail : hana\_catur@yahoo.co.id

### ABSTRACT

One of the components of the vehicle are of particular interest is the brake system , because its main function is to stop the rotation axis, set the axis of rotation and to prevent unwanted rotation. One classification system is the drum brake that has been widely made of cast iron, cast iron and cast steel special. This study makes drum brake of composite materials aluminum-based, with reinforcement is silicon carbide (SiC), obtained optimum composition of 15%, so it is written (Al-Si) -SiC/15%. Physics testing includes testing of thermal conductivity and thermal expansion coefficient, and Chemistry testing the corrosion penetration rate when the test material was coating with regular polish, with chrome, with nickel and with nickel + chrome. The final results showed that the value of conductivity and thermal expansion coefficient of the composite material is lower than cast iron, aluminum and other alloys. That is pretty good heat resistance when applied to drum brake material. Lowest corrosion rate on coating material with a layer of Ni-Cr.

### Keywords

*Drum brake, composite base on aluminum, SiC, thermal conductivity, thermal expansion coefficient, corrosion penetration rate*

This Paper is Published in Advanced Materials Research Journal

## Oxidation Characteristics of Various Nickel Composite Coated on Ferritic Stainless Steel

**Asep Ridwan Setiawan, Raden Dadan Ramdan, Budi Prawara, Steven,  
Rochim Suratman**

*Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung, Jl. Ganesha 10 Bandung,  
West Java, Indonesia 40132  
Email: asepridwans@material.itb.ac.id, dadan@material.itb.ac.id, budi.prawara@lipi.go.id, steven1@gmail.com,  
rochim@material.itb.ac.id*

### ABSTRACT

The present work concerns in developing alternative interconnect material for solid oxide fuel cell (SOFC) application. For this purpose, ferritic stainless steel is used as the substrate material while various nickel composite layers were coated on the substrate in order to improve its oxidation resistance at SOFC application temperature. Nickel layers were deposited on ferritic stainless steel by high velocity oxy-fuel (HVOF) method. In order to create nickel-oxide layer, the coated samples is then heated at temperature of 950°C for 1 hour, whereas sol-gel coating was performed on the coated samples in order to create nickel manganese oxide spinel composite layers. All samples were then oxidized at temperature 800°C for 8 hours, in order to evaluate their oxidation characteristics at SOFC service temperature. Before and after oxidation, x-ray diffraction (XRD) and scanning electron microscope (SEM) were performed to all samples. It was observed that coated samples effectively inhibit the formation of chromium oxide that normally occurs on stainless steel surface at SOFC service temperature.

### Keywords

*Interconnect, nickel composite coating, ferritic stainless steel, thermal spray, oxidation*

This Paper is Published in Advanced Materials Research Journal

## Effect of Equal Channel Angular Pressing and Post Heating on Microstructure and Hardness of Cu-Zn 70/30

Suryadi<sup>a,b</sup>, R. A. M. Napitupulu<sup>c</sup>, Dedi Priadi<sup>a</sup>, Amin Suhadi<sup>b</sup>, E.S. Siradj<sup>a</sup>

<sup>a</sup>Department of Metallurgy and Materials Engineering, Faculty of Engineering, University of Indonesia,  
Depok, Indonesia  
Email: dedi@eng.ui.ac.id, eddysiradj@yahoo.com

<sup>b</sup>Centre of Industrial Processing Technology (PTIP), Agency for Assessment and Application of Technology (BPPT), Kawasan Puspiptek  
Serpong, Banten, Indonesia  
Email: ax662@yahoo.co.uk,

<sup>c</sup>Department of Mechanical Engineering, University of HKBP Nommensen, Medan, Indonesia  
Email: suryadi\_chun@yahoo.co.id, richard\_alf@yahoo.com

### ABSTRACT

Severe plastic deformation (SPD) using various pass number of Equal Channel Angular Pressing (ECAP) experiment and followed heating at 400°C has been done for rod brass Cu-Zn 70/30 to investigate the operation on microstructure and hardness of the alloy. Optical microscopy and SEM are used to examine the microstructure change. Mechanical testing such as macro and micro hardness test is used in order to examine the change of mechanical properties. The grain structure of the alloy was refined from 34 µm to 2 µm after 4 passes ECAP and increased to 4 µm after post heating. The hardness of the alloy significantly increased from 78 Hv to 235 Hv after 4 passes and decreased to 135 Hv after post heating after ECAP. The microstructure and mechanical properties of the alloy was homogenous after 4 passes ECAP because the strain was found more homogenous.

### Keywords

ECAP, Cu-Zn 70/30, microstructure, hardness, homogeneous

This Paper is Published in Advanced Materials Research Journal

## **Simulation of Metal Flow to Investigate the Application of Antilock Brake Mechanic System in Deep Drawing Process of Cup**

**Susila Candra, I Made London Batan, Agus Sigit P, Bambang Pramujati**

*Mechanical Engineering, Institute of Technology Sepuluh Nopember (ITS), Indonesia  
Email: susilac@yahoo.com, londbatan@me.its.ac.id, pramono@me.its.ac.id, pramujati@me.its.ac.id*

### **ABSTRACT**

This paper presents the importance of simulation of metal flow in deep drawing process which employs an antilock brake mechanic system. Controlling the force and friction of the blank holder is imperative to assure that the sheet metal is not locked on the blank holder, and hence it flows smoothly into the die. The simulation was developed based on the material displacement, deformation and deep drawing force on flange in the radial direction, that it is controlled by blank holder with antilock brake mechanic system. The force to blank holder was applied periodically and the magnitude of force was kept constant during simulation process. In this study, the mechanical properties of the material were chosen such that they equivalent to those of low carbon steel with its thickness of 0.2 mm. The diameter and the depth of the cylindrical cup-shaped product were 40 mm and 10 mm, respectively. The simulation results showed that the application of antilock brake mechanic system improves the ability to control the material flow during the drawing process, although the maximum blank holder force of 13000 N was applied. The optimum condition was found when the drawing process was performed using blank holder force of 3500 N, deep drawing force of 7000 N, friction coefficient of 0.25 and speed of punch stroke of 0.84 mm/sec. This research demonstrated that an antilock brake mechanic system can be implemented effectively to prevent cracking in deep drawing process.

### **Keywords**

*Deep drawing, metal flow, blank holder force, antilock brake system, cracking*

This Paper is Published in Advanced Materials Research Journal

## Hydrogen Absorpsivity-Desorbsivity of Mg doped by Ni, Cu, Al produced by Mechanical Alloying

Widyastuti, Febrian Budi P, Sutarsis

*Department of Materials and Metallurgical Engineering, Faculty of Industrial Technology  
Institute of Technology Sepuluh November (ITS) Surabaya 60111, Indonesia  
Email: wivid@mat-eng.its.ac.id, febu@gmail.com, sutarsis@mat-eng.its.ac.id*

### ABSTRACT

Mg, in the form of  $MgH_2$ , is one kinds of materials widely used as hydrogen storage materials. Absorption and desorption properties of hydrogen which comes from metal hydride depend on materials itself, addition of elements, as well as manufacturing method. In this research, Mg as hydrogen storage were prepared by mechanical alloying with Ni, Cu, and Al as element addition and variation milling time for 10, 20 and 30 hours. Some morphological analyses (XRD, SEM) were done to observe phase transformation. Absorption and desorption properties characterization were employed by DSC and hydrogenation tests. The improvement in milling time decreased particle size, therefore enhanced wt% of absorbed hydrogen and decrease onset desorption temperature. However, the excessive of agglomeration and cold welding on mechanical alloying process resulted in bigger particle size. Alloying elements, Al and Cu, served as catalyst, while Ni acted as alloying which reacted with hydrogen. Mg10wt%Al with 20 hours milling time at hydrogenation temperature 250°C, 3 atm pressure, and 1 hour holding time resulted in the highest weight percent of  $H_2$  (0.38%wt). However, Mg10wt%Al with 30 hours milling time had the lowest onset temperature, 341.49°C

### Keywords

*Absorption, desorption, hydrogen storage materials, mechanical alloying, Mg*

This Paper is Published in Advanced Materials Research Journal

## **Mechanical Properties and Microstructure of Welded Dissimilar Metals using Buttering and Non-Buttering Layer**

**Winarto, Muhammad Anis and Teguh Puji Hertanto**

*Metallurgical and Materials Engineering Department, Faculty of Engineering  
Universitas Indonesia, Depok, Indonesia (16424)  
Tel: (+62 21) 7863510. Fax: (+62 21) 7872350  
winarto@metal.ui.ac.id, anis@metal.ui.ac.id*

### **ABSTRACT**

Joining of dissimilar metals is to compose different properties of metals in order to minimize material costs and at the same time to maximize the performance of the equipment and machinery. There are a lot of methods of joining of dissimilar metals. However, the fusion welding is mostly used in a wide range of industries. This research is carried out for the process of dissimilar welding between carbon steel plates of ASTM A516-70 and austenitic stainless steel plates ASTM A214-316L by using gas metal arc welding (GMAW). Welding design used is a V-groove by using the buttering process and without buttering (non-buttering) process. Types of filler metals used are ER309L and ER316L-Si. The weldment is then tested by using destructive test (DT) and non-destructive test (NDT). Weldment is also characterized by using X-Ray Diffraction (XRD). The results show that the mechanical properties of weldment with buttering process are better compared with the weldment with a non-buttering process. The macro and microstructure of weldment with buttering process revealed finer grained and homogeneous structures compared with the one by using a non-buttering process. Moreover, welds characterization by using XRD show that the precipitation of chromium carbide on HAZ of weldment with buttering process is lower than that of weldment with a non-buttering process.

### **Keywords**

*Dissimilar metal, buttering, gas metal arc welding, microstructure, mechanical property*

This Paper is Published in Advanced Materials Research Journal

## Formation and Characterization of Al-5%Cu-4%Mg/Si<sub>p</sub> MMC by Thixoforming Process

Yusuf Afandi<sup>a</sup>, Anne Zulfia<sup>a</sup>, Dedi Priadi<sup>a</sup>, I Nyoman Jujur<sup>b</sup>

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424, Indonesia  
Email: yusaf67@yahoo.com, anne@metal.ui.id, dedi@eng.ui.ac.id

<sup>b</sup>Center of Material Technology, Agency of the Assessment and Application of Technology,  
Building 224, Science and Technology Park (Puspiptek), South Tangerang 15314, Indonesia  
Email: njujur@yahoo.com

### ABSTRACT

Metal matrix composites (MMCs) are new materials, which are very essential for industry manufacture applications, such as automotive, aerospace and military. So far, an enhancement of the MMCs hardness has been interestingly studied. In this paper, we study the formation of Al-5%Cu-4%Mg matrix with SiC<sub>p</sub> reinforcement by thixoforming process. Several important parameters for increasing the MMCs hardness, such as volume fraction of reinforcement, ageing time and temperature, have been investigated. It is found that the distribution of SiC particles in Al matrix is non homogeneous for both MMCs with 5 vf.% SiC and 10 vf.% SiC. It also is found fine and coarse globular and non-dendritic structures in the matrix as indicated that thixoforming process has succeed. The hardness increased with higher vf.% SiC as well as longer aging time after thixoprocess, therefore such parameters should be considered in order to obtain the optimum performance of Al-5%Cu-4%Mg/SiC MMC.

### Keywords

*Metal matrix composites (MMCs), Al-5%Cu-4%Mg, thixoforming, SiC reinforcement, ageing, hardness*

This Paper is Published in Advanced Materials Research Journal

## Deformation Behaviour of Silicon Carbide Reinforced Al-7Si Composite after Ballistic Impacts

Bondan T.Sofyan<sup>a</sup>, Dwi Rahmalina<sup>b</sup>, Bambang Suharno<sup>a</sup>, Eddy S. Siradj<sup>b</sup>

<sup>a</sup>Department of Metallurgy and Materials Engineering, Faculty of Engineering,  
University of Indonesia, Depok  
E-mail: bondan@eng.ui.ac.id, suharno@metal.ui.ac.id, siradj@metal.ui.ac.id

<sup>b</sup>Department of Mechanical Engineering, Faculty of Engineering, Pancasila University, Jakarta 12640  
E-mail: drahmalina@yahoo.com

### ABSTRACT

The deformation after ballistic impact loading of silicon carbide reinforced aluminium alloy composite is investigated in this research. The composite consists of 10 % volume fraction of silicon carbide particulate in a matrix of Al-7Si-Mg-Zn alloy and were produced through the squeeze casting process with a pressure of 1 MPa at semi-solid melting temperatures of 590-610 °C. The mechanical property of the composite was examined with hardness test. The ballistic tests were performed with two types of projectiles, 9 mm calibre and 5.56 mm calibre of projectiles. Then the deformed surfaces were studied with optical microscopy. During ballistic testing, the 9 mm projectile did not pierce the composite plate although the test resulted in significant cracks on the backside of the plate. The cross section observation of the plate showed ductile deformation in the matrix and silicon carbide particulates give significant rule in withstanding the penetration of the projectile. The 5.56 mm projectile pierced through the composite and caused a brittle fracture of the matrix.

### Keywords

*Deformation, ballistic impact, aluminium composite, silicon carbide, squeeze casting*

This Paper is Published in Advanced Materials Research Journal

## The Influence Of Various Percentage Of $Al_2O_3$ By Using Vortex Method To Tensile Strength And The Distribution Of $Al_2O_{3p}$ Composite

Salahuddin Junus<sup>a,b</sup>, Anne Zulfia<sup>a</sup>, and Eric Tanoto<sup>a</sup>

<sup>a</sup>Departement of Metalurgy and Material, Faculty of Engineering, University of Indonesia,  
Kampus UI-Depok, Jawa Barat, 16424, Indonesia  
Email: anne@metal.ui.ac.id, eric\_tanoto@yahoo.com

<sup>b</sup>Departement of Mechanical Engineering, Faculty of Engineering, Jember University,  
Kampus Univ. Jember-Kalimantan 37, Jawa Timur 68121, Indonesia  
Email: salahuddin\_yunus@yahoo.com

### ABSTRACT

Aluminum composite reinforced ceramic particles can be created through stirring process (Stir Casting) so that the molten aluminum to form a vortex as a space for the reinforced of  $Al_2O_3$  particles well distributed on the aluminum melt. Engineering ceramic particles and vortex formation process will determine the distribution of particles in molten aluminum metal. Mg was added during the melting and argon was flushed to improve wetting system and protect oxidation. In this study, billet Al.6061 was combined with various percentage of  $Al_2O_3$  from 5Vf % to 20Vf%. The results showed that the optimum tensile strength obtained at 10Vf %  $Al_2O_3$  with the value of 190 MPa.

### Keywords

Aluminum composite, billet Al.6061,  $Al_2O_3$  ceramic particles, vortex method (Stir Casting), volume fraction

This Paper is Published in Advanced Materials Research Journal

# Role of Coordination Sphere Geometry to Properties Control of Powder Metallurgy Process

Wahyono Suprpto

Mechanical Engineering Department, Engineering Faculty, Brawijaya University  
wahyos\_metfiub@yahoo.com  
Wahyos@ub.ac.id

## ABSTRACT

Broadly, P/M process to produce of engine and automotive components high quality. Advantage of P/M process is efficient of used material is higher than near net shape processes such as casting and forging. Principally, product quality of P/M process is determined by its density. Generally the quality of the product manufacturing process is measured from the physical, mechanical, and metallography properties. Variety of experimental methods of compression, vibration, and temperature has been used to control density P/M. This article describes the approach to the calculation of geometry of the grain size fractions to control P/M density. The study analyzes P/M density is based on space equilibrium of mold cavity by rounded powder particles with coarse, medium, and fine sizes. In this article the results of density calculations validated by experiment of P/M HIP process of 10 metric tons pressure, 500°C temperature and 20 minutes holding time. Object of study is the bushing from duralumin powder is contained in a mold with homogeneous size and grain size fractions 12 : 3x12 : 3x3x12. Testing of P/M density, hardness, metallographic was conducted by Picnometry, Micro Hardness Tester, SEM, respectively. The test results and analysis states that density and P/M hardness on a powder feeding with a grain size fraction is higher than homogeneous filler grain size. And the results of metallographic characteristics of SEM studies show the size comparison of the bonding neck on the grain size fraction increased from 0.05 to 0.09 time point particles forming.

### Keywords:

*P/M, geometry, HIP, duralumin, picnometry, neck.*

## 1. Introduction

In particular manufacturing machinery and automotive industries, metal has several advantages over conventional material composite materials and ceramics, but the availability of world decreases. Therefore use of metal to be optimized either transformed into finished products as well as further utilization of waste generated such as chips, fins, scrap. The process of casting and P/M is a metal working process that transformable waste metal into finished products or components. One of the advantages of the process of casting, forging, and P/M can produce a near net shape parts. Product quality problems near net shape is determined by the density and porosity. Generally manufactured product with low density is high porosity and effect of porosity variations in the properties of other materials such as mechanical, metallographic, chemical, electrical, and be able to form. According Ademeso et al. [1], bulk density and porosity are two of the physical properties that have been found to significantly affect the mechanical properties, particularly. The bulk density values ranged from 2.63 to 2.81 and the porosity from 0.16 to 0.03. The P/M is a metal processing technology that can transform the metal particles into a finished product by micro-porosity.

During this time, porosity in the product manufacturing is one of types of defects that lead to decreased quality of product. Generally porosity occurs in the macro scale and distribution is not homogeneous, but are distributed homogeneously micro-porosity be a positive influence in the system. Because at a basic level possible crystal micro-porosity provide dynamic behavior of the atoms to rotate or translation affecting dimensional stability. Now micro-porosity combined with other material properties to provide an exchange (impregnation) and ion separation (filter), and the catalysis of hydrogen cracking. Therefore the porosity of the solid material must be disposed micro-porosity arrangement that provides dynamic behavior. Attempt to relate the dynamics of the molecules are linked to the harmony arrangement (ordered) of crystal lines as metal organic frameworks (MOFs), Travis [2]. Experiment the P/M with a variety of compression and vibration have been made in an effort to control the optimization of structuring micro-gap to control micro-porosity but the results have not been up to since their porosity and macro-size distribution is not homogeneous to form clusters or groups. Porosity is often caused shrinkage in the sintering process is not controlled, more distortion in the P/M products.

Generally, the optimization of the ordered of the micro powder particles space P/M through the variation of compression and vibration. In this research performed a micro structuring innovation space particles P/M with inserts of powder particles. In disordered of space through the insertion of micro powder particles, described by the coordinate geometry calculations system and principles of algebra micro space formed by the coordination of the powder particles P/M. By Won-Chun Oh [3], the phenomenon of the aggregate pattern is determined by the difference in the shape and size of the metal particles. In this article coordination powder particles consist of large particle size (forming particles), medium (primary fillers), and small size (secondary fillers). The aim structuring powder particles to form a point of contact between the particles forming, the main filler, and second filler to produce micro porosity with homogeneous distribution.

## Optimization Design of Airfoil Propellers of Modified NACA 4415 Using Computational Fluids Dynamics

Sudarsono<sup>a</sup>, Purwanto<sup>b</sup>, Johnny Wahyuadi<sup>a</sup>

<sup>a</sup>Doctoral Program in Environmental Sciences Graduate Program of Universitas Diponegoro, Semarang  
E-mail : sudarsono1574@gmail.com

<sup>b</sup>Departments of Materials and Metallurgy, Universitas Indonesia, Jakarta  
E-mail : p.purwanto@gmail.com, johny.ws@gmail.com

### ABSTRACT

Utilization of wind power in Indonesia is less attractive compared with utilization of conventional fuel. This is because the price of wind energy is not competitive when compared with fossil energy prices, and as a result of the implementation of energy pricing policy through subsidies. Before designing the Wind Energy Conversion System, simulation of computational fluid dynamics needs to be done in order for reducing designing time and cost. In this research, modeling and simulation work has been done to figure out the optimum aerodynamics coefficient of wind turbine blades at different Reynolds number. This blade is a modification of standard airfoil of NACA 4415. The aerodynamics coefficient of modify and standard airfoil is then compared. FLUENT software and Spalart-Allmaras Turbulent Model are used in this work. Based on the comparison of the coefficient of aerodynamic, modification NACA 4415 airfoil has better performance at Reynolds number of  $4.1 \times 10^4$  to  $2.5 \times 10^5$ . The experiment results also showed that based on a numerical study of the modification NACA 4415 airfoil can be used as a basis for the establishment of wind turbine blades.

### Keywords

Energy, propeller, NACA 4415, CFD

This Paper is Published in Advanced Materials Research Journal

## Study About Surface Hardening On Local Disc Brakes With Direct Current Plasma Nitrocarburizing Apparatus

Usman Sudjadi

Center For Nuclear Fuel Technology – National Nuclear Energy Agency  
Kawasan PUSPIPTEK – Tangerang 15314, Indonesia  
Phone: 062-021-7560915, Facs: 062-021-7560909  
Email: usmannunung@yahoo.com

### ABSTRACT

Surface hardening on local disc brakes with DC-plasma nitrocarburizing apparatus has been carried out. Local disc brake was nitrocarburized at temperatures of 700 °C, 800°C, and 900°C for 3 hours, respectively. The results show that the hardness of sample of local disc brake before nitrocarburization was 167.86 Kgf/mm<sup>2</sup>, after the sample was nitrocarburized at temperature 900 °C for 3 hours, the hardness increased up to 649.38 Kgf/mm<sup>2</sup>. Matrixes on the base material were austenite, ferrite, and perlite.

### Keywords

*Nitrocarburizing, DC- plasma, local disc brakes, hardness, microstructure*

This Paper is Published in Advanced Materials Research Journal

## Study on PbSn Composites Produced by Powder Metallurgy as Core Bullet Projectile

Widyastuti<sup>1,a</sup>, Vuri Ayu setyowati<sup>1,b</sup>, Taufik Akbar<sup>1,c</sup>

<sup>1</sup>Department of Materials and Metallurgical Engineering, Faculty of Industrial Technology  
Institute of Technology Sepuluh November (ITS) Surabaya 60111, Indonesia  
[a](mailto:wiwid@mat-eng.its.ac.id)[wiwid@mat-eng.its.ac.id](mailto:wiwid@mat-eng.its.ac.id), [b](mailto:vuriayu@gmail.com)[vuriayu@gmail.com](mailto:vuriayu@gmail.com), [c](mailto:akbar_mt11@gmail.com)[akbar\\_mt11@gmail.com](mailto:akbar_mt11@gmail.com)

### ABSTRACT.

PbSn composites have been prepared by powder metallurgy for Advance Energy Transfer Bullet Application. Sn compositions was variety 5, 10, 15wt%. The compacting pressure performed at 10, 15, and 20 MPa. Temperature and holding time of sintering constantly in 150°C for 2 hours. The microstructure and mechanical performance of PbSn composites are investigated by Scanning Electron microscope (SEM), and compression tests. The results show that the Pb-15wtSn Composite which is compacted in 20 MPa has result greatest density which was 10.969 gr/cm<sup>3</sup> and the smallest porosity (1.5%). Mechanical performance test of PbSn composite show the greatest hardness, compressive strength and modulus elasticity reach are 11.01 HV, 46.82 MPa and 34.96 GPa

### Keywords:

*core projectile, metalurgi serbuk, Pb-Sn*

This Paper is Published in Advanced Materials Research Journal

# The Oxygen Control System Design (GAS SKID) and Oxygen Fuel Equipment (OFB) On Combustion: Metal, Glass, Glass and Ceramics in the Framework of Industrial Fuel Use Efficiency and Reduce Global Warming

Setiyono<sup>a</sup>, Gede Eka Lesmana<sup>b</sup>, Yohannes Dewanto<sup>b</sup>.

<sup>a</sup>Mechanical Department, Faculty of Engineering, Pancasila University  
 E-mail : simondewanto@gmail.com

<sup>b</sup>Mechanical Department, Faculty of Engineering, Pancasila University  
 Jl.Srengeng Sawah, Jagakarsa, Jakarta Selatan 12640  
 telp (021)7272290, fax (021)7270128  
 email: gd\_eka\_1@yahoo.com, simondewanto@gmail.com

## ABSTRACT

This paper discusses a research that aims to improve the efficiency of fuel consumption. The equipment consist of: the combustion process control engineering, engineering distribution system of fuel and system burner. Those system equipment used for the combustion reaction in which oxygen as an oxidant. The result is a detailed design for manufacture and for testing the prototypes of fuel-gas control system (SKID) and oxy-fuel burner (OFB) devise.

The advantages of this product is a production system equipment to be more fuel efficient. Fuel saving potential is expected to 20-25%, and the gas stag emissions reduced by 65%. In addition to this product designed is safely, also increase production, reduce production downtime and improve production quality.

## Keywords

*Control of oxygen supply, fuel savings, reduced emissions.*

## 1. INTRODUCTION

Industrialists were needed of better fuels economy, especially at this time, where there is no term fuel price will go down. It is very difficult for the people, businesses and governments. Although everything else was difficult matters concerning fuels, but no idea who published / recommended to try to reduce fuels by analyzing the way back from basic techniques and their combustion reaction control equipment used in the production process.

If we look at the developed countries, the actual burning technique in the world now is up to seven. While Indonesia has reached level two. This is why Indonesia miss 60-75 years in combustion engineering. To catch up is very difficult to obtain the result that there is no cooperation between industry and universities. Industry research affairs handed off to college while the government as an facilitator.

Industries that require fuels saving techniques are primarily in the industrial production process requires heat generated from solid fuels, liquid or gas. The industry group such as:

- The steel industry work in temperatures: 1650 °C
- Rolling mill steel works at temperature 1050 °C
- Casting of iron works at temperatures: 1400 °C
- Copper smelting works at tempt: 1450 °C
- Aluminum smelting works at tempt: 950 °C
- Tin smelting works at temperatures: 850 °C
- Manufacture of glass work on temperature: 1650 °C
- The industry works on temperature: 1650 °C
- PLTG working temperature: 1150 °C
- Pulp and paper
- Chemical industry

Industries mentioned above requires approximately 12.98 million kiloliters of fuel per year (2008). Conceivably that could save you 20% only.

The research aims:

- Increase production
- Improved fuel economy

- Reduced production down time
- Improving the quality of production
- Reduce emissions and improve exhaust gas.
- Shorten the flame (flame) out of the appliance combustion (burner).

The results of this studies will reduce fuels consumption in the industrial sector between 20-25%. If this happens, then the government feels lucky because it will reduce the cost of fuel imports and reduce the subsidy borne by the government, jobs and raise per-capita income is called CRS (Carbon Reduction Sales)

## 2. THE METHOD

### 2.1 Reaction combustion using air as an oxidant.

As an example we use the fuel and the combustion reaction CH<sub>4</sub> as follows:



The air is made of 20,5% O<sub>2</sub> + 79,5% N<sub>2</sub>, or 1 part of O<sub>2</sub> + 3,878 part of N<sub>2</sub>, the reactions above can be changed as follows :



→ The air as an oxidant

Nitrogen is an gas inerts, the total volume of incoming and outgoing fixed in the reaction, only the temperature is different.

### 2.2 Combustion reactions using oxygen as an oxidant

By using oxygen as an oxidant, the reaction CH<sub>4</sub> combustion by the following :



The Simpler reaction, without N<sub>2</sub> participate in burning.

### 2.3 Comparison of Reaction

From combustion reactions (2) and (3) can be summarized as follows:

- The amount of exhaust gas is greatly reduced because without nitrogen.
- Heat carried nitrogen to the chimney does not occur
- Heat combustion will rise, the hot gas flow in the combustion chamber down.
- The temperature in the combustion chamber will rise.

With the increase of heat in the combustion chamber fuel consumption to be reduced or increased machine production capacity

### 2.4 Analysis of Combustion Process

The results of the analysis using the combustion reaction in the foundation theory of thinking, is as follows see at Table 1:

Table 1. Flues gas composition

SISTIM PEMBAKARAN	KOMPOSISI GAS BUANG					TOTAL
	CO2	H2O	SO2	O2	N2	
Heavy oil + udara	159.79	120.09	0.49	0.35	850.15	1130.87
Heavy oil + oxygen	159.79	120.09	0.49	0.35	0.56	281.28
NG + udara	104.00	200.50	0.001	0.00	789.57	1094.07
NG + oxygen	104.00	200.5	0.00	0.00	0.50	305.00

From the analysis above combustion reaction can be seen that:

1. Exhaust gases in the combustion process with air as an oxidant number 4 fold from flue gases in the combustion process with oxygen as an oxidant. This brings the hot exhaust gases to the chimney, so a lot of heat loss.
2. Due the volume flues of gas less (on combustion using oxygen), the gas flow in the combustion chamber is low, it will improve the absorption of heat and energy loss less.
3. From the above combustion reaction, the energy carried by nitrogen to the chimney reaches 42% and it will be 0% if the combustion process uses oxygen as an oxidant. In practice, the combustion efficiency is never achieved by 42% because

some of the heat is used to heat the combustion equipment components and partly lost due to the flow of air around the kitchen.

4. Exhaust emissions of pollutants can be controlled by regulating the amount of oxygen used in the process (at least 4% oxygen in the exhaust gas).
5. Target research: achieving fuel savings between 20-25%.
6. The amount of fuel depending on the working temperature, the type of kitchen that is used and the type of fuel used.
7. All analyzes should use the energy and mass balance analysis.

### 3. THE RESULTS AND THE DISCUSSION

#### 3.1 THE MAKING SYSTEM

Prototyping activity / workshop models made at Corporate Partners assembly in the Laboratory of Industrial and Production Department of Mechanical Engineering Faculty of Engineering, University of Pancasila. Before we begin the prototyping activities should be made standard operating procedures (SOP) for each manufacturing parts. Engineering design of these controls will be a basic tool assortment research and development in the field of energy research.

The composition of the equipment consists of a 3-group as follows:

- Storage tanks for oxygen, fuel, and air (fuel distribution system, air and oxygen)
- Tools discharge regulator, the pressure of the gas, the fuel and air (SKID) (controls, safety systems and instrumentation)
- Combustion chamber, combustion equipment (burner) and sensors (temperature, pressure and flow).

Schematic arrangement shown in Figure 1.

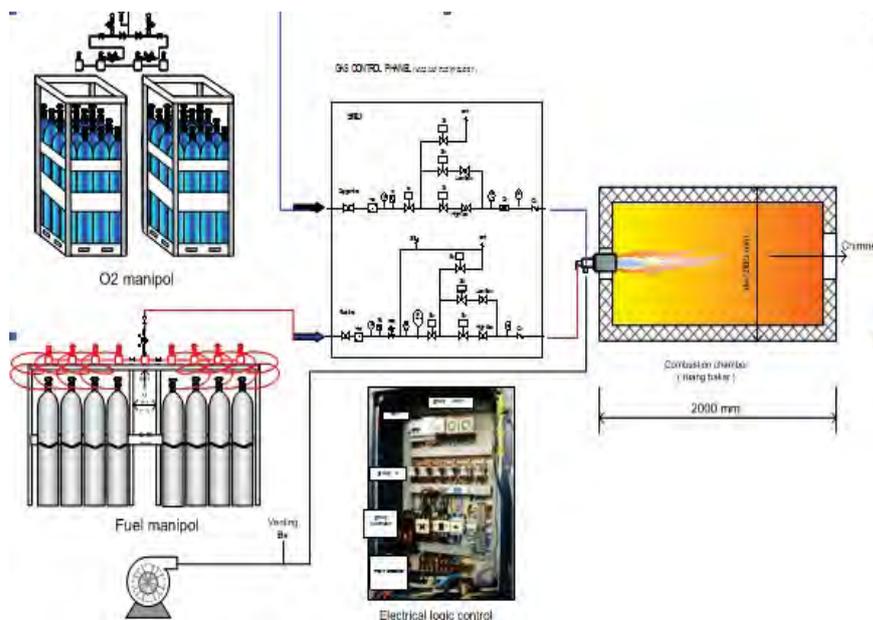


Figure 1 arrangement of equipment

#### 3.1.1. Storage tanks of fuel and oxidizer.

- The oxygen tank did not buy but just renting, which is used to buy gas and manifold system to buy spare-partsnya and assembled themselves.
- The LPG tank should buy, then made a manifold to regulate the gas supply in accordance with the needs and the discharge pressure to process. The LPG tank can be replaced with a liquid fuel such as kerosene or diesel fuel or other gases.
- The Industrial blower is required when using air as an oxidant or when using oxygen as an oxidant to cool the inner wall of flint.

#### 3.1.2. The Controls

SKID consists of the pressure regulator, the regulator discharge of fuel and oxidizer. The tool becomes complex because it comes with a safety system at the time of use. Control devices purchased and then assembled themselves in order to guarantee the safety of the system.

Electrical logic controller to regulate the working order of each process in accordance with the wishes of the researchers. This tool also regulates workplace safety system.

### 3.1.3. Combustion chamber.

- Combustion chamber made of steel pipe diameter of 1000 mm and a length of 2000 mm on the outside and on the inside of the castable. Castable type C-18 is required to work until the temperature 1800°C.
- The bodies later combustion chamber installed 10 sets of temperature sensors to determine the spread of heat occurs in the combustion chamber.

### 3.1.4. Fuels (burner).

- Installed a burner to create combustion. Burner split model, spare parts designed and built himself. Burner is not sold in the market.

### 3.2. Research Methods

Combustion method was used in this research in accordance with Table 1 above, the observations attached Table 2, 3 and 4 are referred to the following reaction:

1. Heavy oil combustion air.
2. Heavy oil combustion with oxygen.
3. Burning natural gas to oxygen

Table 2. The reaction of heavy oil combustion with air as an oxidant

HEAVY OIL		Cold air		1 KMOL		22.4 M3								
1-KG diesel oil =	0.85 liters					ALUNDO-APPLICATION-STY-0501								
Ch.comp.	%	Diesel oil Kg	100 kg mol-weight	Kmol	calorific value min. max. kcal/kg kcal/kg		chemical reaction with oxygen							
C	85.6	85.6	12	7.1333			1 C + 1 O2 = 1 CO2							
H2	10.5	10.5	2	5.2500			1 H2 + 0.5 O2 = 1 H2O							
S	0.7	0.7	32	0.0219			1 S + 1 O2 = 1 SO2							
O2	0.5	0.5	32	0.0156										
H2S	0		34	0.0000			1 H2S + 1.5 O2 = 1 H2O + 1 SO2							
N2	0.7	0.7	28	0.0250										
H2O	2	2	18	0.1111										
CO	0	0	28	0.0000			1 CO + 0.5 O2 = 1 CO2							
CxHy	0	0	0	0.0000										
CO2	0	0	44	0.0000										
Total	100	100		12.55694										
$Q = 4.187 \{ 81 X C + 300 X H - 26 ( O - S ) - 6 ( H2O - 9 X H ) \}$				KJ/KG										
				Q MIN :		44565.59 KJ/KG	KJ							
						10646.72 KCAL/KG	Kcal							
						12525.55 KCAL/L	0.2389							
Diesel oil 100 kg		AIR = 20.5 % O2 + 79.5 % N2				FLUE GAS COMPOSITION, M <sup>3</sup>								
Ch.comp.	%	Kg	Mol.W	Kmol	O2	N2	AIR	CO2	H2O	SO2	O2	N2	TOTAL	
					KMOL	KMOL	M3							
C	85.6	85.6	12	7.1333	7.1333	27.6634	34.7967	779.447	159.79	0.00	0.00	0.00	619.66	779.45
H2	10.5	10.5	2	5.2500	2.6250	10.1799	12.8049	286.829	0.00	117.60	0.00	0.00	228.03	345.63
S	0.7	0.7	32	0.0219	0.0219	0.085	0.1067	2.390	0.00	0.00	0.49	0.00	1.90	2.39
O2	0.5	0.5	32	0.0156	0.0000	0.0000	0.0000	0.000	0.00	0.00	0.00	0.35	0.00	0.35
H2S	0	0	34	0.0000	0.0000	0.0000	0.0000	0.000	0.00	0.00	0.00	0.00	0.00	0.00
N2	0.7	0.7	28	0.0250	0.0000	0.0000	0.0000	0.000	0.00	0.00	0.00	0.00	0.56	0.56
H2O	2	2	18	0.1111	0.0000	0.0000	0.0000	0.000	0.00	2.49	0.00	0.00	0.00	2.49
CO	0	0	28	0.0000	0.0000	0.0000	0.0000	0.000	0.00	0.00	0.00	0.00	0.00	0.00
CxHy	0	0	0	0.0000	0.0000	0.0000	0.0000	0.000	0.00	0.00	0.00	0.00	0.00	0.00
CO2	0	0	44	0.0000	0.0000	0.0000	0.0000	0.000	0.00	0.00	0.00	0.00	0.00	0.00
Total	100	100		12.5569	9.7802	37.9281	47.7083	1068.667	159.79	120.09	0.49	0.35	850.15	1130.87
%					20.5	79.5			14.13	10.62	0.04	0.03	75.18	100.00
				Initial temperatur °C				30	→ 1,550 °C end temperatur					
				Spec.heat Cp				cal/C/L	0.5578	0.4425	0.5440	0.6530	0.3449	
				FLUE GAS ENERGY				kcal/kg	1354.76	807.72	4.05	3.47	4456.89	6626.90
													2170.00	
				% pengurangan %N2		%N2.red.		Air - %	O2-%add	Q <sub>N</sub> - losses	%-losses	New-heat		
				0		0		100.00	0.00	4453.96	41.83	10,646.72		
				10		10		90.00	2.05	4008.56	37.65	11,092.12		
				20		20		80.00	4.10	3206.85	30.12	11,893.83		
				30		30		70.00	6.15	2244.80	21.08	12,855.88		
				50		50		50.00	10.25	1122.40	10.54	13,978.28		
				70		70		30.00	14.35	336.72	3.16	14,763.96		
				90		90		10.00	18.45	33.67	0.32	15,067.01		
				100		100		0.00	20.50	0.00	0.00	15,100.68		
								heat-increased %				41.83		

Table 3 heavy oil combustion reaction with oxygen as oxidant

HEAVY OIL																			
1-KG diesel oil =		0.85 liters		Oxygen		1 KMOL		22.4		M3									
ALINDO-APPLICATION-STY-05.01																			
Ch.comp.	%	Diesel oil 100 kg			calorific value		chemical reaction with oxygen												
		Kg	mol-weight	Kmol	min. kcal/kg	max. kcal/kg													
C	85.6	85.6	12	7.1333			1 C +	1 O2 =	1 CO2										
H2	10.5	10.5	2	5.2500			1 H2 +	0.5 O2 =	1 H2O										
S	0.7	0.7	32	0.0219			1 S +	1 O2 =	1 SO2										
O2	0.5	0.5	32	0.0156															
H2S	0		34	0.0000			1 H2S +	1.5 O2 =	1 H2O +	1 SO2									
N2	0.7	0.7	28	0.0250															
H2O	2	2	18	0.1111															
CO	0	0	28	0.0000			1 CO +	0.5 O2 =	1 CO2										
CxHy	0	0	0	0.0000															
CO2	0	0	44	0.0000															
Total	100	100		12.55694															
$Q = 4.187 \{ 81 X C + 300 X H - 26 ( O - S ) - 6 ( H2O - 9 X H ) \}$																			
KJ/KG																			
Q MIN : 44565.59 KJ/KG																			
10646.72 KCAL/KG																			
12525.55 KCAL/L																			
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 10%;"></td> <td style="width: 10%; text-align: center;">KJ</td> <td style="width: 10%; text-align: center;">Kcal</td> </tr> <tr> <td style="text-align: center;">1</td> <td style="text-align: center;">1</td> <td style="text-align: center;">0.2389</td> </tr> </table>															KJ	Kcal	1	1	0.2389
	KJ	Kcal																	
1	1	0.2389																	
Diesel oil 100 kg		AIR = 20.5 % O2 + 79.5 % N2				FLUE GAS COMPOSITION, M <sup>3</sup>													
Ch.comp.	%	Kg	Mol.W	Kmol	O2	N2	AIR	CO2	H2O	SO2	O2	N2	TOTAL						
					KMOL	KMOL	KMOL	M3											
C	85.6	85.6	12	7.1333	7.1333		7.1333	159.787	159.79	0.00	0.00	0.00	159.79						
H2	10.5	10.5	2	5.2500	2.6250		2.6250	58.800	0.00	117.60	0.00	0.00	117.60						
S	0.7	0.7	32	0.0219	0.0219		0.0219	0.490	0.00	0.00	0.49	0.00	0.49						
O2	0.5	0.5	32	0.0156	0.0000		0.0000	0.000	0.00	0.00	0.00	0.35	0.35						
H2S	0	0	34	0.0000	0.0000		0.0000	0.000	0.00	0.00	0.00	0.00	0.00						
N2	0.7	0.7	28	0.0250	0.0000		0.0000	0.000	0.00	0.00	0.00	0.56	0.56						
H2O	2	2	18	0.1111	0.0000		0.0000	0.000	0.00	2.49	0.00	0.00	2.49						
CO	0	0	28	0.0000	0.0000		0.0000	0.000	0.00	0.00	0.00	0.00	0.00						
CxHy	0	0	0	0.0000	0.0000		0.0000	0.000	0.00	0.00	0.00	0.00	0.00						
CO2	0	0	44	0.0000	0.0000		0.0000	0.000	0.00	0.00	0.00	0.00	0.00						
Total	100	100		12.5569	9.7802		9.7802	219.0767	159.79	120.09	0.49	0.35	281.28						
					20.5	79.5													
					Initial temperatur °C				1,550 °C end temperatur										
					30														
					Spec.heat Cp														
					FLUE GAS ENERGY kcal/kg														
									1354.76	807.72	4.05	3.47	2.94	2172.94					

Table 4. Natural gas combustion reaction with oxygen as oxidant

NATURAL GAS											
Cold air Cirebon								1 kcal=		3.9683 BTU	
								1 m3=		35.2113 scf	
Chemical composition:		calorific value		chemical reaction							
%		kcal/m3	kcal/m3								
CH4	94.70%	8599	9542	1 CH4 +	2 O2 =	1 CO2 +	2 H2O				
C2H6	1.50%	15303	16718	1 C2H6 +	3.5 O2 =	2 CO2 +	3 H2O				
C3H8	0.60%	21907	23794	1 C3H8 +	4 O2 =	3 CO2 +	2 H2O				
C4H10	0.90%	28493	30851	1 C4H10 +	6.5 O2 =	4 CO2 +	5 H2O				
C5H12	0.00%	35069	37900	1 C5H12 +	8 O2 =	5 CO2 +	6 H2O				
C6H14	0.00%	41656	44958	1 C6H14 +	9.5 O2 =	6 CO2 +	7 H2O				
N2	0.50%	0									
CO2	0.66%	0									
H2	0.90%	2581	3052	2 H2 +	1 O2 =	2 H2O					
H2S	0%	5600	6100	1 H2S +	1.5 O2 =	1 H2O +	1 SO2				
C	0%	8137	8137	1 C +	1 O2 =	1 CO2					
S	0%	2216	2216	1 S +	1 O2 =	1 SO2					
CO	0.24%	3022	3022	2 CO +	1 O2 =	2 CO2					
<b>Q = Qco.%CO + QH2.%H2 + QCH.%CH</b>				<b>Q mim</b>		8795.40	kcal/m3	<b>Qmax</b>		9714.72	kcal/m3
ref. heat of combustion 3-155		PERRY'S				34902.78	BTU/m3			38550.92	BTU/m3
						991.24	BTU/scf			1094.85	BTU/scf
Fuel gas	100 m3	M <sup>3</sup>				FLUE GAS COMPOSITION					M3
comp.	% m3	O <sub>2</sub>	N <sub>2</sub>	AIR	CO <sub>2</sub>	H <sub>2</sub> O	O <sub>2</sub>	N <sub>2</sub>	SO <sub>2</sub>	TOTAL	
CH4	94.70%	94.7	189.40	734.50	923.90	94.70	189.40	0.00	734.50	0.00	1018.60
C2H6	1.50%	1.50	5.25	20.36	25.61	3.00	4.50	0.00	20.36	0.00	27.86
C3H8	0.60%	0.6	2.40	9.31	11.71	1.80	1.20	0.00	9.31	0.00	12.31
C4H10	0.90%	0.9	5.85	22.69	28.54	3.60	4.50	0.00	22.69	0.00	30.79
C5H12	0.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C6H14	0.00%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2	0.50%	0.50				0.00	0.00	0.00	0.50	0.00	0.50
CO2	0.66%	0.66				0.66	0.00	0.00	0.00	0.00	0.66
H2	0.90%	0.90	0.45	1.75	2.20	0.00	0.90	0.00	1.75	0.00	2.65
H2S	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C	0%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO	0.24%	0.24	0.12	0.47	0.59	0.24	0.00	0.00	0.47	0.00	0.71
<b>Total</b>	<b>100.00%</b>	<b>100.00</b>	<b>203.47</b>	<b>789.07</b>	<b>992.54</b>	<b>104.00</b>	<b>200.50</b>	<b>0.00</b>	<b>789.57</b>	<b>0</b>	<b>1094.07</b>
			20.50%	79.5%	100.00%	9.51%	18.33%	0.00%	72.17%	0.00%	100.00%
Initial temperatur °C		30		→ 1,550 °C end temperatur							
Spec.heat Cp		cal/C/L	0.5578	0.4425	0.6530	0.3449	0.5440				
FLUE GAS ENERGY		kcal/m3	881.77	1348.56	0.00	4139.29	0.00	6369.62			
% pengurangan N2		N2-%red.		Air - %	O <sub>2</sub> -%.add	Q <sub>N</sub> -losses	%-losses	New-heat			
		0		100.00	0.00	4136.67	42.58	9,714.72			
		10		90.00	2.05	3723.00	38.32	10,128.39			
		20		80.00	4.10	2978.40	30.66	10,872.99			
		30		70.00	6.15	2084.88	21.46	11,766.51			
		50		50.00	10.25	1042.44	10.73	12,808.95			
		70		30.00	14.35	312.73	3.22	13,538.65			
		90		10.00	18.45	31.27	0.32	13,820.11			
		100		0.00	20.50	0.00	0.00	13,851.39			
				heat-increased %		42.58					

#### 4. CONCLUSION

1. Exhaust emissions of pollutants can be controlled by regulating the amount of oxygen used in the process (at least 4% oxygen in the exhaust gas).
2. The fuel savings achieved between 20-25%.
3. The amount of fuel depending on the working temperature, the type of kitchen that is used and the type of fuel used.

## **5. REFERENCES**

- [1] W.Braker and A.L.Mossman Matteson ,”Gas Data book Sixth edition”, D.S.M.Products USA Inc.1980.
- [2] Oxygen Material Safety Data Sheet AL-France
- [3] Material Compatability, Prax-air USA
- [4] Perry, “Chemical Engineers Handbook Sixth Edition,1984.
- [5] “Oxygen Safe-work”, AL – France.
- [6] “Oxygen Pipe Line Consultance”, AL – France.
- [7] B.A.Krivandin & B.L.Markov, “ Industrial Fur- nace”, Metalurgi-Moscow 1987.
- [8] M.A. Kacenko,” Heating device for metal industry, Mashgis-machinebuild.Moscow 1962.
- [9] Robert C. Reid, T.K. Sherwood, “Sifat Gas dan Zat Cair”, Gramedia 1991.
- [10] Pedoman Keselamatan Kerja untuk Gas APGI – 1992.
- [11] Refractory Catalogue product specification P.T.Indoporlent 2005.
- [12] Ir.Djokosetyardjo ,”Ketel uap”, Pradnya Paramita 1987.
- [13] Mohd.Taib Sutan Sati,” Buku Polyteknik”, C.V..Mandar Maju Bandung 1999.
- [14] Metal Handbook 8<sup>th</sup> edition vol.5 Forging and Casting, American Society for Metal 1970.
- [15] Metal Handbook 9<sup>th</sup> edition vol.2. Nonferrous and Pure Metal. American Society for Metal 1979.
- [16] Metal Handbook 9<sup>th</sup> edition vol.15. Casting. American Society for Metal 1988

## The Phenomena of Dinamic Cyclic Trend to Cement-Fly ash Smart Concrete Compressive Strength and Resistivity in Various Composition of Polymer Carbon Fiber

Yulinda Lestari<sup>a</sup>, Setyo Hardono<sup>b</sup>, Gilang Ramadhan<sup>a</sup>, Ari Yustisia Akbar<sup>a</sup>,  
Eni Sugiarti<sup>c</sup>

<sup>a</sup>Research Center for Metallurgy  
Indonesian Institute of Sciences, Puspiptek Serpong 15314  
Email: yulinda.lestari17@gmail.com, setyo\_hardono@yahoo.com, gilram\_curup@yahoo.com

<sup>b</sup>Research Center for roads and bridge  
Ministry of Public Work, Bandung  
Email: ari\_yst@yahoo.com

<sup>c</sup>Research Center for Physics  
Indonesian Institute of Sciences, Puspiptek Serpong 15314  
Email: eni\_ayumi@yahoo.com

### ABSTRACT

Smart concrete is an innovative material because it can serve as a sensor without any additional sensors in it. It is reinforced with carbon fiber that has gone through the pyrolysis process at high temperature to produce carbon content above 90%. The carbon fiber used in this study was Polyacrylonitrile. The working principle of carbon fiber sensor works piezoresistivity that respond to changes in mechanical (stress and strain) to electrical impulses. The resistivity changes that will be converted into units of load on the display circuit system. Key to success of this research was the concrete formulations and systems were sensitive and accurate readings so that any small change in resistivity could be directly detected. Variations in carbon fiber were added to the 0-1% by weight of cement with interval 0.5. Fly ash was added as a filler to reduce the use of cement. Results obtained from dynamic cyclic testing showed that the compressive strength was the best in the concrete without carbon fiber, then decline in line with the increased number of carbon fiber. But inversely proportional to the resistivity of the concrete produced. Smart concrete must have a high sensitivity to changes in stress / strain, it should also meet the required concrete strength both press and flexible to avoid initial crack.

### Keywords

*Smart concrete, Carbon Fiber, Dinamis Cyclic, Resistivity, Compressive Strength*

This Paper is Published in Advanced Materials Research Journal

## Grain Growth in Millimeter Wave Sintered Alumina Ceramics

S. Mitsudo, S. Inagaki, I.N. Sudiana, K. Kuwayama

*Research Center for Development of Far Infrared Region,  
University of Fukui, Bunkyo 3-9-1, Japan  
Tel : (+81) 776278654. Fax : (+81) 776278752*

*Email: mitsudo@fir.u-fukui.ac.jp, inagaki@fir.u-fukui.ac.jp, sudiana75@yahoo.com, kuwayama@fir.u-fukui.ac.jp*

### ABSTRACT

The millimeter wave (MMW) sintering of alumina ceramic had been performed. The results revealed that MMW sintered alumina has higher density than that of conventional method on all sintering temperature. However microstructure evaluation demonstrates that grain growth of MM wave annealed alumina is faster than in conventional annealing. It indicates that MM wave enhanced mass transport and solid state reaction rates during sintering. The empirical observations of microwave enhancements have been broadly known as microwave effect. Even though no satisfactory theory existed to explain the effect but the presence the electromagnetic waves (EMW) during microwave heating is clearly the key. In this paper, microwave effect on grain growth of alumina ceramic is presented. Some effective and unique characteristics of the EMW sintering were also discussed as well.

### Keywords

*Alumina, grain distribution, millimeter-wave sintering, gyrotron, microwave effect*

This Paper is Published in Advanced Materials Research Journal

## A Study on the Structural Analysis of Novel Polyurethanes Based on N,N'-1,2-Ethanediybis-(4-Hydroxy-Pentanamide) and 4-Hydroxy-N-(2-Hydroxyethyl)-Pentanamide

Mochamad Chalid<sup>a</sup>, Hans J. Heeres<sup>b</sup>, Antonius A. Broekhuis<sup>b</sup>

<sup>a</sup>Dept of Met. and Mat. Eng., Fac. of Eng., Universitas Indonesia, 16424, Depok, Indonesia

<sup>b</sup>Dept. of Chem. Eng., Univ. of Groningen, Nijenborgh 4, 9747 AG, Groningen, The Netherlands  
Email: chalid@metal.ui.ac.id

### ABSTRACT

As versatile biomass-based diol precursors, N,N'-1,2-ethanediybis-(4-hydroxy-pentanamide) (1) and 4-hydroxy-N-(2-hydroxyethyl)-pentanamide (2) are potential monomers to synthesize novel polyurethanes through adding di-isocyanates. This study reported the structural analysis and molecular behavior of polyurethanes obtained from polymerization of the diol precursors with aliphatic and aromatic di-isocyanates (hexamethylene diisocyanate, HDI (3), and phenyl-diisocyanate, PDI (4)) in (N,N-dimethylacetamide (DMA) solvents with triethylamine (TEA) catalysts. <sup>1</sup>H-NMR, <sup>13</sup>C-NMR and Elemental Analysis confirmed structure of the polyurethanes built from both diols and di-isocyanates and FTIR indicated interaction among polyurethane molecules showed at lower wave numbers such as 2855-2976 cm<sup>-1</sup> for hydrogen-bonded –NH groups and 1621-1643 cm<sup>-1</sup> for hydrogen-bonded –C=O groups. Furthermore a study on influence of the inter- and intra-molecular hydrogen bonding on the thermal and mechanical properties of the polyurethanes would be an interesting investigation for the next study.

### Keywords

Diols, di-isocyanates, backbone structure, functional groups and hydrogen bonding.

This Paper is Published in Advanced Materials Research Journal

## Classification of Ceramic Tiles By Identifying Defect on Ceramic Tile Surface Using Local Texture Feature

**Bertalya<sup>a</sup>, Prihandoko<sup>a</sup>, Rakhma Oktavina<sup>b</sup>, Yogi Febrianto<sup>b</sup>**

<sup>a</sup>*Faculty of Computer Science and Information Technology  
Gunadarma University, Depok, 16424, Indonesia*

<sup>b</sup>*Faculty of Industrial Technology  
Gunadarma University, Depok, 16424, Indonesia*

*Email: bertalya,pri,oktavina@staff.gunadarma.ac.id, dyogi@student.gunadarma.ac.id*

### ABSTRACT

In ceramic tiles industry, the process of ceramics classification plays an important part. At present, the process of classification is carried out manually by using the human eyes observation. However, the capability of the human eyes is very limited. This condition leads to the low accuracy of the ceramic tile selection. This paper proposes a mechanism which could classify the ceramic tiles automatically using local texture feature. The result of our experiment shows a recognition rate of 76%, which means that this method can be used to classify the ceramic tiles.

### Keywords

*Ceramic tile, Classification, Defect, Texture*

This Paper is Published in Advanced Materials Research Journal

## Structural Characterization of Mullite-Based Ceramic Material from $\text{Al}_2\text{O}_3$ and Silica Xerogel Converted from Sago Waste Ash

Haji Aripin<sup>a</sup>, Seitaro Mitsudo<sup>b</sup>, Prima Endang S<sup>c</sup>, I Nyoman Sudiana<sup>d</sup>, Hikamitsu Kikuchi<sup>e</sup>, Saboru Sano<sup>f</sup>, Sliven Sabchevski<sup>g</sup>

<sup>a</sup>Faculty of Learning Teacher and Education Science, Siliwangi University, Tasikmalaya, Indonesia  
Email: aripin1967@yahoo.com

<sup>b</sup>Research Center for Development of Far Infrared Region, University of Fukui, Fukui, Japan.  
Email: mitsudo@fir.u-fukui.ac.jp

<sup>c</sup>Department of Chemistry, Faculty of Mathematics and Natural Sciences, University of Haluoleo, Kendari, Indonesia  
Email: primachem\_kdi@yahoo.com

<sup>d</sup>Department of Physics, Faculty of Mathematics and Natural Sciences, University of Haluoleo, Kendari, Indonesia  
Email: dsudiana75@yahoo.com

<sup>e</sup>Department of Applied Physics, Faculty of Engineering, University of Fukui, Fukui, Japan  
Email: kikuchi@apphy.u-fukui.ac.jp

<sup>f</sup>Ceramic Research Institute, National Institute of Advanced Industrial Science and Technology (AIST), Nagoya, Japan.  
Email: sano-saboru@aist.go.jp, gsabch@ie.bas.bg

<sup>g</sup>Lab. Plasma Physics and Engineering, Institute of Electronics of the Bulgarian Academy of Sciences, Bulgaria.  
Email: sabch@ie.bas.bg

### ABSTRACT

In this investigation, mullite ceramics were produced by mixing  $\text{Al}_2\text{O}_3$  and amorphous silica xerogel (SX) extracted from sago waste ash. The composition was prepared by adding an amount from 0 to 80 mol% of  $\text{Al}_2\text{O}_3$  into SX. The samples were dry pressed and sintered in the temperature range between 900°C and 1200°C. Their properties have been characterized on the basis of the experimental data obtained using thermal analysis (DSC/TGA, X-ray diffraction and scanning electron microscopy (SEM)). The results show that two major differences become obvious when comparing the samples loaded by the smaller and larger amount of  $\text{Al}_2\text{O}_3$ . First, cristobalite formation is retarded in the sample loaded by the larger amount of  $\text{Al}_2\text{O}_3$ . Second, at 1200°C, the observed volume fraction of mullite is higher in the sample loaded by the larger amount of  $\text{Al}_2\text{O}_3$ . The DSC analysis indicates that the mullite crystallization takes place at 1200°C for 60 mol%  $\text{Al}_2\text{O}_3$  loaded SX sample as confirmed by the XRD pattern. It was found that there was not a complete reaction of mullitization for sample sintered up to 1200°C.

### Keywords

Mullite ceramic,  $\text{Al}_2\text{O}_3$ , amorphous silica xerogel, sago waste ash, sintering temperature, thermal analysis, X-ray methods

This Paper is Published in Advanced Materials Research Journal

## **Correlation of Normal Incidence Sound Absorption Coefficient (NAC) and Random Incidence Sound Absorption Coefficient (RAC) of Polyester/Ramie Fibre Composite Materials**

**Mohammad Farid and Tri Heriyanto**

*Department of Materials and Metallurgical Engineering  
Institut Teknologi Sepuluh Nopember (ITS), Surabaya 60111, Indonesia  
Email: faredo09@yahoo.com, material@its.ac.id*

### **ABSTRACT**

The acoustical properties of polyester/ramie fibre composite materials that was applied as a sound absorbing material is discussed in this paper. The aim was to determine the correlation between Normal Incidence Sound Absorption Coefficient (NAC) and Random Incidence Sound Absorption Coefficient (RAC) of the fibre composites. The acoustic measurement with Impedance Tube Kit followed the ASTM 1986 E – 1050 – 98 standard. The portion of the ramie fibre was modified with fibre length varied from 0.25 cm, 1 cm to 1.5 cm but at a constant fibre diameter. A constant volume fraction of fibre 20 % was used. The Beavers method was applied to characterize the fibre's diameter. Results indicated that the sound absorption performance of the composite fibre can reach as high as 99% at frequency of 1225 Hz at aspect ratio of 42. A correlation between NAC and RAC was presented based on a quantitative result.

### **Keywords**

*Composite, polyester, ramie, fibre, acoustic*

This Paper is Published in Advanced Materials Research Journal

## Electroless Plating of Al<sub>2</sub>O<sub>3</sub> Particles Reinforced Composites

Anne Zulfia and Andika Insan Adyatma

*Department of Metallurgy and Materials, Faculty of Engineering, University of Indonesia,  
Kampus Baru Universitas Indonesia, Depok 16424, Indonesia  
Email : anne@metal.ui.ac.id*

### ABSTRACT

Electroless plating is one method to coat Al<sub>2</sub>O<sub>3</sub> particles reinforced. This process has been carried out to coat Al<sub>2</sub>O<sub>3</sub> with electrolyte solution which content of nitride acid (HNO<sub>3</sub>), Al and Mg powders. The metal oxide layer of spinel phase (MgAl<sub>2</sub>O<sub>4</sub>) is formed on the surface of Al<sub>2</sub>O<sub>3</sub> which can improve wettability of Al<sub>2</sub>O<sub>3</sub>. The addition of Mg powder into solution was various from 0.002 to 0.012 mol while Al powder was kept constant i.e. 0.018 mol. The effect of Mg on formation of metal oxide layer on Al<sub>2</sub>O<sub>3</sub> particles have been studied. It is found that the addition of 0.004 mol of Mg generated homogeneous thin spinel layer (MgAl<sub>2</sub>O<sub>4</sub>) on the surface of Al<sub>2</sub>O<sub>3</sub> particles. This condition was applied to form spinel layer on Al<sub>2</sub>O<sub>3</sub> particles reinforced for making Aluminium Matrix Composites (AMC) with 12.5Vf% of Al<sub>2</sub>O<sub>3</sub> particles reinforced. It is found that tensile strength and hardness as well as wear resistance of AMC has been improved compare to unreinforced.

### Keywords

*Metal oxide coating, Al<sub>2</sub>O<sub>3</sub> particles, electroless plating.*

This Paper is Published in Advanced Materials Research Journal

# Crystal Structures and Thermal Properties of Composite Brake Friction Materials Fabricated of Glass and Metal Wastes with Reinforcement of Bambo Nano Fibers

**Sutikno, Sukiswo Supeni Edi, and Dany Sigit Saputra**

*Department of Physics, Faculty of Mathematics and Natural Sciences,  
Semarang State University, D7 Building, 2nd Floor, Sekaran Campus, Unnes, Gunungpati, Semarang,  
Republic of Indonesia, 50229  
Email: smadnasri@yahoo.com*

## ABSTRACT

In Indonesia, a lot of wastes of glasses and metals have potency to be one of brake raw materials. For example, little bottles of used food packages are usually directly thrown into environment. The scraps of metal machining wastes are usually collected to be manufactured into other products. In this research, both wastes are used as fillers for brake friction materials, the effects of them on the thermal properties are studied in details. The glass wastes are crushed, grinded and filtered to simplify the mixing process with other raw materials when the fabrication of brake fiction materials done. During fabrication, samples are cured at 190°C for 3 hours. The samples are characterized using x-ray diffractometer and thermogravimetric analysis. Based on these characterizations, the increase of glass powders content plays role in increasing the percentage of crystallinities. This is suspected the glass used as ingredient of friction material has crystalline structure. The glass waste quantity does not influence significantly on the thermal properties. During heating up to 1200°C, the mass loss occurs due to epoxy, bamboo fiber and styrene butadiene rubber decompose. The optimum composition is found at sample B2, a sample with lowest total mass loss (2 mg).

### Keywords

*Glass; metal, friction material, crystallin, thermal properties*

This Paper is Published in Advanced Materials Research Journal

## Synthesis of Highly-Ordered TiO<sub>2</sub> through CO<sub>2</sub> Supercritical Extraction for Dye-Sensitized Solar Cell Application

Bambang Priyono<sup>a</sup>, Akhmad Herman Yuwono<sup>a</sup>, B. Munir<sup>a</sup>, A. Rahman<sup>a</sup>, A. Maulana<sup>a</sup>, H. Abimanyu<sup>b</sup>

<sup>a</sup>Department of Metallurgy and Materials Engineering, Faculty of Engineering, Universitas Indonesia, Depok-Jawa Barat, Indonesia

<sup>b</sup>Research Center for Chemistry, Indonesia Institute of Sciences (LIPI), PUSPIPTEK, Serpong-Banten, Indonesia  
Email: bambang.priyono@ui.ac.id, bahyuwono@metal.ui.ac.id

### ABSTRACT

Dye-sensitized solar cell (DSSC) is one of the very promising alternative renewable energy sources to anticipate the diminishing in the fossil fuel reserves in the next few decades and to make use of the abundance of intensive sunlight energy in tropical countries like Indonesia. TiO<sub>2</sub> nanoparticles have been used as the photo electrode in DSSC because of its high surface area and allow the adsorption of a large number of dye molecules. In the present study, TiO<sub>2</sub> aerogel have been synthesized via sol-gel process with water to inorganic precursor ratio ( $R_w$ ) of 2.00, followed with subsequent drying by CO<sub>2</sub> supercritical extraction (SCE). As comparison, the TiO<sub>2</sub> xerogel was also prepared by conventional drying and annealing. Both types of gels were subjected to conventional and multi-step annealing. The resulting nanoparticles in aerogel and xerogel have a band-gap energy of 3.10 and 3.04 eV, respectively. The open circuit voltage ( $V_{oc}$ ) measurement reveals that the DSSC fabricated with aerogel provided a higher voltage (21,40 mV) than xerogel (1,10 mV).

### Keywords

Super critical extraction, TiO<sub>2</sub> aerogel, xerogel, dye sensitized solar cell, multi-step calcination

This Paper is Published in Advanced Materials Research Journal

## Improvement of Stress Corrosion Resistance in Aluminum Alloy 7075 through Retrogression and Re-aging Modification

Enung Nurlia, Sunara Purwadaria

Faculty of Mining and Petroleum Engineering  
Institute Technology Bandung  
Tel: (022) 25022399. Fax: (022)2504209 Indonesia  
Email: enung.nurlia@yahoo.com, sunara\_p@yahoo.com

### ABSTRACT

So far, application of RRA (Retrogression and Re-aging) heat treatment in improving SSC (stress corrosion cracking) resistance of aluminum alloy 7075 is limited to thin samples as it is constrained by short retrogression time at high temperature. The aim of this research is to obtain thick aluminum alloy 7075 plate with good SCC resistance through RRA modification. In RRA modification, the retrogressed alloy samples were rolled at three different temperatures (27° C, 120° C, and 180° C) and at three different thickness reductions (10%, 15%, and 20%) followed by re-aging at 120° C for 16 hours. SCC resistance was determined from time to failure ( $t_f$ ) at fixed loading at 0.8 yield strength of material in test solution of 3 wt % NaCl at pH 4. The sample with longest time to failure is referred to as the most SCC-resistant. Generally, modified RRA alloy has better SCC resistance compared to T6 alloy and conventional RRA alloy. Highest SSC resistance was found at three conditions, namely 27° C-20% reduction, 27° C-15% reduction, and 180° C-20% reduction). Micro-structurally, these conditions produce large precipitates with wider space in grain boundaries. Around grain boundaries, they also produce smaller intermetallic particles with broader distribution.

### Keywords

Aluminum alloy 7075, RRA modification, intermetallic particle, microstructure.

This Paper is Published in Advanced Materials Research Journal

## Behavior of CO<sub>2</sub> Corrosion of API 5L X52 Steel in NaCl Solution Under Turbulent Flow Condition

Andi Rustandi, Nitiyoga Pandyo, Tezar Nurhamzah, Nur Aziz

*Department of Metallurgy and Materials  
Faculty of Engineering Universitas Indonesia, Depok 16424  
Email: rustandi@metal.ui.ac.id*

### ABSTRACT

The presence of carbon dioxide (CO<sub>2</sub>) and water in the fluid can cause severe internal corrosion in the pipelines. This study aims to observe corrosion behavior during the changes in flow rate and acidity conditions in order to obtain the relationship between the parameters by the measured corrosion rate. Corrosion rate measurements were performed for API 5L X52 steel material by using polarization method in 3.5% NaCl solution with saturated CO<sub>2</sub> injection. Solution with different acidity were applied which has pH 4, 5, and 6 respectively. To simulate the flow rate, a Rotating Cylinder Electrode RCE was used at various rotation rates 0, 375, 750, 1500, and 3000 rpm, at room temperature (25°C) and atmospheric pressure. Based on testing results, the changes in rotation converted to flow rate showed that the corrosion mechanism of API 5L X52 steel in NaCl solution with saturated CO<sub>2</sub> content was mainly controlled by mass transport at pH=4 whereas chemically controlled involved both at pH=5 and pH=6 conditions.

### Keywords

*CO<sub>2</sub> corrosion, carbon steel, turbulent, transport mass, wall shear stress*

This Paper is Published in Advanced Materials Research Journal

## Hot Corrosion of Aluminized 1020 Steel with NaCl Deposit

Mohammad Badaruddin and Sugiyanto

*Mechanical Engineering Department-University of Lampung  
Jalan Prof. Brojonegoro No. 1 Bandar Lampung 35145, Indonesia  
Tel: +62721-3555519, Fax: +62721-704947  
Email:mbruddin@unila.ac.id, sugi@unila.ac.id*

### ABSTRACT

The oxidation of hot-dip aluminized AISI 1020 steel coated with NaCl in static air at 700 °C for a duration of time 49 h was studied by employing thermogravimetry, Scanning Electron Microscopy (SEM), Electron Dispersive Spectroscopy (EDS) and X-ray Diffraction (XRD) analysis. It was found that NaCl deposits markedly accelerated the oxidation of the AISI 1020 steel. The aluminide coating on the bare steel gives the best oxidation protection by forming continuous alumina scale ( $\text{Al}_2\text{O}_3$ ). The degradation of aluminide layer and alumina scale on the steel are associated by chloridation/oxidation cyclic reactions. In addition, the released chlorine will be as catalytic actions and leads to the formation of loose  $\text{Al}_2\text{O}_3$  during corrosion.

### Keywords

*AISI 1020 steel, aluminum coating, NaCl deposit, alumina scale, oxychloridation*

This Paper is Published in Advanced Materials Research Journal

# Tafel Polarization Evaluation of Myrmecodia Pendans Extract as Eco-Friendly Corrosion Inhibitor for Material API 5L Grade B in 3,5% NaCl Solution

Atria Pradityana<sup>a</sup>, Sulistijono<sup>b</sup>, Abdullah Shahab<sup>a</sup>

<sup>a</sup>Mechanical Engineering Dept., Faculty of Industrial Technology  
Institut Teknologi Sepuluh Nopember, Surabaya  
E-mail : atria2007@me.its.ac.id

<sup>b</sup>Metallurgical and Materials Engineering Dept., Faculty of Industrial Technology  
Institut Teknologi Sepuluh Nopember, Surabaya  
E-mail : ssulistijono@mat-eng.its.ac.id

## ABSTRACT

The main objective of this research is to investigate the effectiveness of Myrmecodia Pendans (MP) wood extract on corrosion of material API 5L Grade B in 3,5% NaCl solution using potentiodynamic polarization curve, Gas Chromatography-Mass Spectrometer (GC-MS) and Electrochemical Impedance spectroscopy (EIS). MP usually called as sarang semut in Indonesia. We analyzed MP in different concentration of extract. There are 500, 1000, 1500, 2000 and 2500 ppm. The experiment was started by extraction of the MP. According to the polarization potentiodynamic data, the rate corrosion could be decrease about 90,36% on concentration 500 ppm. It means MP extract could serve as an effective inhibitor for the corrosion. This is consistent with the initial hypothesis that MP contains antioxidant compounds that can inhibit oxidation thereby reducing the corrosion rate.

## Keywords

*Eco-friendly corrosion inhibitor, Myrmecodia Pendans, API 5 L Grade B, 3,5% NaCl solution*

This Paper is Published in Advanced Materials Research Journal

## High Temperature Oxidation Behavior of Co-based Coating at 800 °C as Alternative Coating Material for SOFC Interconnect

Asep Ridwan Setiawan and Rochim Suratman

Research Groups of Material Science and Engineering,  
Faculty of Mechanical and Aerospace Engineering, Institute of Technology Bandung,  
Jl. Ganesha No. 10 Bandung 40132, Indonesia  
Phone: (022) 2508411 Fax: (022) 2508411  
Email: asepridwans@material.itb.ac.id, rochim@material.itb.ac.id

### ABSTRACT

Cobalt based oxide are promising as coating material for solid oxide fuel cell interconnect due to their high oxidation resistance and conductivity. In this report, Co-based coating layer was deposited on AISI 430 ferritic stainless steel substrate using thermal spray methods. The high temperature oxidation behavior of Co-based coating was studied in air atmosphere at 800 °C. Optical and SEM observation shows that the total thickness of Co-based layer was about 100-120 µm. The coatings were mainly growth by the melted particles impacting on the substrate that flatten to form splats which later on piled on top of the others. Phase identification by XRD showed that the coating layer contained  $\text{Co}_3\text{O}_4$ , and NiO oxides. EDS analysis indicated that the coating layer were sufficient to prevents the formation and the growth of  $\text{Cr}_2\text{O}_3$  scale. The Co-based coating shows relatively a large mass gain during oxidation compared to the uncoated steel, with parabolic rate constant,  $K_p = 4 \times 10^{-15} \text{ gr}^2 \cdot \text{mm}^{-4} \cdot \text{ks}^{-1}$ .

### Keywords

SOFC,  $\text{Cr}_2\text{O}_3$ , XRD, Thermal spray, Oxide.

This Paper is Published in Advanced Materials Research Journal

## Influence of Hot Dip Galvanizing Layer to Cleavage Failure of AISI 4140 Bolt for Padeye Fixing in Marine Environment

Badrul Munir<sup>a,b</sup>, Suryadi<sup>a,b</sup> and Bintang Suryo<sup>b</sup>

<sup>a</sup>Department of Metallurgy and Materials Engineering, Universitas Indonesia, Depok, 16424  
E-mail: bmunir@ui.ac.id

<sup>b</sup>Center for Materials Processing and Failure Analysis (CMPFA)  
Department of Metallurgy and Materials Engineering, Universitas Indonesia, Depok, 16424

### ABSTRACT

A high strength bolt with hot dip galvanizing treatment failed shortly after being installed for two days on padeye of a mooring dolphin. The bolt was installed with increasing stress on the second day in which the value was nearly twice. Investigation results showed the bolt fractured with the nut head separated from the pin. Corroded fracture surface with brittle characteristic and no plastic deformation observed dominating the failed area. Characterization of hardness and chemical composition followed with microstructure and fractography observation on the fracture surface then conducted in order to analyze the reason for this brittle fracture occurrence. Results indicate that, while the bolt conforms to the material specification in term of chemical composition, the hardness value was high. The microstructure observation reveals a transgranular crack propagation and cleavage failure occurred. The cleavage failure was clearly observed under fractography observation using scanning electron microscope. Failed galvanize layer due to mechanical failure becomes preferential site for hydrogen evolution in marine environment, which leads to hydrogen diffusion into the matrix, thus results in hardness increase. The increasing stress during installation become detrimental to the bolt and facilitate the hydrogen induce cracking. Detrimental effect of hot dip galvanize layer is pointed out in the application of high strength material in marine environment.

### Keywords

*Failure analysis, bolt, hot dip galvanizing, cleavage, hydrogen embrittlement*

This Paper is Published in Advanced Materials Research Journal

## Corrosion Inhibitor Performance with presence of $\text{FeCO}_3$ film in $\text{CO}_2$ Corrosion Environment under Fluid Flow Effect

Sarini Mat Yaakob<sup>a</sup>, Mokhtar Che Ismail<sup>b</sup>

<sup>a</sup>Department of Mechanical Engineering, Universiti Teknologi Petronas, Malaysia  
E-mail : sarinimatyaakob@yahoo.com

<sup>a</sup>Department of Mechanical Engineering, Universiti Teknologi Petronas, Malaysia  
E-mail : mokhtis@petronas.com.my

### ABSTRACT

Corrosion due to carbon dioxide ( $\text{CO}_2$ ) has a major impact on the oil and gas industry by severely affecting production and process facilities. One of the most economic methods to prevent the corrosion of piping and plants is the application of corrosion inhibitors. The presences of corrosion product such as iron carbonate ( $\text{FeCO}_3$ ) film may affect to the performance of corrosion inhibitor. In addition to that, fluid flow effect in pipeline may also influence the performance of corrosion inhibitor. Thus, the present work is conducted to study the effect of  $\text{FeCO}_3$  film to the performance of corrosion inhibitor under fluid flow effect. The experiments were done in glass cells at  $80^\circ\text{C}$ . The hydrodynamic condition experiment was simulated using rotating cylinder electrode (RCE). Corrosion inhibitor was added at two different concentrations in the iron carbonate film formation. A corrosion rates were measured by linear polarization resistance (LPR) method. The film was later analyzed using scanning electron microscopy (SEM). It was found that a better corrosion protection is still offered by corrosion inhibitor even with presence of  $\text{FeCO}_3$  film. A synergistic effect is offered by these two films of corrosion inhibitor and  $\text{FeCO}$  in reducing corrosion rate.

### Keywords

$\text{CO}_2$  corrosion, corrosion inhibitor,  $\text{FeCO}_3$  film, rotating cylinder electrode (RCE)

This Paper is Published in Advanced Materials Research Journal

## Effect of CaO Dopant on The Dielectric Properties of NiO

Sharifah Aishah Syed Salim<sup>a</sup>, Julie Juliewatty Mohamed<sup>b</sup>, Zainal Arifin Ahmad<sup>c</sup>

*School of Materials and Mineral Resources Engineering Campus,  
Universiti Sains Malaysia, 14300 Nibong Tebal, Penang, Malaysia.  
Email: shaishahss88@gmail.com, srjuliewatty@eng.usm.my, Zainal@eng.usm.my.*

### ABSTRACT

$\text{Ca}_x\text{Ni}_{1-x}\text{O}$  was prepared by conventional solid state reaction. The properties of undoped and CaO doped NiO ceramics have been studied. The raw mixture of CaO and NiO were ball milled for 24 hours. The samples were calcined at 1000°C for 2 hours, pressed into pellet shape at 200 MPa and sintered at 1300°C for 4 hours. The sintered samples were subjected to XRD, Scanning Electron Microscopy (SEM) and Impedance Analyzer for phase identification, microstructural observation and dielectric analysis. The grains size becomes larger with the increment of dopant amount. Enhanced dielectric constant was observed for all Ca doped NiO at the frequency range from 100 Hz to 1 MHz. The dielectric constant of sintered  $\text{Ca}_x\text{Ni}_{1-x}\text{O}$  decreased with an increasing frequency. The result indicates that Ca ions have effectively changed the properties of NiO.

### Keywords

*Ca-doped NiO, XRD, SEM, dielectric*

This Paper is Published in Advanced Materials Research Journal

## Plasmonic Photocatalyst Ag/AgCl Nanohybrids on Titanate Thin Film for Photocatalytic Application

Yuxin Tang, Zhong Chen, and Zhili Dong

*School of Materials Science & Engineering, Nanyang Technological University,  
50 Nanyang Avenue, Singapore 639798, Singapore*

### ABSTRACT

Semiconductor photocatalysts have been widely used for the removal of organic compounds in waste water using solar energy in the past decades [1, 2]. An optimal photocatalytic material would have the following properties: to be able to dissociate organic molecules, to have a band gap that absorbs light in the visible range, and to remain stable in aqueous media. Besides, it should be non-toxic, abundant and easy to fabricate to a desired shape. Based on this concept, we demonstrate a novel plasmonic silver/silver chloride nanohybrid on the titanate thin film via a facile and inexpensive approach [3, 4]. The preparation is as follows: Firstly, the sodium titanate thin film was prepared via a traditional hydrothermal method at 200 °C for 6 hours. Then, by using an ion-exchange process, the Na<sup>+</sup> ions in the interlayer of titanate is replaced by Ag<sup>+</sup> ions without changing its morphology. After that, the silver titanate reacts with HCl vapor to form the AgCl particles on titanate thin films. Finally, the visible-light-driven plasmonic photocatalyst Ag/AgCl/titanate is obtained by partially reducing Ag<sup>+</sup> ions from AgCl particles with the aid of Xe lamp illumination.

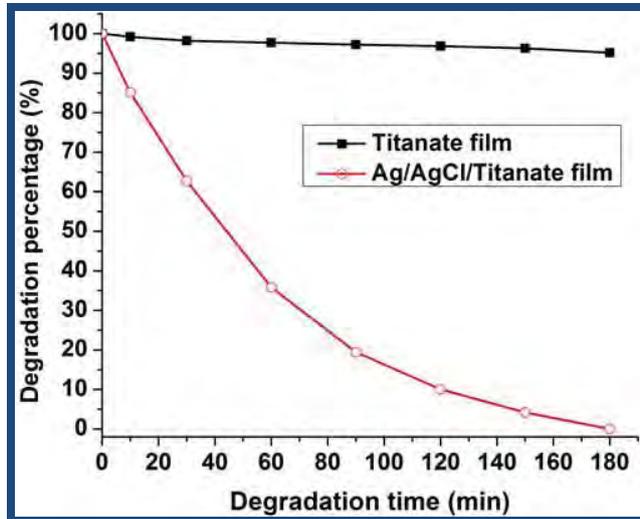
Figure 1 shows that the as-prepared Ag/AgCl/titanate film photocatalyst exhibits higher activity in the visible region of the solar spectrum for the degradation of phenol solution, while the titanate thin film shows negligible activity for the phenol removal. This room-temperature synthesis route could be easily extended to prepare various solar light responsive semiconductors via metal ion exchange and gas reaction process for photocatalytic applications.

### Acknowledgements

The authors thank Singapore Environment and Water Industry Programme Office (EWI) for the financial support (grant MEWR651/06/160).

### References

- [1] X. C. Wang, K. Maeda, A. Thomas, K. Takanebe, G. Xin, J.M. Carlsson, K. Domen, M. Antonietti, *Nat. Mater.* 8 (2009) 76-80.
- [2] X. Chen, S. S. Mao, *Chem. Rev.* 107 (2007) 2891-2959.
- [3] Y. X. Tang, V. P. Subramaniam, T. H. Lau, Y. K. Lai, D. G. Gong, P. D. Kanhere, Y. H. Cheng, Z. Chen, Z. L. Dong, *Appl. Catal. B: Environ.*, 106 (2011) 577.
- [4] Y. X. Tang, Z. L. Jiang, J. Y. Deng, D. G. Gong, Y. K. Lai, H. T. Tay, I. T. K. Joo, T. H. Lau, Z. L. Dong, Z. Chen, *ACS Appl. Mat. Interfaces*, 4(2012) 438.



**Figure 1.** Comparison of photocatalytic activity of titanate film and Ag/AgCl/titanate film samples for the photocatalytic decomposition of phenol in water under the visible light illumination. The light intensity is around  $115 \text{ mW/cm}^2$ .

## Synthesis and Characterization of Nanocrystalline TiO<sub>2</sub> by Non-Aqueous Sol Gel in Acidic Condition for Dye-sensitized Solar Cells

Lia Muliani<sup>a</sup> and Bambang Sunendar<sup>b</sup>

<sup>a</sup>Research Center for Electronics and Telecommunication - Indonesian Institute of Sciences  
(PPET-LIPI) Bandung – Indonesia  
Email: liamuliani@gmail.com

<sup>b</sup>Advance Material Processing, Physics Engineering Department – Institut Teknologi Bandung (ITB)  
Bandung - Indonesia  
Email: purwa@tf.itb.ac.id , liamuliani@gmail.com

### ABSTRACT

Nanocrystalline TiO<sub>2</sub> has been synthesized through non-aqueous sol gel using acetic acid (HOAc) and hydrochloric acid (HCl) as a catalyst. Titanium isopropoxide (TTIP) as precursor was prepared by reaction between TiCl<sub>4</sub> with isopropyl alcohol (IPA) in concentration of 0.3 M. The sol gel process employed at around 60°C using tert-butanol as solvent and HOAc was added as ligand to stabilise the reaction. Controlled hydrolysis and condensation reactions were achieved through in-taking of water molecules released from the esterification reaction of HOAc with tert-butanol. In this paper, the influence of acidic catalyst was described at the volume ratio of HOAc:HCl are 0:2 ; 1:1 and 2:0. The crystallinity and crystal phase of the samples were characterized by X-ray Diffraction and nanocrystalline TiO<sub>2</sub> with anatase phase was resulted. The morphology of the TiO<sub>2</sub> powder was analyzed by Scanning Electron Microscopy. Pore size and the BET surface area were determined by Brunauer-Emmett-Teller (BET) analysis. Nanocrystalline TiO<sub>2</sub> produced was applied for photoelectrode of dye-sensitized solar cell. The optical properties of the TiO<sub>2</sub> photoelectrodes were measured using by UV-Vis Spectrophotometer. The performance of the cell was measured using a solar simulator with light at an intensity of 50 mW/cm<sup>2</sup> generated by a xenon lamp. The best efficiency of 0.5% was achieved for active area of 0.48 cm<sup>2</sup>.

### Keywords

*Nanocrystalline TiO<sub>2</sub>, non-aqueous sol gel, acidic catalyst, dye-sensitized solar cells*

This Paper is Published in Advanced Materials Research Journal

## Physical Characteristic and Magnetic Properties of Barium Hexaferrite $\text{BaFe}_{12}\text{O}_{19}$ Derived from Mechanical Alloying

Rahmat Doni W<sup>a</sup>, A. Manaf<sup>b</sup>, P. Sardjono<sup>c</sup>

<sup>a</sup>Postgraduate Program of Materials Science, University of Indonesia  
Email : rahmat.doni@ui.ac.id

<sup>b</sup>Materials Science, Department of Physics, University of Indonesia  
Email : azwar@ui.ac.id

<sup>c</sup>Pusat Penelitian Fisika LIPI, Kawasan Puspitek Serpong  
Email : priyo\_sardjono@yahoo.com

### ABSTRACT

Barium hexaferrite and strontium titanate are respectively well established permanent magnet and piezoelectric materials which are technologically and scientifically attractive due to their potential for various applications in the field of magnetic electronics functional materials. However, the material properties for both require a careful control of grain structure as well as microstructure design to meet specific applications. In this work, we report some results of materials characterization especially particles and crystallites in a  $\text{BaFe}_{12}\text{O}_{19}/\text{SrTiO}_3$  composite which were promoted during mechanical milling. The composite was synthesized using a planetary ball mill with a ball to powder ratio 10:1. Changing in the particle and crystallite-sizes at various milling time up to 60 hours are studied with the aid of particle-size analyzer and X-ray diffraction. It was found that the particle size of composite powders initially increased due to laminated layers formation of a composite and then decreased to an asymptotic value of  $\sim 8 \mu\text{m}$  as the milling time extended even to a relatively longer time. However, based on results of line broadening analysis the mean crystallite size of the particles was found in the nanometer scale. We thus believed that mechanical blending and milling of mixture components for the composite materials has promoted heterogeneous nucleation and only after successive sintering at  $1100^\circ\text{C}$  the milled powder transformed into particles of nanograin. The crystallite growth kinetics at isothermal temperatures follow the relaxation equation with the activation energy value for BHF ( $Q_{\text{BHF}}$ ) and STO ( $Q_{\text{STO}}$ ) are respectively 73.63 kJ/mol and 122.69 kJ/mol.

### Keywords

Particle size, crystallite size, grain growth kinetics, barium hexaferrite, strontium titanate, mechanical milling.

This Paper is Published in Advanced Materials Research Journal

## SrTiO<sub>3</sub> Thin Films Deposition Using Pulsed Laser Deposition Technique

Pia Dinari<sup>a</sup>, Christian Chandra<sup>a</sup>, Joko Suwardy<sup>a</sup>, Salim Mustofa<sup>b</sup> and  
Yudi Darma<sup>a</sup>

<sup>a</sup>Quantum Semiconductor and Device Laboratory, Department of Physics, Institut Teknologi Bandung, Ganesha 10 Bandung, Indonesia  
40132

<sup>b</sup>Pusat Teknologi Bahan Industri Nuklir, Badan Tenaga Nuklir Nasional, Kawasan Puspitek Serpong,  
Indonesia 15314  
Email: yudi@fi.itb.ac.id

### ABSTRACT

Strontium titanate (SrTiO<sub>3</sub>) thin film has been deposited on Si (100) substrate using pulsed laser deposition technique. Film deposition was carried out at low temperature (150°C) by maintained the pressure at 10<sup>-4</sup>Torr. Nanometer-thick SrTiO<sub>3</sub> film on Si substrate was characterized using SEM, AFM, XRD, and Raman Spectroscopy. SEM and AFM images show that SrTiO<sub>3</sub> film has growth on Si substrate uniformly. Raman and XRD spectroscopy also support the growth of SrTiO<sub>3</sub> film on Si substrate. Furthermore, to investigate the effect of post-deposition thermal annealing, the samples were annealed up to 900°C. Thermal stability of SrTiO<sub>3</sub>/Si structure was studied by mean XRD spectra. The X-Ray Diffraction pattern indicates the crystallinity improvement through atomic arrangements during thermal annealing process.

### Keywords

SrTiO<sub>3</sub> thin films, pulsed laser deposition, annealing, thermal stability, structure properties

This Paper is Published in Advanced Materials Research Journal

## Photocatalytic Degradation of C.I. Reactive Red 2 by Using TiO<sub>2</sub>-Coated PET Plastic under Solar Irradiation

Tuty Emilia Agustina<sup>a</sup>, FitriSuryani Arsyad<sup>b</sup>, and Mikrajuddin Abdullah<sup>c</sup>

<sup>a</sup>Chemical Engineering Department Sriwijaya University South Sumatera, Indonesia

<sup>b</sup>Physics Department Sriwijaya University South Sumatera, Indonesia

<sup>c</sup>Physics Department Bandung Technology Institute Indonesia  
Email: tutycurtin@yahoo.com, tuty\_agustina@unsri.ac.id

### ABSTRACT

The synthetic dyes are a refractory and poisonous material. Most of industrial textile today used the synthetic dyes that can be dangerous to the environment because of the colored wastewater produced from their processes. This study concentrates on the application of Advanced Oxidation Processes (AOPs) for synthetic dyes wastewater treatment. Photocatalysis process as one of AOPs was applied for the degradation of organic content of synthetic dyes wastewater. The reactive dye, C.I. Reactive Red 2 (RR 2) was used as the organic pollutant model at the concentration of 100 mg/l. The TiO<sub>2</sub> concentration of 0.05-0.4 g/ml was used as the photocatalyst. The bulk and nano-size of TiO<sub>2</sub> were coating on the PET plastic and the degradation of organic content was examined in the term of color and COD within 0-12 hrs under solar irradiation. By using 0.4 g/ml of bulk TiO<sub>2</sub>, the color degradation of 88% and COD removal of 46% was achieved. Furthermore, by using 0.4 g/ml of nano-size TiO<sub>2</sub>, the enhancement of color degradation and COD removal was observed, that is 98% and 56%, respectively.

### Keywords

*Advanced oxidation processes (AOPs), dyes wastewater, synthetic dyes, photocatalysis process, solar irradiation*

This Paper is Published in Advanced Materials Research Journal

## Development of Plasma Electrolytic Oxidation Coating for Structural, Electrochemical, and Biological Applications

Young Gun Ko

*School of Materials Science and Engineering, Yeungnam University, Gyeongsan 712-749, South Korea  
Tel : +82-53-810-2537. Fax : +82-53-810-4628  
E-mail : younggun@ynu.ac.kr*

### ABSTRACT

The application of nanocrystalline solids has long been facilitated by the wide range of cutting edge techniques such as sol-gel, vapor condensation, mechanical milling, and chemical anodizing. At present, the nanostructured coating utilizing high energy plasma has been shown to possess unique and often enhanced materials properties in comparison to the cermet coatings via current technology. Now, the behavior of nanostructured materials subjected to plasma electrolytic coating was rendered complex by the choice of factors such as electrolyte, electric parameters, and cell atmosphere. Thus, it is essential to optimize the processing design which could lead to the achievement of excellent materials performance heretofore unattainable via conventional coatings. The present paper is to offer a general overview of recent progress in the area of high performance nanostructured coatings, paying much attention to underlying fundamental issues as well as exploring various applications.

**Keywords:** Plasma electrolytic oxidation; metal; nanostructure; processing design

This Paper is Not Available

## Electrochemical Behavior of $\text{Li}_4\text{Ti}_5\text{O}_{12}$ under in situ Process of Sintering and Surface Coating with Cassava Powder

Bambang Prihandoko, Achmad Subhan and Slamet Priyono

Research Center for Physics – LIPI  
PUSPIPTEK, Tangerang Selatan – Indonesia  
Email: bamb012@lipi.go.id, achm037@lipi.go.id, slam013@lipi.go.id

### ABSTRACT

Anode active material  $\text{Li}_4\text{Ti}_5\text{O}_{12}/\text{C}$  has an advantage to increase the life time and the ability to charge and discharge lithium batteries. An experiment was carried out to make  $\text{Li}_4\text{Ti}_5\text{O}_{12}/\text{C}$  more cheaper and simple process. Preparation of  $\text{Li}_4\text{Ti}_5\text{O}_{12}/\text{C}$  was carried out with stoichiometric composition of raw materials  $\text{TiO}_2$  (Merck) and  $\text{LiOH}\cdot\text{H}_2\text{O}$  (Germany) under powder metallurgy method. After mixing and calcinations cassava starch as a source of carbon black coating could be mixed under comparison 1:1 with calcinations powders. Pyrolysis process was done in - situ by the sintering process at temperature variation, i.e. 800, 850 and 900<sup>o</sup>C for 1 hour. XRD test results indicated the presence of anatase  $\text{TiO}_2$  entire sample. The best results of powder  $\text{Li}_4\text{Ti}_5\text{O}_{12}/\text{C}$  with in situ process under 850<sup>o</sup>C for 1 hour had conductivity in the order of 10<sup>-4</sup>S/cm and capacity round 5mAh/g. Carbon coating of cassava starch that is well identify in the black color of sample powder and EDX analysis, gave influence on electrochemical graphics of oxidation and reduction by cyclic voltammeter. The working voltage of  $\text{Li}_4\text{Ti}_5\text{O}_{12}/\text{C}$  is in general 1.55V.

### Keywords

Anode active material,  $\text{Li}_4\text{Ti}_5\text{O}_{12}/\text{C}$ , lithium battery, cassava, electrochemical

This Paper is Published in Advanced Materials Research Journal

## Microstructure and Phase Analysis of $\text{La}_{0.8}\text{Ba}_{0.2}\text{Ti}_x\text{Mn}_{(1-x)}\text{O}_3$ system for Microwave Absorber Material ( $x = 0 - 0.7$ )

Wisnu Ari Adi<sup>a</sup> and Azwar Manaf<sup>b</sup>

<sup>a</sup>Post graduate for materials science, University of Indonesia

<sup>a</sup>Center for Technology of Nuclear Industry Materials

National Nuclear Energy Agency, South Tangerang 15314

Tel : (021) 7560922 Fax : (021) 7560926

E-mail : dwisnuaa@batan.go.id

<sup>b</sup> Dept of Physics, Faculty of Mathematics and Natural Sciences

University of Indonesia, Depok 16424

Tel : (021) 7872610 Fax : (021) 7872610

E-mail : azwar@ui.ac.id

### ABSTRACT

The synthesis and characterization of the magnetic materials of  $\text{La}_{0.8}\text{Ba}_{0.2}\text{Mn}_{(1-x)}\text{Ti}_x\text{O}_3$  system ( $x = 0 - 0.7$ ) by mechanical alloying process have been performed. This magnetic material is prepared by oxides, namely  $\text{La}_2\text{O}_3$ ,  $\text{BaCO}_3$ ,  $\text{MnCO}_3$  and  $\text{TiO}_2$ . The mixture was milled for 10 h and then sintered at  $1000^\circ\text{C}$  for 10 h. The refinement results of x-ray diffraction pattern showed that the doping concentration ( $x < 0.5$ ) was a single phase, which has a structure monoclinic (I12/a1) with lattice parameters  $a = 5.5169(5)\text{ \AA}$ ,  $b = 5.5437(5)\text{ \AA}$  and  $c = 7.8553(7)\text{ \AA}$ ,  $\alpha = \gamma = 90^\circ$  and  $\beta = 89.75(1)^\circ$ ,  $V = 240.25(4)\text{ \AA}^3$  and  $\rho = 6.345\text{ gr.cm}^{-3}$ . The microstructure analysis showed that the particle shapes was polygonal with the varied particle sizes distributed homogeneously on the surface of the samples. We concluded that the maximum number of titanium atoms substituting manganese atom is around  $x \sim 0.43$  without changing the structure of this system.

### Keywords

Microwave absorber, magnetic, manganite, crystal structure, and microstructure

This Paper is Published in Advanced Materials Research Journal

## Synthesis and Characterization of Nanocrystalline TiO<sub>2</sub> by Non-Aqueous Sol Gel in Acidic Condition for Dye-sensitized Solar Cells

Lia Muliani<sup>a</sup> and Bambang Sunendar<sup>b</sup>

<sup>a</sup>Research Center for Electronics and Telecommunication - Indonesian Institute of Sciences  
(PPET-LIPI) Bandung – Indonesia  
Email: liamuliani@gmail.com

<sup>b</sup>Advance Material Processing, Physics Engineering Department – Institut Teknologi Bandung (ITB)  
Bandung - Indonesia  
Email: purwa@tf.itb.ac.id , liamuliani@gmail.com

### ABSTRACT

Nanocrystalline TiO<sub>2</sub> has been synthesized through non-aqueous sol gel using acetic acid (HOAc) and hydrochloric acid (HCl) as a catalyst. Titanium isopropoxide (TTIP) as precursor was prepared by reaction between TiCl<sub>4</sub> with isopropyl alcohol (IPA) in concentration of 0.3 M. The sol gel process employed at around 60°C using tert-butanol as solvent and HOAc was added as ligand to stabilise the reaction. Controlled hydrolysis and condensation reactions were achieved through in-taking of water molecules released from the esterification reaction of HOAc with tert-butanol. In this paper, the influence of acidic catalyst was described at the volume ratio of HOAc:HCl are 0:2 ; 1:1 and 2:0. The crystallinity and crystal phase of the samples were characterized by X-ray Diffraction and nanocrystalline TiO<sub>2</sub> with anatase phase was resulted. The morphology of the TiO<sub>2</sub> powder was analyzed by Scanning Electron Microscopy. Pore size and the BET surface area were determined by Brunauer-Emmett-Teller (BET) analysis. Nanocrystalline TiO<sub>2</sub> produced was applied for photoelectrode of dye-sensitized solar cell. The optical properties of the TiO<sub>2</sub> photoelectrodes were measured using by UV-Vis Spectrophotometer. The performance of the cell was measured using a solar simulator with light at an intensity of 50 mW/cm<sup>2</sup> generated by a xenon lamp. The best efficiency of 0.5% was achieved for active area of 0.48 cm<sup>2</sup>.

### Keywords

*Nanocrystalline TiO<sub>2</sub>, non-aqueous sol gel, acidic catalyst, dye-sensitized solar cells*

This Paper is Published in Advanced Materials Research Journal

## Microstructural Characterisation and Microwave Absorption Characteristics of $\text{La}_{(1-x)}\text{Ba}_x\text{Fe}_{0.25}\text{Mn}_{0.5}\text{Ti}_{0.25}\text{O}_3$ ( $x = 0, 0.25, 0.75, 1$ )

Endyas Pratitajati<sup>a</sup> and Azwar Manaf<sup>b</sup>

<sup>a</sup>Fakultas Matematika dan Ilmu Pengetahuan Alam  
Graduate Program of Materials Science, Universitas Indonesia  
Kampus UI, Depok 16424, Indonesia  
E-mail: endyasp@yahoo.com

<sup>b</sup>Fakultas Matematika dan Ilmu Pengetahuan Alam  
Graduate Program of Materials Science, Universitas Indonesia  
Kampus UI, Depok 16424, Indonesia  
E-mail: azwar@ui.ac.id

### ABSTRACT

Perovskite lanthanum manganites, especially those doped  $\text{LaMnO}_3$  (LMO), have shown potentials for applications in magnetic electronic functional materials. Partial substitution of La ion with divalent ions or Mn ion with trivalent ions gives rise to new properties. Substituted LMO has ability for absorbing electromagnetic waves. In this paper, we report recent investigations on substituted  $\text{LaMnO}_3$  with designated  $\text{La}_{(1-x)}\text{Ba}_x\text{Fe}_{0.25}\text{Mn}_{0.5}\text{Ti}_{0.25}\text{O}_3$  ( $x = 0, 0.25, 0.75, 1$ ) compositions. Materials were prepared by mechanical alloying technique. After heat treatments at sintering temperatures 1100°C, 1200°C and 1300°C to the quasi-crystalline powders, presence of material phases were confirmed by XRD. Single phase material was obtained in samples of  $0.25 \leq x < 0.75$  compositions. Mean crystallite size of sintered materials showed that crystallites were in a Nano crystalline regime. It is then concluded, during mechanically alloyed sintering powder materials, solid-state reaction and crystallisation promoted formation of particles containing Nano crystallites. Microwave absorption data showed that materials with large amount of substituted Ba ion gives broad absorption profiles. Total substitution of La by Ba ions ( $x=1$ ) has significantly changed absorption profile. Smaller mean crystallite sizes indicated an increase in reflection loss value. In this report, empirical relationship between nanostructure and absorption profile of material is discussed.

### Keywords

Lanthanum manganite, mechanical alloying, microwave absorbers, nanoparticles, nano crystalline materials, particle size

This Paper is Published in Advanced Materials Research Journal

## Preliminary Observation on Macro Texture of Nb<sub>3</sub>Sn Low Temperature Superconductor (LTS)

**Andika W. Pramono**

*Research Centre for Metallurgy – Indonesian Institute of Sciences  
Kawasan PUSPIPTEK Building 470  
Serpong 15314 – Indonesia  
E-mail: andika\_pram@yahoo.com*

### ABSTRACT

The macro texture of Nb<sub>3</sub>Sn superconductor was observed in order to identify the tendency of crystallographic orientation of such A15 compound. The Nb<sub>3</sub>Sn samples were prepared through the powder metallurgy process with the composition of 24at%Sn-76at%Nb. The well-blended Nb-Sn powder was consolidated by means of the uni-axial compression method, while the subsequent sintering was performed at T = 700°C for t = 96 hr. The macro texture of the sintered samples was measured using D8 Advance XRD Goniometer and the corresponding results were analyzed in the form of pole figures. Preliminary results indicate that the crystallographic orientations of Nb<sub>3</sub>Sn for both green compact and sintered samples show the strong textures in {112}-pole figures. The intensity of Nb<sub>3</sub>Sn textures decreases from green compact sample to sintered sample, probably due to the mechanism of recovery – recrystallisation following the Nb-Sn inter-diffusion process during sintering.

### Keywords

*Nb<sub>3</sub>Sn, macro texture, pole figures, recovery – recrystallisation, inter-diffusion*

This Paper is Published in Advanced Materials Research Journal

## Crystallite Size Characterization of Mechanically Alloyed of (Ba,Sr) Hexaferrite and (Ba,Sr) Titanate Composite System

Novizal<sup>a</sup>, A. Manaf<sup>b</sup>, D. Rahmat<sup>c</sup>

Faculty of Mathematics and Sciences, University of Indonesia, Depok 16424

<sup>a</sup>novizal@ui.ac.id, <sup>b</sup>azwar@ui.ac.id, <sup>c</sup>rahmat@ui.ac.id

### ABSTRACT

Barium - Strontium Hexaferrite and Barium – Strontium Titanate are both well established materials which widely used respectively as permanent magnets and piezoelectric devices. As the properties are a structure sensitive, materials structure as well as crystal structure must be properly designed to meet a specific application. In this paper, we report our recent investigation on material structure analysis of  $Ba_{0.3}Sr_{0.7}Fe_{12}O_{19}$  and  $Ba_{0.7}Sr_{0.3}TiO_3$  composite system prepared by a mechanical alloying process to promote ferroic properties. The average of particle size for composites system was found initially increased to a large size of 9  $\mu m$  after mechanically milled for 30 hours and then start to decreased to smaller size of  $\sim 5 \mu m$  when the milling time was extended to 80 hours and showing trend toward further reduction in mean particle sizes. In the latter case, the XRD trace for milled powders showed broadened diffracted peaks pattern due to deformation during mechanically milling. After sintering at a temperature of 1050  $^{\circ}C$  much finer crystallites of 7-13 nm size in a dense pellet were observed. Hence, sintering to the milled particles has promoted formation of nanocrystal containing particles. The mean crystallite size for magnetic phase was about more than 350 times smaller than the mean particle size of composite particles. Finer crystallite sizes were found in  $B_3SF$  in which the mean was about 700 times smaller than the mean particle size. The magnetic and electric properties of the composite system are also discussed.

### Keyword

*Mechanical alloying, hexaferrite, piezoelectric, ferroic, permanent magnets*

This Paper is Published in Advanced Materials Research Journal

## Quantum Approximation for Josephson's Tunneling in $\text{Th}_x \text{DUO}_2$ Nano Material for 535 Tesla at Muon Cyclotron

Moh. Hardiyanto

*Industrial Engineering Department, Institut Teknologi Indonesia  
Jalan Raya Puspiptek Serpong – Tangerang 15320  
Beta Group Large Hadron Collider (LHC) CERN Lyon, France 77414  
E-mail : moh\_hardiyanto\_iti@yahoo.com*

### ABSTRACT

The convergence quantum states of free covariant equation in Einstein's space with quantum condition is studied using the ABR (Abrikosov-Balseiro-Russell) formulation in convergence approximation for Josephson tunneling is important role for determine of neutrino particle existing, especially after Cerenkov's effect for 517 tesla super magnetic at Large Hadron Collider (LHC) Cyclotron in CERN, Lyon, France based on  $\text{Th}_x \text{DUO}_2$  nano material. This approaching will be solved the problem for determine the value of interstellar Electrical Conductivity (EC) on  $\text{DUO}_2$  chain reaction, then the post condition of muon has been known exactly. In this research shown the value of EC is  $4.32 \mu\text{eV}$  at 378 tesla magnetic field for  $2.1 \times 10^4$  ci/mm fast thermal neutron floating in 45.7 megawatts adjusted power of CERN's Cyclotron. The resulted by special Electron-Scanning-Nuclear-Absorbtion (ESNA) shown any possibilities of Josephson's tunneling must be boundary by muon particles without neutrino particle existing for 350 – 456 tesla magnetic field on  $\text{UO}_2$  more enrichment nuclear fuel at CERN, whereas this research has purpose for provide the mathematical formulation to boundary of muon's moving at nuclear research reactor to a high degree of accuracy and with Catch-Nuc, one of nuclear beam equipment has a few important value of experimental effort.

### Keywords

*ABR formulation, EC value,  $\text{Th}_x \text{DUO}_2$  nano material, super magnetic field value*

This Paper is Published in Advanced Materials Research Journal

## Nanosize Effects on Magnetic Properties and Peak Shifting of X-Ray Diffraction Pattern of BaFe<sub>12</sub>O<sub>19</sub> Produced by Sol Gel Method

Dwita Suastiyanti<sup>a</sup>, Bambang Soegijono<sup>b</sup>, M.Hikam<sup>c</sup>

<sup>a</sup>Graduate Program of Material Science, Department of Physics  
University of Indonesia, Depok 16424, Indonesia  
Email: dwita\_suastiyanti@yahoo.com

<sup>b</sup>Mechanical Department of Indonesia Institute of Technology (ITI)  
Puspiptek-Serpong, Indonesia  
Email: bambangsg11@yahoo.com

<sup>c</sup>Multiferroic Laboratory, Department of Physics  
University of Indonesia, Depok 16424, Indonesia  
Email: m.hikam@gmail.com

### ABSTRACT

The formation of barium hexaferrite, BaFe<sub>12</sub>O<sub>19</sub> single phase with nanosize crystalline is very important to get the best performance especially magnetic properties. The samples were prepared by sol gel method in citric acid-metal nitrates system. Hence the mole ratios of Ba<sup>2+</sup>/Fe<sup>3+</sup> were varied at 1:12 and 1:11.5 with pH of 7 in all cases using ammonia solution. The solution was then heated at 80-90°C for 3 to 4 hours. Then it was kept on a pre- heated oven at 150°C. The samples were then heat treated at 450°C for 24 hours. Sintering process was done at 850°C and 1000°C for 10 hours. Crystallite size was calculated by X-Ray Diffraction (XRD) peaks using scherrer formula. To confirm the formation of a single phase, XRD analyses were done by comparing the sample patterns with standard pattern. The peak shifting of pattern could be seen from XRD pattern using rocking curves at extreme certain 2θ. It was used MPS Magnet – Physik EP3 – Permagraph L to know magnetic characteristics. This method can produce BaFe<sub>12</sub>O<sub>19</sub> nanosize powder, 22-34 nm for crystallite size and 55.59-78.58 nm for particle size. A little difference in nanosize affects the peak shifting of XRD pattern significantly but shows a little difference in magnetic properties especially for samples at 850°C and 1000°C with mole ratio of 1:12 respectively. The well crystalline powder is formed at mole ratio of 1:11.5 at 850°C since it has the finest particle (55.59 nm) and crystalline (21 nm), the highest remanent magnetization (0.161 T) and the lowest intrinsic coercive (275.8 kA/m). It is also fitting exactly to the standard diffraction pattern with the highest value of best Figure of Merit (FoM), 90%. XRD peak position of this sample is almost same with XRD peak position of another sample with sinter temperature 1000°C at same mole ratio.

### Keywords

Sol gel, crystallite size, particle size, XRD pattern peak, single phase

This Paper is Published in Advanced Materials Research Journal

## Properties of Fe-Mn-C Alloy as Degradable Biomaterials Candidate for Coronary Stent

Sri Harjanto<sup>a</sup>, Yudha Pratesa<sup>a</sup>, Yudi Prasetyo<sup>a</sup>, Bambang Suharno<sup>a</sup>,  
Junaidi Syarif<sup>b</sup>, Fuad Hakim<sup>a</sup>

<sup>a</sup> Department of Metallurgy and Materials Engineering  
Faculty of Engineering  
Universitas Indonesia, Depok 16424  
E-mail: harjanto@metal.ui.ac.id

<sup>b</sup> Department of Mechanical and Materials Engineering  
University Kebangsaan Malaysia, Selangor, Malaysia  
Email : syarif@eng.ukm.my

### ABSTRACT

Fe-Mn alloys in biomedical materials application are prospective to be developed because of their properties, such as biodegradable and compatible with MRI (Magnetic Resonance Imaging). Many researches were focused on degradable rate of this alloy in order to adjust with healing time process at about 12 months as coronary stent. Several methods were investigated to produce excellence properties for this application, such as addition of alloying elements and powder metallurgy with mechanical alloying (MA). In this study, carbon is added as an alloying element. Material compositions were set to the value of Fe-25%Mn-1%C and Fe-35%Mn-1%C with MA or Non-MA treatment. Specimens were compacted for 15 minutes and followed by sintering process in vacuum furnace. XRD pattern and Ferrite Scope test showed the effects of the addition of Carbon allowed to produce a material that is dominated by the austenite phase (99%) with manganese content lower than previous studies. This result could reduce the toxicity issue from Manganese content in alloy. MA treatment gave smaller particle size, lower porosity and reduce corrosion rate than alloy material that formed without MA treatment. This study offers an easier fabrication process and produces alloys with manganese content lower than previous studies and dominated by Austenite phase

### Keywords

*Biodegradable material, mechanical alloying, powder metallurgy, planetary ball mill*

This Paper is Published in Advanced Materials Research Journal

# Structure and Mechanical Properties of Al-Cu/SiC Composite Prepared by Hot Press Method

Anggara Budi Susila<sup>a,b</sup>, E. Handoko<sup>b</sup>, and B. Soegijono<sup>a,c</sup>

<sup>a</sup> Materials Science, Graduated Program, Faculty Mathematics and Natural Science  
University of Indonesia, Salemba  
Tel : (021) 3907693 Fax : (021) 3907693  
E-mail : anggoro1960@yahoo.com

<sup>b</sup> Department of Physics, Faculty Mathematics and Natural Science  
State University of Jakarta, Jakarta 13220  
Tel : (021) 4894909 Fax : (021) 4894909  
E-mail : erfisika@yahoo.com

<sup>c</sup> Department of Physics, Faculty Mathematics and Natural Science  
University of Indonesia, Depok 16424  
Tel : (021) 7872610 Fax : (021) 7863441  
E-mail : bambang@fisika.ui.ac.id

## ABSTRACT

The Al-Cu/SiC composite was obtained by hot press (5 tons) method without addition element. The XRD pattern show specific pattern of Al-Cu/SiC composite with no other phases. The Al-Cu ingot without reinforcement has heterogeneous nucleation precipitates. However, the Al-Cu with reinforcement by SiC composite has smoother surface as indicating the nucleation less heterogeneous. Furthermore, the hardness of Al-Cu/SiC composite by ageing treatment has better quality.

## Keywords

*Al-Cu/SiC composite, hot press, XRD, heterogeneous nucleation, hardness*

## 1. INTRODUCTION

To date, metal matrix composite (MMC) is becoming potential candidate as structural material, automotive, aerospace.[1] MMC of Al-Cu/SiC are now claimed as possible solution as electronic packaging industry. Aluminium (Al) and Copper (Cu) reinforced by SiC has excellent thermo-physical properties such as low coefficient of thermal expansion (CTE), high thermal conductivity and improved mechanical properties such as higher specific strength, better wear resistance and specific modulus.[2,3]

The Al matrix composite are produced by casting route or powder metallurgy.[4] Nevertheless, the difficulties of casting is non wettability of the ceramic particles by liquid Al.[4] In order to improved the non wettability, Al matrix was coated by metals such as Ni and Cu.[5] Other also reported that the non wettability can be improved by adding surface active elements such as Mg into liquid Al or by preheating of the particles added into liquid Al.[4,5] However, the addition of Mg can reduce mechanical properties of the Al matrix.[2]

In this paper, we report the structure and mechanical properties of composite material of Al-Cu/SiC without any addition elements. The Al-Cu/SiC composite alloy has been prepared by using hot press method.

## 2. EXPERIMENTAL METHODS

Al-Cu ingot as the matrix with various Cu contents (3.8 wt%, 4.4 wt%, 4.9 wt%) were melted up to 1200°C for 30 minutes and cooled at room temperature. Al-Cu was cut and mixed with SiC powder. Vibration ball mill was performed in order to get smoother powder. Then, Al-Cu/SiC (10 wt%) composite were pressed by hot press (5 tons) at temperature 500°C for 10 minutes. Cooling process of the Al-Cu/SiC alloy was done by flowing water into mold porous. The next step was ageing by temperature 190 °C for 15 hours. The crystal structure and morphology were analyzed by using X-ray diffraction (XRD) and digital microscope. Furthermore, the mechanical properties of all composition of Al-Cu/SiC were characterized using hardness Vickers (HV).

## 3. RESULTS AND DISCUSSION

### 3.1 Phase identification and microstructure

In order to confirm phase of Al-Cu, the x-ray diffraction (XRD) has been performed. Figure 1 shows the XRD pattern of Al-Cu ingot with various Cu contents.

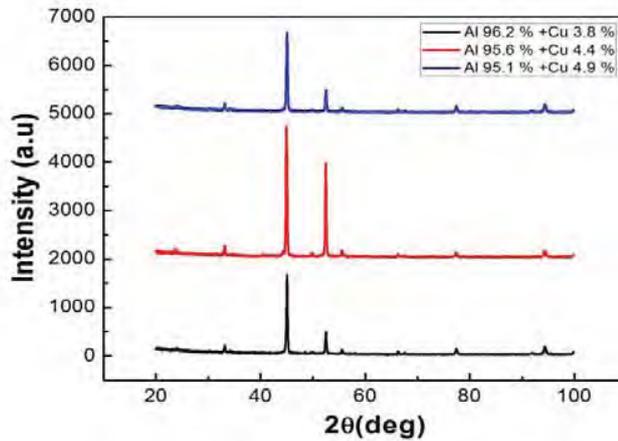


Figure 1: XRD patterns of Al-Cu ingot with various Cu contents were melted up to 1200°C for 30 minutes and cooled at room temperature

The XRD spectra shows the observed peaks at  $2\theta = 45^\circ$  and  $52^\circ$  corresponding to Al phase. Meanwhile, minor phase ( $Al_2Cu$  and  $Al_2O_3$ ) also observed eventhough the intensity low. It's indicates that the Al-Cu alloy was formed by casting process. The minor phase of  $Al_2Cu$  originates from precipitate atoms which diffuse into Al matrix during melting process. However, at cooling process, the precipitate atoms moveback to the grain boundary and the composite surface. Therefore, it can be understood that there is no other new phase forms in Al-Cu composite.

Figure 2 shows the XRD patterns of Al-Cu ingot, Al-Cu/SiC hot press, and Al-Cu/SiC hot press with ageing at temperature 190°C for 15 h. The XRD pattern observed that the highest peaks corresponding to Al phase. It's confirmed that the Al contents has dominant composition compare to other phase even after mixed with SiC. By ageing, the other peaks at  $2\theta = 78^\circ$  and  $95^\circ$  increased. It is predicted that by ageing, the orientation of structure of the Al matrix was changed.

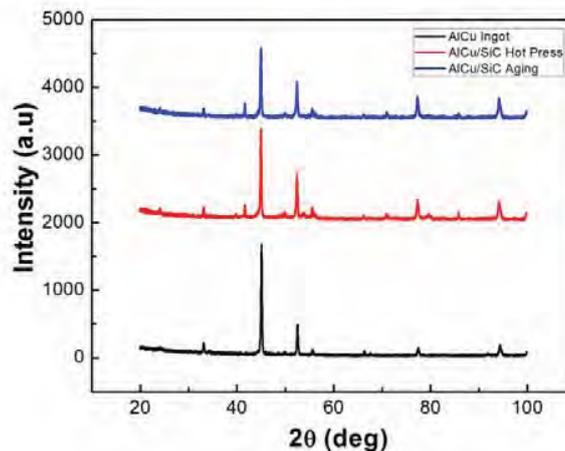


Figure 2: XRD patterns of Al-Cu ingot, Al-Cu/SiC hot press, and Al-Cu/SiC hot press with ageing at temperature 190°C for 15 h

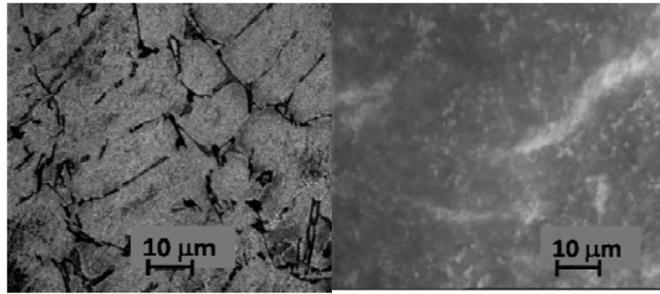


Figure 3: (a) Microstructure of Al-Cu ingot, (b) Microstructure of Al-Cu/SiC

Figure 3 (a) shows the morphology of the microstructure of Al-Cu ingot which melted at temperature 1200°C. It can be seen that the grains and grain boundary clearly observed. It is assumed that Al-Cu without reinforcement has greater dislocation density. As results, the dislocation provide heterogeneous nucleation of the precipitates. Nevertheless, figure 3 (b) shows the Al-Cu/SiC looks smoother compared to Al-Cu ingot. Its because the Al-Cu was reinforced significantly by SiC alloy composite.

### 3.2 Mechanical properties

Figure 4 shows the hardness Vicker (HV) value of Al-Cu ingot with various Cu contents which are melted up to 1200°C for 30 minutes and cooled at room temperature. The hardness of Al-Cu varies with distance and Cu contents. It can be assumed that during cooled process, the interface of the matrix interfaces has heterogeneous dislocation density which provide heterogeneous nucleation of precipitates. As results, the hardness of Al-Cu varies for each distance.

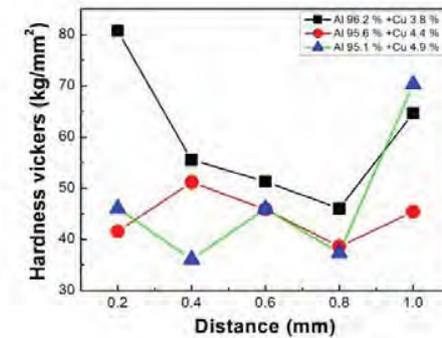


Figure 4: HV value of Al-Cu ingot with various Cu contents were melted up to 1200°C for 30 minutes and cooled at room temperature.

Figure 5 shows the HV of Al-Cu ingot, Al-Cu/SiC, and Al-Cu/SiC with ageing at temperature 190°C for 15 hours. The HV values confirm that the hardness of Al-Cu/SiC with ageing (temperature 190°C for 15 hours) has strongest value compared to the others.

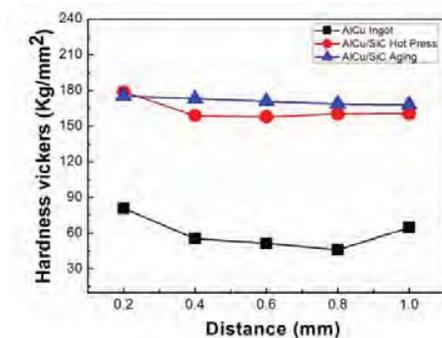


Figure 5: HV of Al-Cu ingot, Al-Cu/SiC hot press, and Al-Cu/SiC hot press with ageing at temperature 190°C for 15 h

Its predicted that reinforcement matrix composite of Al-Cu by SiC was improved by ageing treatment. Eventhough, the hardness improvement not significantly different with Al-Cu/SiC. It can be assumed that the volume fraction of SiC has significant effect on the ageing kinetics of Al-Cu alloy matrix in the cast composite.[6]

#### 4. CONCLUSION

In conclusions, the Al-Cu/SiC composite was obtained by hot press (5 tons) method without addition element. The XRD pattern show spesific pattern of Al-Cu/SiC composite with no other phases. The Al-Cu ingot without reinforcement has heterogeneous nucleation precipitates. However, the Al-Cu with reinforcement by SiC composite has smoother surface as indicating the nucleation less heterogeneous. Furthermore, the hardness of Al-Cu/SiC composite by ageing treatment has better quality.

#### ACKNOWLEDGMENT

Financial support from Beasiswa Program Pasca-sarjana (BPPS) Direktorat Jenderal Pendidikan Tinggi (DIKTI) Kementerian Pendidikan dan Kebudayaan (KEMENDIKBUD) Republik Indonesia tahun 2010 is gratefully acknowledged.

#### REFERENCES

- [1] Rusianto, Toto, "Hot Pressing Metalurgi Serbuk Aluminium Dengan Variasi Suhu Pemanasan", Jurnal Teknologi vol 2, Yogyakarta: 89-95, 2009
- [2] Bukhari MZ, Brabazon D, Hashmi MSJ, "Application of Metal Matrix Composite of CuSiC and AlSiC as Electronics Packaging Materials", international manufacturing confrence, 2009
- [3] Halverson, Danny C. & Pyzik, Alexander J,"Processing of Boron Carbide-Aluminum Composites", J. Am. Ceram, California, 775-780, 1989.
- [4] B. Mallick, P.C Maity, V.K Sinha," Production of Al-SiC cast particle composite without magnesium", confrence on material science and technology, NMLINDIA, 2009.
- [5] P.K. Rohatgi, R. Asthana and S. Das, Int. Met. Reviews, 31, 115, 1986.
- [6] Sharmilee Pal, R. Mitra, V.V. Bhanuprasad, "Aging behaviour of Al-Cu-Mg alloy-SiC composites", Material science and engineering A, 480, 496-505, 2008.

## Synthesis and Characterization of TiO<sub>2</sub> Nanoparticle Using Starch as a Template by Sol-Gel Method for the Application of UV Protection

Maya Komalasari , Bambang Sunendar

Faculty of Mechanical and Aeronautica Engineering Study Program, ITB, Indonesia  
Advance Material Processing Physics Departement Research and Applies Physical, ITB  
Email: maya.komalasari@yahoo.com, purwa@tf.itb.ac.id

### ABSTRACT

Nanotechnology is one of the key technology had been developed since in all fields including textile industries for medical, hygienic, and technical textiles. Particle size with nano had been indicated in particular for the application of controlled release material for functional textiles. TiO<sub>2</sub> nano powder has remarkable photo-catalytic and semiconductor as material for various advanced technology fields of application such as UV Protection. In this research the synthesis of TiO<sub>2</sub> nanoparticle and characterization had been conducted successfully by sol-gel method. The starch was used as a template to get nanoparticles structure. TiO<sub>2</sub> sol with narrow particle size distribution using TiCl<sub>4</sub> as the starting material. The sol was prepared by a process where HCl was added to a gel of hydrated titanium oxide to dissolve it. The effect of preparation parameters were investigated, by deionized water : HCl 1 M was slowly added to TiCl<sub>4</sub> at 5 °C. In this study the production of anatase or rutile TiO<sub>2</sub> nanostructured powder by forced hydrolysis of aqueous Ti (IV) chloride solution and concentration from 0,3, 0,5 then 1 M. TiO<sub>2</sub> sphere were fabricated by a facile and low – cost stable starch assisted by sol-gel method. Aqueous solution of starch was added and then heated in temperature 80°C and aqueous solution of ammonium hydroxide was added to adjust pH to 8. After aging period of time, the white precipitate was filtered and then calcined in temperature 500° C. The as-obtained samples were characterize, kjnhjd by SEM (Scanning Electron Microscope), UV-vis diffuse reflectance spectroscopy, X-Ray Diffraction (XRD) and Brunauer Emmett Teller (BET) analysis. The particle size is less than 100 nm and if it uses template particle TiO<sub>2</sub> more uniform distribution and spherical shape with particle size 170 – 200 nm. Crystallinity particle is 4 – 19 nm and the phase structure of anatase and rutile. The energy band gap semiconductor TiO<sub>2</sub> synthesis is 3.1 to 3.7 eV. Surface area without template starch 40.655 m<sup>2</sup>/g, with total for volume 0.278 cm<sup>3</sup>/g and pore size of 27 nm, and used template starch surface area 35.488m<sup>2</sup>/g with total for volume 0.196 cm<sup>3</sup>/g and pore size of 22 nm. Based on this research, the best a crystal phase for UV protection application is rutile phase.

### Keywords

Nanoparticle, sol-gel method, starch, titanium dioxide.

This Paper is Published in Advanced Materials Research Journal

## Synthesis of Mesoporous Silica from Tetraethylorthosilicate by Using Sodium Ricinoleic as a Template and 3Aminopropyltrimethoxysilane as Co-Structure Directing Agent with Volume Variation of Hydrochloric Acid 0.1 M

Andriyani<sup>a</sup>, Seri Bima Sembiring<sup>a</sup>, Nida Aksara<sup>a</sup> and Nofrijon Sofyan<sup>b</sup>

<sup>a</sup>Department of Chemistry, Faculty of Mathematics and Natural Sciences, University of Sumatera Utara,  
Medan 20155

Email: andrikim@yahoo.com, nidamckee@gmail.com

<sup>b</sup>Department of Metallurgical and Materials Engineering, University of Indonesia, Depok 16424. Also at ISI Surakarta, Surakarta 57126.

\*Correspondence author

Email: nofrijon.sofyan@ui.ac.id

### ABSTRACT

Synthesis of mesoporous silica from tetraethylorthosilicate (TEOS) by using sodium ricinoleic as a template and 3-aminopropyltrimethoxysilane (APMS) as a co-structure directing agents (CDSA) in a volume variation of acid addition has been carried out. Preparation of mesoporous silica was conducted in HCl 0.1 M at volume variations of 2 ml, 35 ml, 40 ml and 50 ml. In acid conditions, the amine groups of APMS will protonate, which will then interact electrostatically with the carboxylate groups from ricinoleic acid, while the methoxy groups from APMS will condense with the silanol groups from TEOS to form an end product of mesoporous silica. The reaction products were characterized by using X-ray diffractometer (XRD), Fourier transform infra-red spectrometer (FTIR), surface area analyzer (BET), scanning electron microscope (SEM), and transmission electron microscope (TEM). X-ray diffractograms of the products from all of the acid volume variation additions show broadening peaks indicating amorphous materials as a characteristic of mesoporous materials. Infrared spectra show that all of the products have Si-OH and Si-O-Si groups that are characteristics for mesoporous silica. Imaging results from SEM and TEM show morphology and particle size differences in accordance with the differences in volume variation of acid addition. Adsorption/desorption isotherm by using nitrogen at 77 K of the products from the addition of 2 ml of HCl show an isotherm Type II (adsorption on the surface layer) with irregular pore size distribution, whereas from the addition of 30 ml, 35 ml, 40 ml and 50 ml HCl show an isotherm Type IV with a hysteresis loop that is characteristic for mesoporous materials with a regular pore size distribution.

### Keywords

Adsorption/desorption isotherm, aminopropyltrimethoxysilane, co-structure directing agents, mesoporous silica, sodium ricinoleic, tetraethylorthosilicate

This Paper is Published in Advanced Materials Research Journal

## Synthesis And Characterization of Silica-Lavender Microencapsulation by Sol Gel – Emulsion Method for Anti Mosquito Textile

Rr. Wiwiek Eka Mulyani<sup>a</sup> , Bambang Sunendar<sup>b</sup>

<sup>a</sup>Faculty of Mechanical and Aeronautica Engineering, Materials engineering Study Program,  
Institute of Technology Bandung, Indonesia  
Email : wieweksusandi@gmail.com

<sup>b</sup>Advanced Material Processing, Engineering Physics Departement, Research at Applies Physic Dept,  
Institute of Technology Bandung, Indonesia  
Email : purwa@tf.itb.ac.id

### ABSTRACT

Microencapsulation is a new breakthrough in the field of nanotechnology that can be used for various applications, in particular for the application of controlled release material for functional textiles which were added by certain active substances and gave effects when used such as fragrance and anti mosquito textile. In this research, the synthesis of silica-lavender microencapsulation for anti-mosquito textile had been conducted successfully via sol-gel emulsion process. Sodium silicate solution which was emulsified into the lavender oil as an active ingredient acted as oil phase and ethanol solution acted as water phase. The addition of chitosan as surfactant and polymer for encapsulation with starch as soft template affected the rod-structure formation of nanorod. SEM result showed the morphology of silica-lavender. The rod has the average diameter size of 0.042-0.206  $\mu\text{m}$ . The optimum result of rod-structure was obtained by adding 1% (v/v) of chitosan. FTIR analysis indicated the presence of absorbance peaks at wavenumber of 1411.89, 958.62, and 1078.2  $\text{cm}^{-1}$  respectively for C-H (alkanes), C-H (alkenes) and ester functional groups which indicated the lavender compound in silica-lavender. UV-Vis analysis showed the maximum absorbance at wavelength of lavender at 350 nm. The combination of morphology and chemical properties of silica-lavender modified by chitosan-starch made this material as a candidate material for application in functional textile.

### Keywords

*Silica-lavender, microencapsulation, sol gel emulsion method, functional textiles, nanorod*

This Paper is Published in Advanced Materials Research Journal

## **Sensitive Layer Thickness Dependence on Microcantilever Sensor Sensitivity**

**Nuning Aisah, Lia Aprilia and Ratno Nuryadi**

*Center for Materials Technology Agency for the Assessment and Application of Technology  
South Tangerang, Indonesia*

*Email: nuning.aisah@bppt.go.id, lia.aprilia@ui.ac.id, ratno.nuryadi@bppt.go.id*

### **ABSTRACT**

The purpose of this paper is to investigate an application of a piezoresistive microcantilever for gas sensor using a dynamic mode operation. The working principle of the microcantilever sensor is based on the measurement of microcantilever deflection or resonance frequency change due to the objects attached on the microcantilever surface. The measurement was performed by using Wheatstone bridge circuit, which is constructed by two piezoresistors in the microcantilever and two external resistors, in order to measure the resonance frequency shift of the microcantilever vibration. The result shows that the voltage of oscillation peak-to-peak from the output of Wheatstone bridge circuit, which represents the microcantilever vibrations, decreases with the time due to the gas detection. This occurs due to the resonance frequency shift caused by the addition of gas molecules mass on the microcantilever surface. This result indicates that the developed system can be used as gas sensor

### **Keywords**

*Microcantilever, piezoresistive, gas sensor, dynamic mode, amplitude*

This Paper is Published in Advanced Materials Research Journal

## Improvement Biocompatibility of NiTi Orthodontic Wire from Various Coatings

**Yuli Setiyorini and Sungging Pintowantoro**

*Department of Material and Metalurgical, Institut Teknologi Sepuluh Nopember, Surabaya 60111, Indonesia  
Email: yulisetiyorini@yahoo.com, sunggingp@yahoo.com*

### ABSTRACT

NiTi alloy is one of important materials in orthodontics. Shape memory effect of this material ensures the possibility to deliver highly desirable light forces for tooth movement. Unfortunately, NiTi has problem in the high amount content of Ni that can cause allergy or even risk of poisoning in the human body due to Ni ion released. To overcome this problem, several methods of coatings were performed to prevent the releasing of Ni ion. They were Electropolishing Pretreatment combined with Photo Electrochemical Oxidation, TiN Pack Cementite, Advanced Oxidation Process and Biomimetic Hydroxyapatite. The objective of this research was to analyze the effect of various coatings to the biocompatibility of orthodontic wire. Biocompatibility of coated NiTi wire was investigated through MTT assay using BHK-21 fibroblast cell in order to analyze the toxicity of each coating method. In addition, the surface roughness was determined using Atomic Force Microscope (AFM). Furthermore, the attachment and spreading of fibroblast cell were observed by Scanning Electron Microscope (SEM). The result was revealed that biomimetic HA coating has the highest cell viability percentage due to its surface morphology.

### Keywords

*Biocompatibility, Fibroblast, NiTi Orthodontic wires, Toxicity*

This Paper is Published in Advanced Materials Research Journal

**Plenary 3****Microbial cell factories for the production of bio-fuels and bio-based chemicals from cellulosic materials****Akihiko Kondo***Department of Chemical Science and Engineering,**Graduate School of Engineering**Kobe University,**1-1 Rokkodai, Nada, Kobe 657-8501, Japan**Tel : +81-78-803-6196. Fax : +81-78-803-6196**E-mail : akondo@kobe-u.ac.jp*

To build an energy and material secure future, a next generation of renewable fuels and bio-based chemicals produced from lignocellulosic biomass is required. Consolidated bioprocessing (CBP), which integrates enzyme production, saccharification and fermentation into a single process, is a promising strategy for effective production of bio-based materials. As a key technology for the development of recombinant cellulolytic microbial strains, cell surface engineering, which enables the display through genetic engineering of various types of functional proteins on microbial cell surfaces without loss of their function, is a promising tool reducing the requirement for cellulase addition, as cellulases can be displayed on the microbial cell surface. The display of cellulolytic and hemicellulolytic enzymes on the yeast cell surface effectively hydrolyzed lignocellulosic materials (e.g. hydrothermally pretreated rice straw). High-titer and high-yield ethanol production was achieved by short-term liquefaction and fermentation of high-solid lignocellulose biomass using a yeast strain developed for the cell-surface display of fungal endoglucanase, cellobiohydrolase, and  $\beta$ -glucosidase. Also, rice straw hydrolysates were directly converted to ethanol by constructing a recombinant yeast that not only hydrolyzed hemicelluloses by codisplaying endoxylanase and  $\beta$ -xylosidase, and  $\beta$ -glucosidase but also assimilated xylose through the expression of xylose reductase, xylitol dehydrogenase, and xylulokinase in the cell. Regardless of the process used for the biomass hydrolysis, CBP-enabling microorganisms encounter a variety of toxic compounds released during biomass pretreatment that inhibit microbial growth and ethanol yield. Systems biology approaches including transcriptomics and metabolomics have been recently exploited to gain insight into the molecular and genetic traits involved in tolerance and adaptation to the fermentation inhibitors. A combination of a cell surface displayed enzyme system and an intracellular metabolic engineering system is a very effective approach to develop cells with novel fermentation ability for industrial applications. The technology will open up the various new applications of cell factories to the industrially important processes.

**Keywords***Biomass, Lignocellulose, Biofuels, Bio-based Chemicals***This paper is not available from the author(s)**

## Structure and Functional Mechanism of Small Heat Shock Proteins

Masafumi Yohda

Department of Biotechnology and Life Science, Tokyo University of Agriculture and Technology,  
 2-24-16 Naka-cho, Koganei, Tokyo 184-8588 Japan  
 E-mail: yohda@cc.tuat.ac.jp

The small heat shock protein (sHsp), categorized into a class of molecular chaperones, binds and stabilizes denatured proteins for the purpose of preventing aggregation. Compared with other chaperones, the overall amino acid sequence homology among sHsps is rather low. Their common feature is the  $\alpha$ -crystallin domain, which is named after the  $\alpha$ -crystallin of the vertebrate eye lens(1). The  $\alpha$ -crystallin domain is flanked by a highly variable N-terminal region and a short, partially conserved C-terminal extension (2). The molecular mechanism of the chaperone function of sHsps resides in the oligomeric structure. The chaperone potential of sHsps is latent when they exist as large oligomeric structures under physiological conditions. At elevated temperatures, the equilibrium shifts to the dissociated state, and the hidden hydrophobic substrate-binding sites are exposed to express chaperone activity (3). In the presence of unfolded proteins, small oligomers form a large stable complex with unfolded proteins to protect against protein aggregation. As sHsps lack refolding activity, trapped polypeptides can be refolded with the assistance of ATP-dependent chaperones, such as Hsp70 and Hsp100 (4-7).

We have been studying the structure and function of sHsps of thermophilic archaea and a fission yeast, *Schizosaccharomyces pombe*. StHsp14.0, the sHsp of acidothermophilic archaeon *Sulfolobus tokodaii*, exists as a spherical 24meric oligomer with a diameter of 115 Å(8), and the oligomer dissociates to exhibit molecular chaperone function over 80°C(9). Mutant StHsp14.0s with the amino acid replacements in C-terminal IKI motif exhibited oligomer dissociation and protected citratesynthase from thermal aggregation at 50°C(10). We examined the temperature dependent oligomer dissociation and complex formation with denatured protein of StHsp14.0 variants by small angle X-ray scattering (SAXS)(11). The results suggest that a partially dissociated oligomer of StHsp14.0 protects a denatured protein from interacting with other molecules by surrounding it. Recently, we reported the oligomer architecture of SpHsp16.0 from *Schizosaccharomyces pombe* determined with X-ray crystallography and small angle X-ray scattering. Both results indicate that 16 monomers of SpHsp16.0 form an elongated sphere with the 422 symmetry (12). The result of temperature dependence of the oligomeric state of SpHsp16.0 investigated by SAXS indicates that the large oligomeric state is maintained at the heat stressed condition. Previously, we have shown that the interaction between an unfolded protein and SpHsp16.0 is transient (13). Recent our study has also shown that the interaction between an unfolded protein and TkHsp20.0, sHsp of hyperthermophilic archaeon, *Thermococcus* strain KS1, at the elevated temperature is transient (Manuscript in preparation). The captured protein was released and started to refold spontaneously at the lowered temperature. In addition, other chaperones captured unfolded proteins that were protected by TkHsp20.0 at the elevated temperatures and enhanced refolding of them in an ATP dependent manner.

Based on these results, I propose a model for the molecular chaperone function of sHsp. In the heat shock response, sHsp is the first aid chaperone to treat thermally damaged proteins. After exposure to heat shock conditions, the oligomer of sHsp partially dissociates to expose hydrophobic surface and protect thermally denatured proteins from aggregation. The interaction seems to be transient. Other chaperones that are expressed as the heat shock response capture the protected unfolded proteins for productive folding after the end of thermal stress.

### REFERENCES

- [1] 1. Caspers, G. J., Leunissen, J. A., and de Jong, W. W. (1995) *J. Mol. Evol.* **40**, 238-248
- [2] 2. Leroux, M. R., Melki, R., Gordon, B., Batelier, G., and Candido, E. P. (1997) *J. Biol. Chem.* **272**, 24646-24656
- [3] 3. Haslbeck, M., Walke, S., Stromer, T., Ehrnsperger, M., White, H. E., Chen, S., Saibil, H. R., and Buchner, J. (1999) *EMBO J.* **18**, 6744-6751
- [4] 4. Cashikar, A. G., Duennwald, M., and Lindquist, S. L. (2005) *J. Biol. Chem.* **280**, 23869-23875
- [5] 5. Ehrnsperger, M., Graber, S., Gaestel, M., and Buchner, J. (1997) *EMBO J.* **16**, 221-229
- [6] 6. Haslbeck, M., Miess, A., Stromer, T., Walter, S., and Buchner, J. (2005) *J. Biol. Chem.* **280**, 23861-23868
- [7] 7. Mogk, A., Deuerling, E., Vorderwulbecke, S., Vierling, E., and Bukau, B. (2003) *Mol. Microbiol.* **50**, 585-595

- [8] 8. Hanazono, Y., Takeda, K., Yohda, M., and Miki, K. (2012) *J. Mol. Biol.* **422**, 100-108
- [9] 9. Usui, K., Ishii, N., Kawarabayasi, Y., and Yohda, M. (2004) *Protein Sci.* **13**, 134-144
- [10] 10. Saji, H., Iizuka, R., Yoshida, T., Abe, T., Kidokoro, S., Ishii, N., and Yohda, M. (2008) *Proteins* **71**, 771-782
- [11] 11. Abe, T., Oka, T., Nakagome, A., Tsukada, Y., Yasunaga, T., and Yohda, M. (2011) *J. Biochem.* **150**, 403-409
- [12] 12. Hanazono, Y., Takeda, K., Oka, T., Abe, T., Tomonari, T., Akiyama, N., Aikawa, Y., Yohda, M., and Miki, K. (2013) *Structure* **21**, 220-228
- [13] 13. Hirose, M., Tohda, H., Giga-Hama, Y., Tsushima, R., Zako, T., Iizuka, R., Pack, C., Kinjo, M., Ishii, N., and Yohda, M. (2005) *J. Biol. Chem.* **280**, 32586-32593

## Measurement of Chemical Markers in Dragon's Blood

Suminar S Achmadi<sup>a</sup>, Umar Toriq<sup>b</sup>, Budi Arifin<sup>c</sup>

<sup>a</sup>Department of Chemistry  
Bogor Agricultural University, Bogor 16680  
Tel: (0251) 862 4567 Fax: (0251) 862 4567  
E-mail: ssachmadi@cbn.net.id

<sup>b</sup>Department of Chemistry  
Bogor Agricultural University, Bogor 16680  
Tel: (0251) 862 4567 Fax: (0251) 862 4567  
E-mail: umar\_toriq@yahoo.com

<sup>c</sup>Department of Chemistry  
Bogor Agricultural University, Bogor 16680  
Tel: (0251) 862 4567 Fax: (0251) 862 4567  
E-mail: budiarifin@yahoo.com

### ABSTRACT

Dragon's blood is a resin exudated by rattan (*Daemonorops draco*) fruit, collected and traded by forest-surrounded communities and is an exportable commodity. However, the National Standardization Agency issued an Indonesia National Standard for dragon's blood designated three qualities, i.e. super, A, and B, based solely on physical characteristics and visual parameters. Some parameters are qualitative and some others need a tedious procedures for the determination. In this study, claims by the traders and laboratory tests based on the national standards were compared. In average, the match between SNI determination and the traders claim was only 50%. In determining resin content, this study revealed that acetone extract was more useful than that of diethyl ether for being not involving heat in the process and the yield was also linearly correlated with absorbance at 473 nm using a UV-visible spectroscopy. A rapid quantitative measurement for revising SNI parameters is proposed. Chemical markers in dragon's blood resin are flavan derivatives, i.e. dracorhodin and 3,4-dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol.

### Keywords

Dracorhodin, dragon's blood, Indonesia National Standard, rattan-fruit resin, UV-vis spectrophotometer

### 1. INTRODUCTION

Dragon's blood, so called *getah jernang* in Indonesian, is exudated by rattan (*Daemonorops draco*) fruit and is specific of Indonesia, especially in Sumatera. This red-color substance gives significant income for the forest-surrounding communities, with the price ranges from 80-100USD/kg, depending on the quality. This commodity is used for dyes, crafts, and even for medicine for treating diarrhea, asthma, syphilis, reported as an aphrodisiac [1]. The substance falls into hard resin, shiny solid, transparent, amorphous, specific gravity of 1.18-1.20, low acid number, ester number approximately 140, melting point approximately 120 °C, soluble in alcohols, ether, partially dissolves in chloroform, ethyl acetate, carbon disulfide, and insoluble in water [2].

Chemical constituents and their bioactivities in dragon's blood have been reported [3]. The main constituents identified among others are dracorhodin, nordracorhodin, 5-methoxy-6-methylflavan-7-ol, nordracorubin, dracoalban; dracoresene; dracoresinotannol, and dammaradienol. However, the quantitative data are not reported, especially those regarding the classification of this commodity.

Badan Standardisasi Nasional (BSN, Indonesian Standardization Agency) categorizes dragon's blood into 3 qualities, namely, Super, A, and B [4]. The parameters are based on the range contents of moisture, ash, resin texture, melting point, impurities, and color (Table 1). These physical properties are very subjective in nature and are potential to inflict financial loss at the farmer side, which are usually having low bargain position in trading. This study aimed to provide quantitative and rapid measurement to designate the quality of dragon's blood.

Table 1 Specification of dragon's blood as stipulated in SNI 1671:2010

Parameter	Unit	Quality requirement		
		Super	A	Mutu B
Resin content (w/w)	%	Min. 80	Min. 60	Min. 25
Moisture content (w/w)	%	Max. 6	Max. 8	Max. 10
Impurities (w/w)	%	Max. 14	Max. 39	Max. 50
Ash content (w/w)	%	Max. 4	Max. 8	Max. 20
Melting point	°C	Min. 80	Min. 80	-
Color	-	Dark red	Pink	Pale red

## 2. METHODS

The experiment was initiated by comparing the quality between the requirements according to SNI [4] and claims by the traders. The second step was identifying chemical markers in the collected samples, and concluded by an attempt to provide rapid measurement of the chemical marker.

### 2.1 Materials

There were 8 samples collected from traders in Sumatera (5 samples from Jambi, 2 from Aceh, and 1 from Medan). There was no claim from trader in Medan regarding the quality of the samples. All samples, in the forms of lumps and powder, were obtained from *D. draco* species.

### 2.2 Quality Classification Based on Standard Procedures

According to SNI [4], resin content was determined by extracting 5 g materials in soxhlet apparatus using diethyl ether, and reported as w/w percentage. Ash content was based on gravimetric analysis after ashing and also reported as w/w percentage. Color quality was determined visually after dissolving 1 g of sample in 20 mL ethanol and spread on a white paper. Level of impurities was determined by dissolving 2 g sample in 10 mL toluene and weighed the dry residue retained on the dried filter paper. Moisture content was following AOAC [5] as well as for melting point determination. All determinations were in duplicates.

### 2.3 Acetone Extraction

Fine ground samples (5 g) was placed in beaker glass, macerated overnight in 50 mL acetone, and filtered. The filtrates from triplicate experiments were combined, concentrated, and evaporated to dryness. The dried red acetone extract was weighed to obtain the percent yield (w/w).

### 2.4 Chemical Identification

Gas chromatography-mass spectrophotometry (GCMS; Shimadzu) was used to identify the chemical constituents contained in the acetone extract. The analysis was carried out in the Center of Forensic Laboratory (Puslabfor), Jakarta. Electron impact ionization was equipped in the gas chromatograph GC-17A (Shimadzu) tandemed with mass spectrometer MS QP 5050A; capillary column DB-5 ms (J&W) (silica 30 m × 250 μm × 0.25 μm); column temperature was raised from 50 °C (0 minute) to 290 °C in the rate of 15 °C/minute; helium as the carrier gas at constant pressure 7.6411 psi, and data base of Wiley 7N 2008 version.

### 2.5 Color Intensity Measurement

Fine ground samples (1 g) were dissolved in 20 mL ethanol in beaker glass and diluted 200 times. The dilute solution was analyzed using ultraviolet-visible spectrophotometer at wavelength 473 nm. The measurements were conducted in duplicates.

## 3. RESULTS AND DISCUSSION

### 3.1 Discrepancies between Quality According to SNI 1 and Claims by The Traders

In average, the match between SNI determination and the claims from traders was 51.1% (Table 2). The lowest match (14.3%) was regarding resin content and the highest was dealing with color (85.7%). Resin content determination requires a tedious work. On the other side, even though the color parameter is relatively easy to determine, is still give some discrepancy. This fact emphasizes the need of quantitative and rapid method in revising the SNI 1671:2010.

Table 2. Quality of dragon's blood resin as determined by SNI parameters and claims by traders

Sample	Traders	SNI					
		Resin (%)	Moisture (%)	Impurities (%)	Ash content (%)	Melting point (°C)	Color
Jambi 1	B	B (37.0)	*B (17.0)	*B (55.2)	A (6.1)	-	B (Pale)
Jambi 2	Super	B (99.6)	B (9.3)	Super (12.6)	Super (0.8)	Super/A (71-73)	Super (Dark)
Jambi 3	Super	Super (95.2)	Super (4.7)	Super (9.8)	Super (0.7)	Super/A (82-91)	Super (Dark)
Jambi 4	Super	Super (92.6)	*B (12.7)	A (20.1)	Super (2.7)	Super/A (80-81)	Super (Dark)
Jambi 5	A	A (61.4)	B (9.0)	A (38.1)	A (4.5)	Super/A (81-84)	A (Pink)
Aceh 1	A	*B (8.1)	*B (11.6)	*B (89.6)	B (9.5)	-	Super (Dark)
Aceh 2	B	Super (81.7)	Super (2.3)	*B (76.7)	Super (0.7)	-	B (Pale)
Medan	-	B (50.9)	Super (4.5)	*B (57.8)	B (8.2)	Super/A (75-80)	A (Pink)
Percent match (%)		14.3	71.4	42.9	57.1	71.4	85.7

- = not measured; \* = poor, do not meet the specification; Super/A = can fall into Super or A quality; Numbers in brackets are average from 2 experimental data

### 3.2 Diethyl Ether Extract vs. Acetone Extract

SNI 1671:2010 requires diethyl ether for extracting resin in the dragon's blood. Diethyl ether is flammable and the 7-hour extraction needs a special apparatus. In practice, maceration using acetone was much easier and faster than the extraction using flammable diethyl ether in soxhlet apparatus. Figure 1 shows that acetone extraction consistently gave higher yield than that of diethyl ether. The correlation between qualities of dragon's blood based on SNI is also seen, however, transition between B and A, as well as between A and Super is not distinct. Pure methanol and methanol:water mixtures were also used in other studies (6, 7] with lower yield.

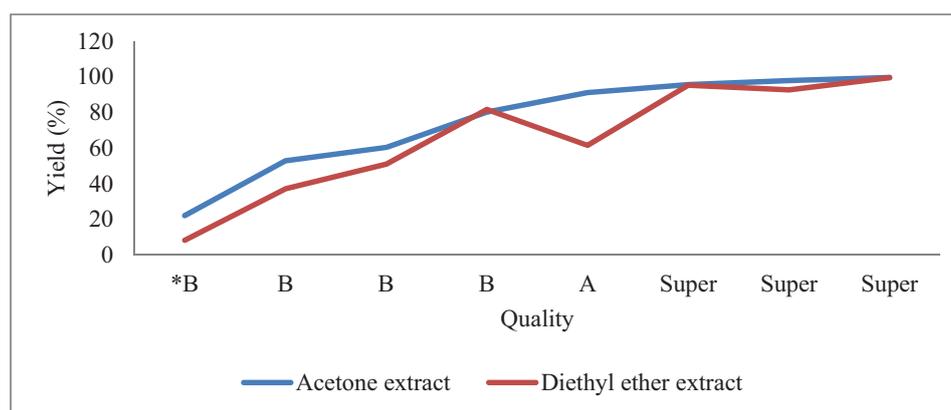


Figure 1. Linearity between acetone extract, diethyl ether extract, and quality of dragon's blood according to SNI 1671:2010

### 3.3 Chemical Markers in Dragon's Blood

Chemical constituents have been identified using GC-MS. There were 59 different compounds detected, however, only 7 that have similarity of higher than 80% as compared to the available database in Wiley 7N/2008 (Table 3). Dracorhodin and 3,4-dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol are almost consistently detected in all samples, followed by 3,4-dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol. The structure of these proposed chemical constituents are depicted in Figure 2.

Table 3. Chemical constituents detected by GCMS equipped with Wiley 7N/2008 database of each sample correspond to quality based on SNI 1671:2010

Compound	Aceh	Medan	Jambi	Jambi	Aceh	Jambi	Jambi	Jambi
	1		1	5	2	3	4	2
	*B	B	B	A	Super	Super	Super	Super
Dracorhodin	√	√	√	√	-	√	√	√
3,4-Dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol	√	√	-	√	-	√	√	√
Trendione	√	√	-	-	-	√	√	-
Linoleic acid	√	√	√	-	√	-	-	-
2,6,10,14-Tetramethyl-pentadecane	-	-	-	-	-	√	√	√
4-(4-Ethylcyclohexyl)-1-pentyl-cyclohexene	√	√	-	-	√	-	-	-
7-Pentadecyne	√	√	-	-	√	-	-	-

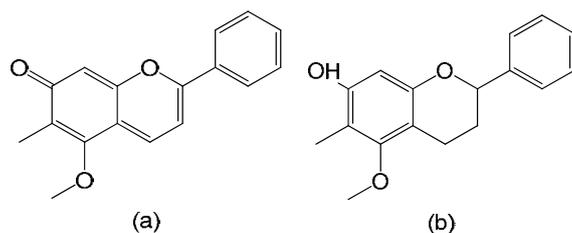


Figure 2. Chemical structures of dracorhodin (a) and 3,4-dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol (b)

Dracorhodin has been reported in the literatures [8-10]. Some previous work also reported dracorhodin and its derivatives as dyes in art articles since 15<sup>th</sup> century [11]. Dracorhodin is claimed to be a derivative of anthocyanins, a natural dye in dragon's blood resin [12]. 3,4-Dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol in this study is also detected in all samples that contain dracorhodin and never been appeared in the literature as a chemical marker of dragon's blood resin.

Dracorhodin was detected in all samples except in Aceh 2. There must be other red dyes in Aceh 2 sample and was not yet identified by the existing GCMS-Wiley 7N2008 data base. 7-Pentadecyne, linoleic acid, 4-(4-ethylcyclohexyl)-1-pentylcyclohexene, and (*E*)-9-octadecenoic acid detected in this particular sample were certainly not dyes. 1-Methoxy-2-(2-methoxycarbonyl-ethyl)-3,8-dimethyldipyrin-9-carbaldehyde was the highest constituent in Aceh 2 sample.

One rational approach to measure red dyes in dragon's blood is by combining constituents, i.e. dracorhodin and 3,4-dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol. Quantitative data were obtained by multiplying areas of the GC chromatograms and the respective resin content (Table 4). There is also inconsistency between SNI qualities and the total content of these two chemical markers. The total content of these two markers is exactly consistent with the quality according to SNI that may be caused by other pigments that could not be identified by the analytical instrument being used. Nevertheless, content of red dyes seems to be more objectively followed in determining the quality of dragon's blood commodity.

Table 4. Dracorhodin and benzopyrene contents (in % w/w of resin) listed according to quality of dragon's blood

Sample	SNI based	Dracorhodin	3,4-Dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol	Total
Aceh 2	B	-	-	-
Aceh 1	B	1.38	1.16	2.54

Medan	B	1.84	2.24	4.08
Jambi 4	Super	2.42	2.78	5.20
Jambi 3	Super	4.05	4.87	8.92
Jambi 1	B	3.08	5.86	8.94
Jambi 5	A	6.54	2.86	9.40
Jambi 2	Super	3.99	6.50	10.49

### 3.4 Rapid Measurement of The Chemical Markers

As previously mentioned, the acetone extract is correlated with the quality based on SNI. On the other hand, the total content of dracorhodin and 3,4-dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol is not consistently increasing with the increasing quality of the resin. In our attempt to find a new method to expedite the measurement of quantitative parameters, ultraviolet-visible wavelength was indeed useful. It is interesting to note that the increasing acetone extract was positively correlated with the increasing absorbance at 473 nm, as well as the increasing the resin quality (Figure 3). Dracorhodin and its variants in different pH at 477 nm have been studied [12]. The workers also stated that dracorhodin is stable quinoid base and constitutes the major species at pH 4-7. This finding, based on the study of all equilibrium constants, implies that does not fit the commonly accepted definitions of anthocyanidin nor 3-deoxy-anthocyanidin.

One of the parameters in SNI is color intensity, which is easily measured using UV-visible spectroscopy. Extended double bonds in dracorhodin and 3,4-dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol facilitated the rapid measurement in determining the quality rather than using GCMS. The acetone extraction must be able to capture all pigments in the material being study. However, absolute quantitative measurement requires pure compounds as has been developed [13]. Based on this experiment, a range of absorbance value can be proposed, namely for super quality, the absorbance shall be  $> 0.50$ , for A quality is  $0.20-0.49$ , and for B quality is  $<0.20$ .

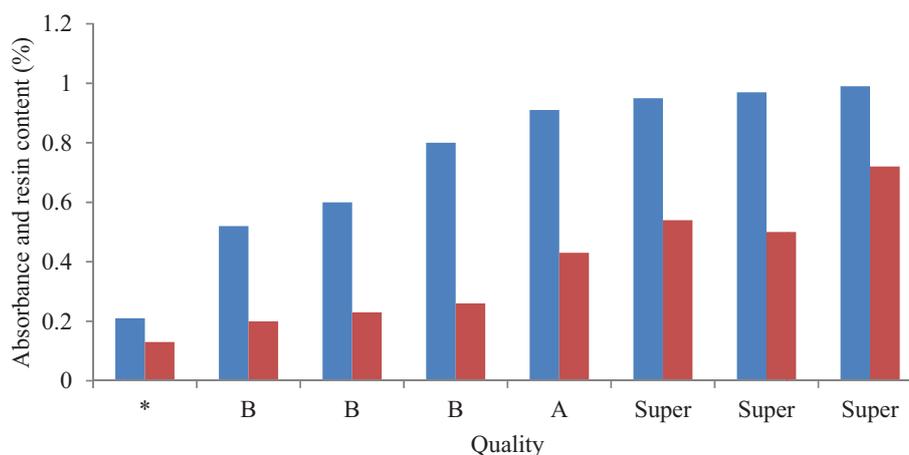


Figure 3 Correlation between resin content (■) and absorbance (■) of dragon's blood according to its quality

## 4. CONCLUSION

Chemical markers that have been confirmed contained in dragon's blood resin are dracorhodin and 3,4-dihydro-5-methoxy-6-methyl-2-phenyl-2H-1-benzopyran-7-ol. These are constituents that are extracted along with other pigments in acetone extract. Further, the absorbance of acetone extract at 473 nm can be proposed as a quantitative parameters stipulated in SNI. Acetone extraction is better than that of soxhlet extraction using diethyl ether and the value of absorbance is a quantitative method in replacing visual method in the SNI. Quantitative measurement using UV-Vis spectrophotometer requires pure forms of these two chemical markers.

## ACKNOWLEDGMENT

Funding came from the Directorate General of Higher Education, the Ministry of Education and Culture through grant *Kerja Sama Antarlembaga dan Perguruan Tinggi (313/SP2H/PL/ Dit.Litabmas/IX/2012)*. Appreciation goes to Mr. TK Waluyo for the samples.

## REFERENCES

- [1] M. Grieve. "Dragon's Blood [Internet]." [accessed 2012 Mar 21]. Available on: <http://www-botanical.com/botanical/mgmh/d/dragon20.html>.
- [2] J. J. W. Coppen. "Gum, Resin, and Latexes of Plant Origin: non Wood Products." Rome: FAO. 1995.
- [3] D. Gupta and R. K. Gupta. "Bioprotective properties of dragon's blood resin: in vitro evaluating of antioxidant activity and antimicrobial activity." *BMC Complem. Altern. Med.*, vol 11, no. 13, pp. 1-9, 2011
- [4] National Standardization Agency (BSN). "Dragon's blood" Indonesia National Standard 1671-2010 (in Indonesia). Jakarta: Badan Standardisasi Nasional. pp. 7. 2010
- [5] AOAC, Association of Official Analytical Chemistry. "Official Methods of Analysis of AOAC International. AOAC 920.156 2005 and AOAC950.46 (B)." Maryland: AOAC. 2005
- [6] S. L. Forda, R. R. Steinerb, R. Thierickec, R. Younga, and W. H. Soinea. "Dragon's blood incense: misbranded as a drug of abuse?" *Forensic Sci. Internat.*, vol. 115, pp. 1-8, 2001
- [7] M. M. Sousa *et al.* "Flavylium chromophores as species markers for dragon's blood resins from *Dracaena* and *Daemonorops* trees." *J Chromat. A*, vol. 1209, pp. 153-161, 2008
- [8] H. Brockman and H. Junge. "Constitution of dracorhodin, a new pigment from "dragon's blood". *Berichte der Deutschen Chemiscen Gesellschaft*, vol. 76, pp. 751-763, 1943
- [9] M. Xia *et al.* "Dracorhodin perchlorate induces apoptosis via activation of caspases and generation of reactive oxygen species." *J. Pharm. Sci.*, vol. 95, no. 2, pp. 273-28, 2005
- [10] D. Gupta, B. Bleakley, and R. K. Gupta. "Dragon's blood: botany, chemistry, and therapeutic uses." *J Ethnopharmacol.*, vol. 115, no. 3, pp. 361-380, 2008.
- [11] U. Baumer and P. Dietemann. "Identification and differentiation of dragon's blood in works or art using gas chromatography/mass spectrometry." *Anal. Bioanal. Chem.*, vol. 397, no. 3, pp. 1363-1376. doi: 10.1007/s00216-010-3620. 2010
- [12] J. M. Melo *et al.* "Identification of 7,4'-dihydroxy-5-methoxyflavylium in "dragon's blood": To be or not to be an anthocyanin." *J Eur Chem.*, vol. 13, no. 5, pp. 1417-1422. doi: 10.1002/chem.200600837, 2007
- [13] J. Shi, R. Hu, Y. Lu, C. Sun, and T. Wu. "Single-step purification of dracorhodin from dragon's blood resin of *Daemonorops draco* using high-speed counter-current chromatography combined with pH modulation." *J Sep Sci.*, vol. 32, no. 23-24, pp. 4040-4047, doi: 10.1002/jssc.200900392, 2009

## Acidogenic Fermentation of Palm Oil Mill effluent (POME) on Volatile Fatty Acids production as Precursor

Martha Aznury<sup>a,b\*</sup>, Azis Trianto<sup>a</sup>, Adi Pancoro<sup>c</sup>, Tjandra Setiadi<sup>a</sup>,

<sup>a</sup>Department of Chemical Engineering Faculty of Industrial Technology,  
Institut Teknologi Bandung, Labtek X, Jl. Ganesha 10, Bandung 40132, Indonesia

<sup>b</sup>Department of Chemical Engineering, Politeknik Negeri Sriwijaya, Palembang

<sup>c</sup> School of Life Sciences and Technology, Institut Teknologi Bandung  
Labtek XI, Jl. Ganesha 10, Bandung 40132, Indonesia

\*Email : martha\_aznury@yahoo.com

### ABSTRACT

Acidogenic fermentation of palm oil mill effluent (POME) can serve as a precursor in a process for production of polyhydroxyalkanoates (PHA) since the produced volatile fatty acids (VFAs) are preferred precursor for PHA production. Acidogenic fermentation of POME was studied in a 2-L reactor with semi-continuous mode operation (once-a-day feeding and draw-off) for optimal volatile acid compositions. Main fermentation products were acetic acid, propionic acid and butyric acid. The results showed acetic acid, propionic acid, and butyric acid with concentrations are 2.79 g/L; 1.18 g/L, and 3.04 g/L, respectively. VFAs that serves as a precursor on PHA production. The result of feeding of synthetic of VFAs or VFAs from POME at the 20<sup>th</sup> and 40<sup>th</sup> in a batch show the concentrations DCW and PHA are 2.38 g/L and 0.74 (g PHA/g DCW) or 2.76 g/L and 0.74 (g PHA/g DCW), respectively.

### Keywords

*Palm oil mill effluent (POME), Volatile Fatty Acid (VFAs), acidogenic, Polyhydroxyalkanoate (PHA)*

### 1. INTRODUCTION

Indonesia is the world largest producer of palm oil [1]. The palm oil extraction from the fresh fruit bunches (FFB) of palm involves a number of processing procedures: sterilization, stripping, digestion, pressing, classification, purification and vacuum drying for which large quantities of water required [2]. The process of one tonne FFB needs about 1.5 m<sup>3</sup> of water, half of this amount ends up as palm oil mill effluent (POME) [2]. In the year 2011, the government is targeting production of FFB for about 35 tonnes/Ha/Y with an area of 7.8 million hectares of plantation, indicating more than 200 million tonnes of POME was generated from around 490 mills in Indonesia [3].

Wastewater treatment in the palm oil industry done by a multistage process that utilizes the pools open. The core component of this process is the biodegradation of organic waste. Anaerobic decomposition of organic matter decomposition compound includes a compound of organic acids and further broken down into gas and water. Methane is formed during wastewater treated in open ponds. Methane off the air will increase the threat of global warming, because methane in air will react with water to form carbon dioxide and water. Reactions that occur in the air causes the accumulation of methane gas and carbon dioxide as well. Methane and carbon dioxide gases are gases that contribute to the greenhouse effect causing global warming synergism [4].

POME has a high organic content (more than 20,000 ppm BOD) and non-toxic that could be as a carbon source in the fermentation system [5]. POME containing high levels of organic matter that could potentially contaminate the environment so that the necessary degradation of organic matter is greater POME substances are usually in complex forms that cannot be directly consumed or production other product such as polyhydroxyalkanoate (PHA).

There is a great potential to bioconvert POME to volatile fatty acids (VFAs), the followed by the recovery of acids for biosynthesis of PHA. On the other hand, species such as *Ralstonia eutropha* as a representative bacterium for PHA synthesis [6]. In a previous study, reported by Aznury [7, 8] the production of PHA with *Ralstonia eutropha* JMP 134 used VFAs POME as a precursor in batch and fed batch fermentations. The study is that effect of feeding time of VFAs POME affected of

DCW and PHA concentrations. In this paper, we present our result on effect of feeding time of VFAs POME on PHA production by *Ralstonia eutropha* JMP 134. It has been demonstrated that the composition of VFAs produced under acidogenic fermentation can be affected by environmental.

## 2. MATERIAL AND METHODS

### 2.1 Material

The main material used in the experiments was palm oil mill effluent (POME) taken from PT. Mitra Ogan South Sumatra.

#### 2.1.1 Media for *Ralstonia eutropha*

A mineral salts medium consisted of: 2.0 g/L  $(\text{NH}_4)_2\text{SO}_4$ ; 2.0 g/L  $\text{KH}_2\text{PO}_4$ , 0.6 g/L  $\text{Na}_2\text{HPO}_4$ , 0.2 g/L  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ; 20 mg/L  $\text{CaCl}_2$ , 10 mL/L trace metal solution, 0.1 g/L yeast extract was used. Trace metal solution consisted of: 1.3 mg/L  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ ; 0.2 mg/L  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ , 0.6 mg/L  $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$  and 0.6 mg/L  $\text{H}_3\text{BO}_3$ . Glucose was used as a source of carbon with a concentration of 40 g/L as a medium for inoculums development and production media. Glucose, yeast extract, and salt solution were sterilized separately at 121°C and then mixed with the inoculation aseptically. As for the pH adjusted to about 7 using 2 N HCl or 2 N NaOH [9].

#### 2.1.2 The source of carbon, nitrogen, and VFAs

The medium used in the experiment were all the same, i.e 40 g/L as carbon source, with the initial volume of 5.2 L, and urea nitrogen from with a concentration of 2 g/L, then VFAs added at 20<sup>th</sup> and 40<sup>th</sup> hours with a volume of 1 L, respectively.

## 2.2 Methods

### 2.2.1 Anaerobic fermentation of POME

POME fermented with active anaerobic microbial seed. Active microbial seeds are added to the oil palm industry waste water with a ratio of 1 L: 4 L in a batch bioreactor with a volume of 8 liters. Anaerobic fermentation is taken and replaced with POME with a ratio of 1 L: 1 L per day. Then, POME fermented has distillation to get VFAs.

### 2.2.2 Analyses and VFAs and Glucose

The content of residual VFAs was determined and described in standard methods [12]. Organic acids and glucose were detected by HPLC (Agilent 1100 equipped with and RID detector, USA) with an Aminex HPX-87 column (300 mm x 7.8 mm, Biorad, USA) at a column temperature of 60 °C, and 0.0055 M  $\text{H}_2\text{SO}_4$  as mobile phase. The injection volume was 20  $\mu\text{l}$ . The eluted time for glucose, acetate, propionate and butyrate was at about 10.7, 15.6, 17.9 and 21.8 min, respectively.

### 2.2.3 Analyses of PHAs

Samples were collected at every 20 hour intervals during incubation and pH was measured using an Ecoscan Hand-held series pH meter (Eutech Instruments, Singapore). At 20<sup>th</sup> until 200<sup>th</sup> hours, 50 ml samples were collected to determine cell dry weights.

In determining the concentration of PHA, biopolymer contained in the cells extracted with the addition of sodium hypochlorite and chloroform on the cell as has been described by Jacquelin N. et al [10]. PHA dissolved in chloroform was analyzed by concentration crotonic acid conducted by Slepecky and Law [11].

### 2.2.4 Experimental Set-Up

The set-up consisted of two bench-scale reactors and a distillation equipment (Fig. 1). The acidogenic fermentation of POME was carried out in a batch reactor under anaerobic conditions.

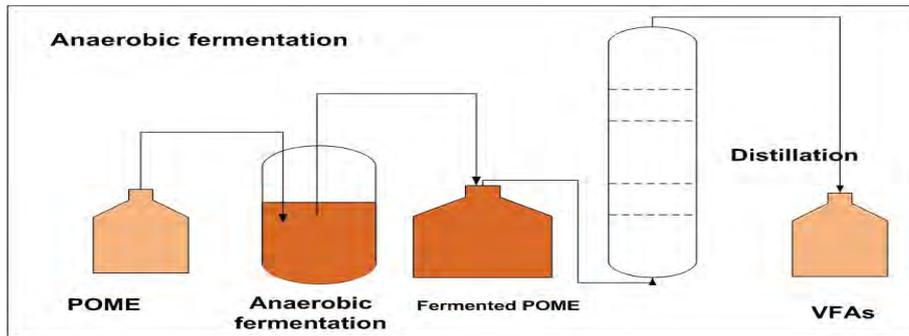


Figure 1: Process POME to VFAs Production

### 3. RESULTS AND DISCUSSION

#### 3.1 Anaerobic fermentation

The batch anaerobic fermentation was conducted to assess determine complexity organic compounds of POME that could be converted into VFAs. The main products produced from fermentation is VFAs. The results of measurements of VFAs shown in Figure 2. VFAs levels before treatment amounted to 8942.39 mg/L, after 1 day of fermentation increased to 10082.1 mg/L. In fermentation 2 and 3 days had concentration VFAs 9862.93 mg/L and 9766.49 mg/L, respectively. The longer the fermentation time will reduce levels of VFAs produced. The concentration of VFAs was 8978.46 mg/L on 4 days fermentation.

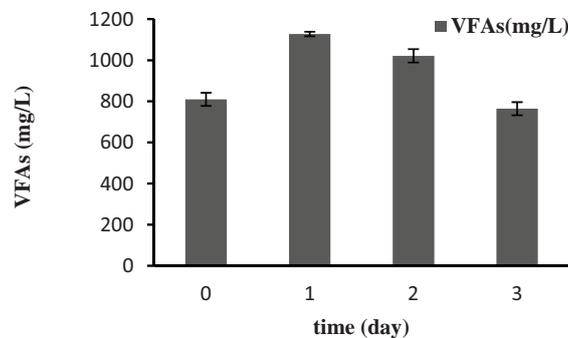


Figure 2: Concentration VFAs from fermented anaerobic POME

Anaerobic fermentation applied as a pretreatment to convert the organic acids into the various components of VFAs which increases the potential for producing PHA from wastewater [12]. Hydrolysis and acidogenesis were early stage to produce organic acids, such as acetic acid, propionic, and butyric which can be used for the synthesis of PHA. Hydrolysis of complex organic components in the POME more soluble compounds. Through the process of acidogenesis, the compound breaks down into VFAs and other monomers. Acidogenesis microbes can produce an acidic solution comprising a mixture of acetic acid and propionic acid or acetic acid and butyric acid [13].

Levels of acid produced in POME correlated with pH value. The results of pH shown in Figure 3, the pH of POME before fermentation was 4.48. The pH value decreased was 4.43 on 1 day fermentation. Fermentation for 2 days at pH values up to 4.67. For fermentation 3 and 4 days was an increase in pH to 4.71 and 4.82, respectively. This resulted in a pH value tends to increase when the fermentation time be longer.

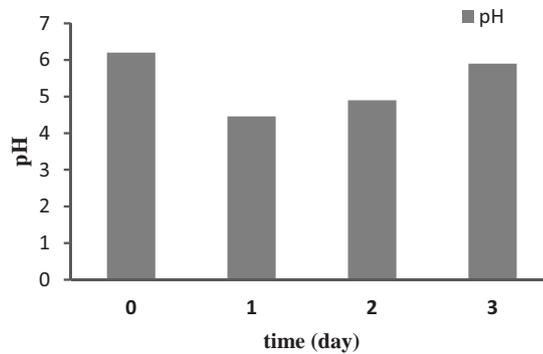


Figure 3: The change of pH with time from anaerobic fermentation

Data anaerobically fermented POME shows the time to produce the fermentation VFAs on the first day because of the acid produced is quite high, which is about 10000 mg/L or 10 g/L. VFAs concentrations used in these experiments is similar to the acid content 10.3 g/L in batch fermentation POME [14].

POME was also analyzed for total nitrogen content. Analysis of total nitrogen content using a Buchi (Buchi 412 scrubber, Buchi 435 digestion unit, Buchi 339 Distillation unit, Germany). Total nitrogen content of POME early, after fermented and fermented wastewater and distilled after each is 136.68 g/L, 183.07 g/L, and 0 g/L, respectively. The ratio of total nitrogen content can be seen in Figure 4.

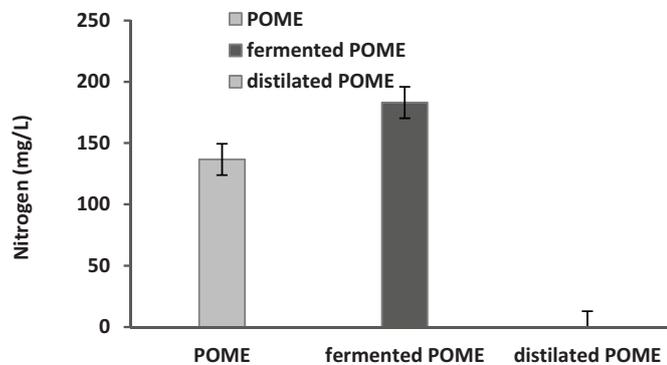


Figure 4: Comparison nitrogen content from POME, fermented POME, and distilled POME

POME has been distilled showed levels of total nitrogen was 0 g/L and containing VFAs. So later in the text will be written is the VFAs from POME. VFAs from POME will be used as a precursor on PHA production.

POME after fermented to start for distilled to obtain pure compounds VFAs. The results of this distillation analyzed using HPLC (Waters, USA) to determine the type and concentration acidic compounds by comparing the standard of acetic acid (JT Baker), propionate acid (Merck), and butyric acid (Sigma-Aldrich). Figure 5 showed concentration of acetic acid, propionate acid and butyric acid from POME, fermented POME, and distilled POME.

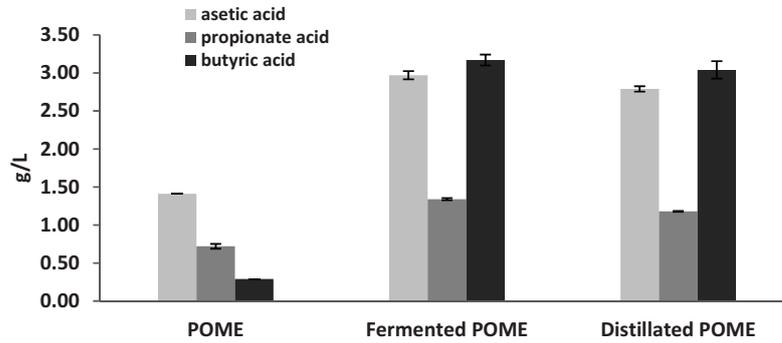


Figure 5: Comparison acetic acid, propionate acid, and butyric acid from POME, fermented POME, destilated POME

POME fermented anaerobic on VFAs production for 1 day and at pH 4.43. POME and fermented POME also contain other fatty acids such as citric acid, formic acid, and malonic acid, while for distillation POME had acetic acid, propionate acid and butyric acid. The results VFAs from POME had acetic acid, propionate acid and butyric acid that the concentration were 1.41 g/L; 0.72 g/L, and 0.29 g/L, respectively. While fermented POME produced acetic acid, propionate acid and butyric acid were 2.97 g/L; 1.34 g/L, and 3.17 g/L, respectively. Destilated POME produced acetic acid, propionate acid and butyric acid, were 2.79 g/L; 1.18 g/L, and 3.04 g/L, respectively. VFAs from destilated POME would used to feed as precursor of Synthetic VFAs on PHA production.

Hassan, et al [15] got the levels of concentration of VFAs from POME depending on the pH of the fermentation. Fermented POME at pH 4 got formic acid, acetic acid, and propionic acid with 1.4 g/L , 4.4 g/L , and 0.5 g/L, respectively. Then fermentation at pH 7 consisted acetic acid and propionic acid with concentration 6.6 g/L and 1.2 g/L, respectively [15].

### 3.2 Application: VFAs as precursor on PHA Production

VFAs from POME were added 1 liter in the batch fermentation at the 20<sup>th</sup> and 40<sup>th</sup> hours. Consumption of glucose, acetic acid, propionate acid, and butyric acid analyzed at the 0<sup>th</sup> to 200<sup>th</sup> hours. Figure 6 shows the cells to consume glucose and VFAs from POME. The concentration of glucose consumed by bacteria as source of growth at the 0<sup>th</sup> to 160<sup>th</sup> hours. Glucose concentration shows a very drastic decrease in the concentration from 20.77 g/L to 3 g/L at the 60<sup>th</sup> to 80<sup>th</sup> hours. The concentration of glucose decreased indicates that the cells require a source of the other substrates on PHA production.

VFAs consumption were an after adaptation phase at the 60<sup>th</sup> and 80<sup>th</sup> hour. The increase of consumption VFAs were need cell on PHA production. VFAs consumption ceased when glucose had also begun to run out can be seen at the 120<sup>th</sup> hour.

Butyric acid consumption was faster consumed than acetic acid and propionate acid by the cell. Effect of addition of VFAs as a precursor suggests that the ability of cells to consume each of the different acids. Effect of high concentrations VFAs will be inhibitory or toxic thus may result in a low growth rate and PHA content [16].

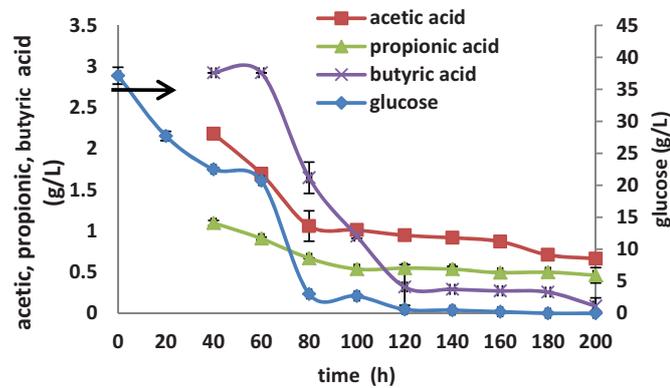


Figure 6. Effect of feeding time of precursor VFAs from POME in batch fermentation at the 20<sup>th</sup> and 40<sup>th</sup> of the consumption of glucose, acetic acid, propionate acid, and butyric acid.

Figure 7 shows concentration of DCW and PHA increased during the first reflected the cell growth at the 20<sup>th</sup> hour. VFAs from POME did not significantly affect the growth of bacteria due to the concentration of DCW at the 20<sup>th</sup> and 40<sup>th</sup> hours were 0.29 g/L and 0.4 g/L, respectively. VFAs had not inhibit cell on growth phase. While the highest number of DCW fermentation occurs in the 200<sup>th</sup> hour was 3.66 g/L. Graph the rate of cell growth has been through a phase when compared to static fermentation at the 160<sup>th</sup>, and 180<sup>th</sup> were 3.57 g/L, and 3.66 g/L, respectively. So the increase ranged only from 0.09 g. A small increase was indicates that the cell has experienced a static phase.

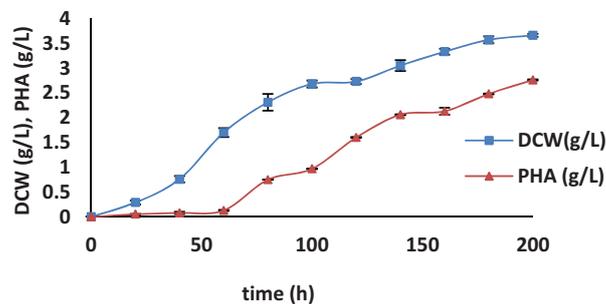


Figure 7. Effect of feeding time of precursor VFAs from POME at the 20<sup>th</sup> and 40<sup>th</sup> hours on production of DCW and PHA

The highest concentration and content of PHAs were 2.76 g/L and 0.75 (g PHA/g DCW) at the 200<sup>th</sup> hour. PHAs were also the rate of increase began to decline from from 160<sup>th</sup> to 200<sup>th</sup> hours and ranged from 0.28 to 0.35. PHAs content in the cell begins to decline or already depolymerization by cells for energy. The cells harvest to produce PHA at the 200<sup>th</sup> hour.

#### 4. CONCLUSION

Acidogenic fermentation of POME in batch resulted in VFAs production. With the condition applied in 1 day and at pH 4.43 the main fermentation products were acetic acid, propionate acid and butyric acid. The composition and concentration of POME acetic acid, propionate acid and butyric acid, were 2.79 g/L; 1.18 g/L, and 3.04 g/L, respectively. For the used VFAs from POME as a precursor in batch and fed batch fermentations. The result of feeding of synthetic of VFAs or VFAs from POME at the 20<sup>th</sup> and 40<sup>th</sup> in a batch show the concentrations DCW and PHA are 2.38 g/L and 0.74 (g PHA/g DCW) or 2.76 g/L and 0.74 (g PHA/g DCW), respectively. The application for this research was that effect of feeding of VFAs from POME affected on DCW and PHA concentrations.

## ACKNOWLEDGMENT

The authors would like to acknowledge the financial support of **Riset DIPA ITB**, Directorate General of Higher Education provides funding research project grants No: 670B/KO1.09/PL/2010, Date: 1 APRIL 2010, entitled Product Bioplastics from Wastewater Industrial Agriculture uses Microbial Fermentation.

## REFERENCES

- [1] BPS Indonesia, *Produksi Perkebunan Besar menurut Jenis Tanaman, Indonesia (Ton)*, 1995 - 2009, <http://www.bps.go.id/> (3 January 2010).
- [2] Mumtaz T., N. A. Yahaya, S. Abd-Azi., N. A. Rahman, P.L. Yee, Y. Shirai, M. A. Hassan, *Turning waste to wealth-biodegradable plastics polyhydroxyalkanoates from palm oil mill effluent - a Malaysian perspective*, *Journal of Cleaner Production* 18, 2010, pp. 1393-1402.
- [3] IOPRI, *Pertemuan teknis kelapa sawit 2011; kiat mencapai 35-26 industri kelapa sawit*, <http://iopri.org/ptks2011>, (1 April 2011).
- [4] Henderson, M. Science Editor, *Methane's impact on global warming far higher than previously thought*, [http://www.timesonline.co.uk/tol/news/science/earth\\_environment](http://www.timesonline.co.uk/tol/news/science/earth_environment), *The Times*, download 1 January 2010
- [5] Hassan, M.A., Nawata, O., Shirai, Y., Nor Aini, A.R., Yee, P.L., Arif, A. and Abdul Karim, M.I. *A proposal for zero emission from palm oil industry incorporating the production of polyhydroxyalkanoates from palm oil mill effluent*. *J. Chem. Eng. of Japan.*, 35(1), 2002, pp. 9-14.
- [6] Salim MR, Ujang Z, Muhd Yunus S, Md Din MF, Ahmad MA. *Biodegradable polymer production from POME using activated enriched sludge by coupled aerobic and anaerobic system*. 4th Seminar on Water Management (JSPS-VCC). Johor, Malaysia; 2006, pp. 153-9.
- [7] Aznury, M., A. Pancoro, T. Setiadi, *Pengaruh Sumber Karbon terhadap Produksi Bioplastik Polihidroksialkanoat (PHA) dengan Ralstonia eutropha*, *Jurnal Teknik Kimia Indonesia*, 9(1), 2010, hal. 28-32.
- [8] Aznury, M., A. Trianto, A. Pancoro, T. Setiadi, *Effect of feeding time of volatile fatty acids from palm oil mill effluent on production of polyhydroxyalkanoates by Ralstonia eutropha JMP 134 in batch fermentation*, *Prociding The 5<sup>th</sup> AUN/SEED-Net Regional Conference on Global Environment*, 2012
- [9] Khanna S., dan A.K. Srivastava, *Production of poly(3-hydroxybutyric-co-3-hydroxyvaleric acid) having a high hydroxyvalerate content with valeric acid feeding*, *J Ind Microbiol Biotechnol* 34: 2007, pp. 457-461.
- [10] Jacquelin, Lo CW, Wei YH, Wu HS, Wang SS. *Isolation and purification of bacterial poly(3-hydroxyalkanoates)*. *Biochem Eng J*; 39:2008, pp. 15-27.
- [11] Slepecky, R.A., and Law, J.H., *Anal. Chem.* 32, 1969, pp. 1697-1699.
- [12] Bengtsson, S., Werker, A., Christensson, dan M., Welander, T., *Production of Polyhydroxyalkanoates by Activated Sludge Treating a Paper mill Wastewater*, *Bioresource Technology*, 99, 2008, pp. 509-516.
- [13] Yu, J., Y.Si, and W. K. R. Wong, *Kinetics modeling of inhibition and utilization of mixed volatile fatty acids in the formation of polyhydroxyalkanoates by Ralstonia eutropha*, *Process Biochemistry* 37, 2002, pp. 731-738.
- [14] Hassan, M.A., Nawata, O., Shirai, Y., Nor Aini, A.R., Yee, P.L., Arif, A. dan Abdul Karim, M.I. : *A proposal for zero emission from palm oil industry incorporating the production of polyhydroxyalkanoates from palm oil mill effluent*. *J. Chem. Eng. of Japan.*, 35(1), 2002, pp. 9-14.
- [15] Hassan MA, Shirai Y, Kusubayashi N, Karim MIA, Nakanishi K, Hashimoto K. *Effect of organic acid profiles during anaerobic treatment of palm oil mill effluent on the production of polyhydroxyalkanoates by Rhodospirillum rubrum*. *J Ferment Bioeng*; 82, 1996, pp. 151-6.
- [16] Axe, D.D. dan Bailey, J.E, *Transport of lactate and acetate through the energized cytoplasmic membrane of Escherichia coli*. *Biotechnol Bioeng* 47, 1995, pp. 8-19.

## Bio-refinery Study in Crude *Jatropha* Oil Process : Co-digestion Sludge of Crude *Jatropha* Oil and Capsule Husk *Jatropha curcas* Linn as Biogas Feedstocks

Roy Hendroko<sup>a</sup>, Ahmad Wahyudi<sup>b</sup>, Satriyo K. Wahono<sup>c</sup>, Praptiningsih G.A<sup>d</sup>, Salafudin<sup>e</sup>,  
and Tony Liwang<sup>f</sup>

<sup>a</sup>Graduate Student – Renewable Energy University of Darma Persada, Jakarta 13450  
Tel : (062)8159555028

E-mail : roy\_hendroko@hotmail.com

<sup>b</sup>Faculty of Agriculture and Animal Husbandry University of Muhammadiyah, Malang 65144  
Tel : (062)8113609227

E-mail : wahyudi\_biotek@yahoo.co.id

<sup>c</sup>Technical Implementation Unit for Development of Chemical Engineering Processes – Indonesian Institute of Sciences, Yogyakarta 55861  
Tel : (062)8157741020

E-mail : dna\_tqim@yahoo.com, satriyo.krido.wahono@gmail.com

<sup>d</sup>Faculty of Agrotechnology University of Merdeka, Madiun 63131  
Tel : (062)8155505260

E-mail : praptiningsih.ga@gmail.com

<sup>e</sup>Faculty of Chemical Engineering, ITENAS, Bandung 40123

Telp (062) 81322326381

E-mail : salafudin2004@yahoo.com

<sup>f</sup>PT Sinarmas Agroresources and Technology Tbk., Jakarta 10350

Telp (062)8811230417

E-mail : tony-liwang@smart-tbk.com

### ABSTRACT

One of the cultivation failure reasons of *Jatropha curcas* Linn (JcL) in Indonesia was only recommended for Crude *Jatropha* Oil (CJO) production which is processed into biodiesel. CJO is only 17-25% of dry seeds weight, while the waste residue is called seed cake. Another waste is dried capsule husk (DH-JcL) about 30-80% of fresh fruit weight and sludge CJO (S-JCO) about 2-5% of the CJO. S-CJO was unutilized which is bad for the ecological when disposal. The research objective was utilization of S-CJO waste for bio-refinery and improvement productivity of biogas made from DH-JcL. The study was conducted at the research garden of PT Bumimas Ekapersada, Bekasi, West Java in November - December 2012. A liter one-stage digester was compiled completely randomized design (CRD) with three replications in water bath on 32°C. The materials are DH-JcL of JatroMas cultivars in toxic category which was mixed with sludge S-CJO as co-substrate about 10% and water in 1:8. Observation variables were biogas production volume (water displacement method), pH and temperature in the outlet slurry. The preliminary study concludes that S-CJO appropriate as co-substrate DH-JcL. It can increase the biogas productivity with feed in less than 10% of S-CJO per day.

### Keywords

Biogas , co-digestion, capsule husk, sludge crude *jatropha* oil, *Jatropha curcas* Linn.

**This paper is published in International Journal of Technology (IJTech)**



This waste pineapple juice is no value for foods, and industrial chemical products. At the present time, the local markets are negligible for waste pineapple juice. Biomass or biological material <sup>[3]</sup> can be used for the production of several products, namely; (1) Fuel and energy such as bioethanol, methanol, fuel oil; (2) Biochemicals such as activated carbon, oxy fuel additive, furfural (3) Fatty and acetic acid, industrial surfactants, and agricultural chemicals, (4) Biomaterials.

## 1.2 The research problem

There is a lot of waste pineapple juice as food waste material has been known, but it is not fully developed and implemented to produce foods and industrial chemicals. A problem of flow rate of waste pineapple juice as substrate and inoculum concentration of *Saccharomyces cerevisiae* in the immobilized cell bioreactor of *Saccharomyces cerevisiae* into ethanol production is not developed and implemented into a large scale. Scaleup of batch bioreactor for an aerobic fermentation of acetic acid is not fully developed and implemented. One of the problems is the bioconversion of a low grade ethanol of about 6 % into acetic acid product. The price of ethanol concentration of about 6% is cheaper than the price of acetic acid product. Acetic acid is a low volume but a high price, on the other hand ethanol is a high volume but a low price

## 3. The objective

The first **objective** is to study immobilization cell bioreactor of *Saccharomyces cerevisiae* inoculum of 2.5%, 5%, 7.5%, and 10% by volume, respectively in the waste pineapple juice as a substrate into ethanol product and the second objective is to study the effect of temperature of 25°C, 30°C, 35°C, 40°C and inoculum concentration of *Acetobacter aceti* of 2.5%, 5%, and 10% by volume, respectively in the ethanol fermentation by *Acetobacter aceti* into acetic acid product. The third objective is to study a verbal model of scale up of a batch bioreactor for acetic acid fermentation in terms of impeller speed N and impeller diameter D.

## 1.4 The benefit

The **benefit** of this research is to increase the additional income for the pineapple farmers in rural areas, and to utilize waste pineapple juice for chemical product of ethanol and acetic acid in order to eliminate waste pineapple juice and finally acetic acid product can be used for food condiments, to increase food flavour, to preserve foods in order to get ecologically sound technologies and good environmental condition. Scale-up of immobilized cell bioreactor of *Saccharomyces cerevisiae* for ethanol production and a batch bioreactor for aerobic fermentation of acetic acid can be used for a large scale operation.

## 1.5 The original finding of this research

The original finding of this research is the approach in the immobilized cell bioreactor of *Saccharomyces cerevisiae* by supported with an insoluble material of pressed solid waste of pineapple fibre and flow rate of substrate in order to cut fermentation time course of ethanol production by *Saccharomyces cerevisiae* inoculum and it can be used for the innovation process and equipment design. The other original findings of this research are the determination of constant for the design of batch bioreactor and it can be used for the process design of innovation process and equipment in the acetic acid fermentation.

## 2. MATERIALS AND METHODS

### 2.1 Preparation of *Saccharomyces cerevisiae*

*Saccharomyces cerevisiae* preparation starts from reaction tubes with pure culture on sterile agar medium in incubator, thus, inoculum was prepared as a step by step employing increasing volume. The initial inoculation from a stock culture of *Saccharomyces cerevisiae*, require the transfer of approximately of 0.5 % to 5%. Scale up of seed culture of *Saccharomyces cerevisiae* from a reaction tube into a erlenmeyer flask of 100 mL scale into a bigger scale was done.

### 2.2 Substrate of waste pineapple juice

Solid waste of pineapple was washed by the wet cleaning method in order to remove all contaminants and it was ground in order to achieve the desired size of solid waste of pineapple. Waste pineapple juice was added by water in the ratio of 1:1 and then this mixture was ground in order to obtain slurry of waste pineapple juice and this slurry was separated by filtration method by a hydraulic press in order to get filtrate and a fine fibre of cellulose solid waste. Filtrate can acts a substrate of ethanol fermentation and a fine fibre of cellulose solid waste may be packed in a column of an immobilized cell bioreactor. Sugar concentration of filtrate is 10.54%. Sugar sources for ethanol fermentation can be obtained from three sources, namely; 57,7 g sugar from 500 g solid waste of pineapple and the addition of 15% sugar is 450 g that is derived from 3,000 mL filtrate and finally, the addition of 10% sugar in the 300 mL of *Saccharomyces cerevisiae* inoculum is 30 g, so that the total amount of sugar is 532.7 g sugar in the 3,000 mL substrate for ethanol fermentation.

This filtrate as a substrate of carbon sources for an immobilized cell bioreactor of *Saccharomyces cerevisiae*. Figure 1 can be shown that binding of an immobilized cell bioreactor of *Saccharomyces cerevisiae* to a fine fibre of cellulose solid waste in the glass column of bioreactor can be used for ethanol production. Immobilized cell bioreactor consists of a glass column with a double glass wall where inside a glass column of bioreactor containing a fine fibre of cellulose solid waste as a supporting material, and outside of a glass bioreactor containing warm water of about 30°C from a water bath thermostat and circulated warm water from a water bath thermostat at temperature of 30°C in order to keep a constant temperature of 27°C inside of a glass column of bioreactor. The total a fine fibre of cellulose solid waste of 500 gram put inside a glass column of bioreactor number 5 in figure 1 and the total volume of substrate of 3,000 mL in the storage tank number 10 in figure 1. A glass column of bioreactor containing of 500 gram a small and a fine fibre of solid waste can act as to bind enzyme of *Saccharomyces cerevisiae* inoculum. Binding of enzyme that is derived from *Saccharomyces cerevisiae* to the small and a fine fibre of solid waste inside a glass column of bioreactor may be by adsorption method.

Fermentation was done as a semi continuous followed by fresh substrate of filtrate and inoculum and finally recycling of outgoing result from a glass column of bioreactor by a circulating pump from a glass column of bioreactor until the desired ethanol product.

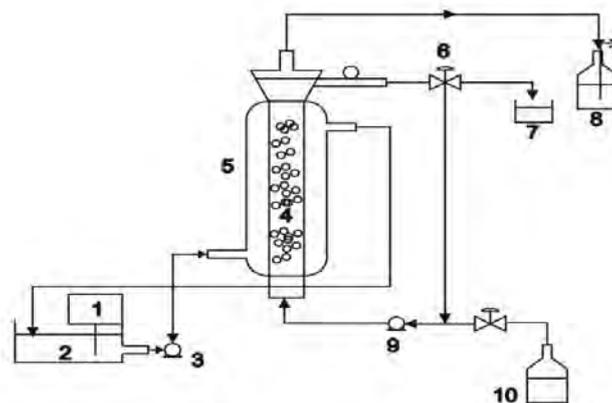


Figure 1: Completely mixed of an immobilized cell bioreactor of *Saccharomyces cerevisiae* with a fine fibre of solid waste in a glass column of bioreactor for ethanol production.

Remarks ;

1. Thermostat to keep a constant temperature,
2. Warm water at temperature of 30°C,
3. Warm water pump to circulate warm water,
4. Supported a fine fibre of solid waste,
5. A glass column of bioreactor,
6. Circulating valve,
7. Sample of ethanol collection,

8. Rinser,
9. Pump for substrate and *Saccharomyces cerevisiae*, and
10. Storage tank of substrate and *Saccharomyces cerevisiae* inoculum.

### 2.3 Preparation of *Acetobacter aceti* inoculum

Slope of a reaction tube containing medium of bacto pepton of 0.30%, dextrose of 2.5%, yeast extract of 0.50%,  $MgSO_4 \cdot 7H_2O$  of 0.02 %,  $KH_2PO_4$  of 0.10% and bacto agar of 1.5 %. Those ingredients were diluted in the sterilized water, heated, entered into a reaction tube of 5 mL volume and finally this reaction tubes were sterilized by using an autoclave at  $121^\circ C @ 20$  minutes.

### 2.4 Medium of liquid for ethanol fermentation into acetic acid

This medium containing medium of bacto pepton of 0.30%, dextrose of 0.50 %, yeast extract of 0.50%,  $MgSO_4 \cdot 7H_2O$  of 0.02%,  $KH_2PO_4$  of 0.10%. Those ingredients were diluted in the sterilized water with a total volume of 300 mL or according to the needs and it was sterilized in the autoclave at  $121^\circ C @ 20$  minutes and after that it was cooled at a room temperature. One ose of needle of *Acetobacter aceti* at the reaction tube into medium of liquid of 300 mL and then this liquid medium incubated at  $30^\circ C @ 24$  hours and after that this medium was homogenized by water bath shaker at  $30^\circ C @ 48$  hours. This inoculum can be used for the next ethanol fermentation by *Acetobacter aceti* into acetic acid.

### 2.5 Substrate of ethanol fermentation by *Acetobacter aceti* into acetic acid product

Ethanol of 6.02% (w/w) can be used as a substrate of aerobic fermentation by *Acetobacter aceti* into acetic acid product. The total volume of ethanol as a substrate of 300 mL.

### 2.6 Chemical analysis

Chemical analysis was done in terms of pH value, sugar, ethanol and acetic acid concentrations.

### 2.7 Microbiological analysis

Microbiological analysis was done in terms of total *Acetobacter aceti* by the total plate count method.

## 3. RESULTS AND DISCUSSION

### 3.1 Result of ethanol production

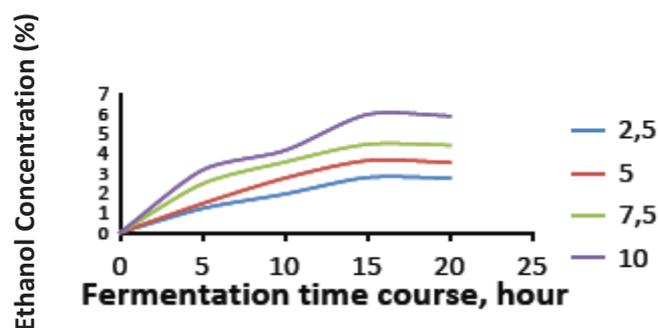


Figure 1: The effect of *Saccharomyces cerevisiae* inoculum in the immobilized cell bioreactor containing filtrate in the ethanol production

From figure 1 can be shown that the higher the *Saccharomyces cerevisiae* inoculum, the higher the ethanol concentration, because of the higher total cell

### 3.2 Result of acetic acid production

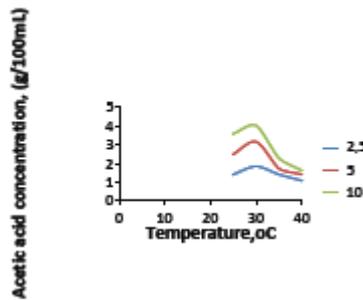


Figure 2: The effect of temperature and *Acetobacter aceti* inoculum concentration in the batch fermentation of ethanol by *Acetobacter aceti* into acetic acid production.

The fermentation medium was sterilized at 60°C@ 15 minutes to kill the residue of *Saccharomyces cerevisiae*. The sterilized fermentation medium was added by glucose of 0.5 -0.7 g/L, ammonium of 20 mg/L, phosphate of 120 mg/L and magnesium of 5 mg/L. Aerobic fermentation of 300 mL ethanol by *Acetobacter aceti* was carried out at the water bath shaker completed with a thermostat and agitation rate of 200 rpm followed by the parameters of temperature of 25°C, 30°C, 35°C, 40°C, respectively and *Acetobacter aceti* inoculum concentration of 2.5%, 5% and 10% by volume and aeration rate of 0.18 vvm in order to produce acetic acid product. The function of water bath thermostat is to keep a constant temperature. Figure 2 can be shown that the higher the temperature of about 25°C to 30°C, the higher the acetic acid concentration. The higher the temperature of 35°C, the decrease in acetic acid concentration and also the higher the temperature of 40°C, the decrease in acetic acid concentration. The temperature of 25°C to 30°C and *Acetobacter aceti* inoculum of 10% were optimal condition for the conversion of ethanol by *Acetobacter aceti* into acetic acid of 4.03 g/100 mL.

In the aerobic fermentation of ethanol by *Acetobacter aceti* mechanisms can be divided into three different kinetic patterns, namely; (1) microbial growth without product formation, (2) microbial growth associated with product formation, and (3) product formation without microbial growth<sup>[7][8][9][10]</sup>. Kinetic of microbial growth of *A. aceti* and product of acetic acid formation can be expressed as follows:

$$dC_x/dt = k_x \Phi C_x \quad (1)$$

$$dC_p/dt = k_{p1} \Phi C_x + k_{p2} (1-\Phi) C_x \quad (2)$$

where  $C_x$  = *Acetobacter aceti* concentration,  $t$  = fermentation time course,  $C_p$  = acetic acid concentration,  $k_x$  = the growth rate of *A. aceti* constant,  $\Phi$  = the coefficient of growth activity,  $k_{p1}$  and  $k_{p2}$  are the production rate constants (per hour).

### 3.3 Scale up of bioreactor

#### 3.3.1 Scale –up

Scale-up of a glass column of bioreactor for ethanol production can be done by scale up ratio that means the ratio of the bigger size or scale 2 divided by the small a glass coulumn of bioreactor or scale 1. In this cell immobilized bioreactor of *Saccharomyces cerevisiae* that product yield of ethanol depend on flow rate of a mixture substrate and inoculum. Therefore, scale up of this a glass column of bioreactor was done in terms of samll flow rate into large flow rate of a mixture of substrate and inoculum.

#### 3.3.2 Scale–up of impeller speed $N$ and impeller diameter $D$ in a batch bioreactor

Scale-up ratio =  $\frac{\text{large scale}}{\text{small scale}}$ . This example is the calculation of small bioreactor with  $N_1$  = impeller speed and  $D_1$  = impeller diameter will be scale-up into large bioreactor with  $N_2$  = impeller speed and  $D_2$  = impeller diameter.

$$N_2^3 D_2^2 = N_1^3 D_1^2 \quad (3)$$

$$N_2 = N_1 \left( \frac{D_2}{D_1} \right)^{\frac{-2}{3}} \quad (4)$$

Table 1: Scale up of the relationship between the impeller speed  $N$  and impeller diameter  $D$  in the bioreactor for ethanol fermentation by *Acetobacter aceti* into acetic acid product at the condition of temperature  $30^{\circ}\text{C}$ , impeller speeds of 100 rpm based on constant power per substrate volume.

$N_1$	$N_2$	$\left(\frac{D_2}{D_1}\right)^{\frac{2}{3}}$
100	34,20	5
00	21,54	10
100	13,57	20
100	10,36	30
100	8,55	40
100	7,37	50

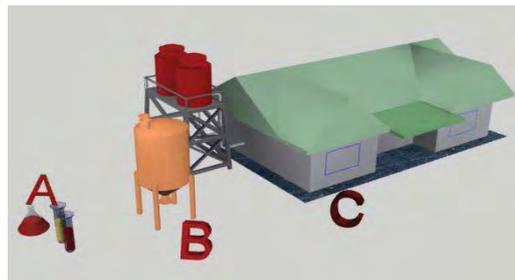


Figure 3. Transfer of scale up from the laboratory scale (A) into pilot plant (B) and finally to industrial scale (C)

#### 4. CONCLUSIONS

1. The approaches for using immobilized cell bioreactor of *Saccharomyces cerevisiae* and substrate with a fine fibre of pine apple solid waste in a glass column of bioreactor for ethanol production are to cut fermentation time course of 2 weeks into 15 hours and simple operation.
2. Scale up of a glass column of bioreactor can acts as an immobilized cell bioreactor for ethanol production depend on flow rate of substrate and inoculum concentraions.
3. The optimum of *Saccharomyces cerevisiae* inoculum is 10% at the fermentation time course of 15 hours in order to produce ethanol concentration of 6.02%.w/w.
4. The optimum condition of etahnol fermentataion by *Acetobacter aceti* were considered optimal, namely; temperature of  $30^{\circ}\text{C}$ , and *Acetobacter aceti* inoculum concentration of 10% , agiatation rate 200 rpm, aeration rate of 0.18 vvm produced the acetic acid concentration of 4.03%.
5. The innovation process and immobilized cell bioreactor of *Saccahromyces cerevisiae* can be used as basis scale up operation.
6. This research results will be one of inputs in the vertical transfer of technology of bioconversion of waste pineapple into ethanol and acetic acid for small and medium scales of ethanol and acetic acid industries.
7. Scale-up of impeller speed  $N$  and impeller diameter  $D$  in a batch bioreactor can be used for other related aerobic fermentation.

#### ACKNOWLEDGEMENT

The authors acknowledge support from the Department of Chemical Engineering, Faculty of Industrial Technology, and Research Institute (LPPM), Parahyangan Catholic University, Bandung, Indonesia made this research result can be presented in The 13<sup>th</sup> International Conference on Quality In Reserach from 25 -28 June 2013, Yogyakarta.

#### REFERENCES

- [1] Atkinson, B and Mavituna, F . *Biochemical Engineering and Biotechnology Handbook*, Macmillan Publisher Ltd, England, 1983, pp.1015-1016.
- [2] Kamm. B., Gruber, P.R., Kamm, M. *Biorefineries Industrial Processes and Products*, Wiley-VCH Verlag GmbH & Co, KgaA, Weinheim, Germany, 2006, pp. 385-389.
- [3] Austin, G.T. *Shreve's Chemical Process Industries*, 5<sup>th</sup> Edition, Mc Graw-Hill International Editions, New York, 1984, p 583.

- [4] Wang,D.I.C; Cooney, C.L; Demain, A.L; Dunhill, P; Humphrey, A. E; and Lilly, M.D. *Fermentation and Enzyme Technology*, John Wiley & Sons,New York, 1978, pp. 41 and 197.
- [5] Richardson,K.C. *Submerged Acetification of a Vinegar Base Produced from Waste Pine Apple Juice*,*Biotechnol.Bioeng.*, 9. 171-176.1967.
- [6] Maldonado,O., Rolz,C., and Schneider,S. *Wine and Vinegar Production From Tropical Fruits*, *J. Food. Sci*,40, 262-265, 1975.
- [7] Aiba,S., Humphrey, A.E., and Millis, N. E. *Biochemical Engineering*, Academic Press, New York, 1965, p.17
- [8] Gaden,E.L. *Fermentation Process Kinetics*, *Biochem. Microbiological. Tech. and Eng.*, 1, 4, 413-415,1959.
- [9] Kono,T. *Kinetics of Microbial Cell Growth* *Biotechnol. Bioeng.*,10, 105-109,1968.
- [10] Kono,T and Asai,T.*Kinetics of Fermentation Process*, *Biotechnol. Bioeng.*,9, 293-298.1969.

# Cellulase from *Bacillus* sp. BPPT CC RK 2 for Saccharifying Process using Pulp and Paper Industry Sludge

Siswa Setyahadi

*Center for Bioindustrial Technology, Agency for the Assessment and Application of Technology.*

## ABSTRACT

*Cellulose is the most abundant polymer in nature and can be converted into sugar molecules with enzymatic reaction. Paper sludge is lignocellulosic biomass. Lignocellulosic biomass represents the largest renewable resources of potentially fermentable carbohydrates. Cellulase enzyme was used for the process of decomposition of ligno-cellulose into saccharides.*

*In this study, the cellulase enzyme produced by *Bacillus* sp. BPPT CC RK2 on natural substrates (rice bran and coconut water). Among pre treatment tested, saccharification percentage was highest in paper sludge after alkaline pre treatment with NaOH at 24 hours.*

*Pre-treatment of lignocellulose opened the structure and removes secondary bonds between glucose chains. The maximum amount of percentage saccharification was accomplished within 96 hours of incubation. The process of paper sludge saccharification is done by variation of the concentration of the enzyme with activity unit 6,12,18 unit and variation of the concentration of substrate 25,50,100,150 and 200 mg. The best results were obtained from the concentration of the enzyme activity 12 units and substrate as 100 mg. pH and temperature optimum was 5.5 and 37°C. Analysis of the final product saccharification was identified by thin layer chromatography. Maltose was found to end product of saccharification process.*

## Keywords

*Cellulase, Paper Sludge, *Bacillus* sp. BPPT CC RK2, Saccharification.*

## 1. INTRODUCTION

The continuously increasing population of Earth is rising a new challenge for biotechnology: supplementation of mankind with commodity products from renewable resources, instead of fossil based ones. Biotechnology producing commodity products should aim to be responsive to societal needs for sustainable resource utilisation and improved environmental quality. As raw materials are often dominant factors in determining the price of commodity products, renewable materials available at large scale are required as feedstock. In addition, these renewable sources are geographically more evenly distributed than fossil fuels; therefore the products will be domestic and provide security of supply. Plant biomass represents a renewable raw material available at large quantity. These feedstocks are mostly built up of lignocelluloses, and their carbohydrate polymer fraction is a brilliant raw material for biotechnology. Utilisation of lignocelluloses as feedstock would make new challenges for biotechnology, such as overcoming the recalcitrance of cellulosic biomass and product diversification. Most agricultural crops have been optimised for producing starch (rather than biomass) over many centuries and as already touched upon; plants have evolved to successfully resist microbial degradation. Reducing production and especially conversion costs through plant genetic engineering is believed to be able to significantly improve the potential for plant biofuel production [1].

Fifty percent of the total biomass of the world is expected to come from lignocellulose, and will produce lignocellulosic waste as much as 10-50 billion tons per year. Lignocellulosic waste accumulates every year and cause pollution problems. Lignocellulosic waste can be converted into simple sugars by hydrolysis, so as to reduce the amount of pollution [2].

Lignocellulosic wastes from paper manufacturing contains 60-70% cellulose, 10-20% hemicellulose and 5-10% lignin. The efficient utilisation of lignocelluloses requires the fractionation and separate utilisation of these components, fermenting the carbohydrate fractions to ethanol or other valuable products, and use lignin as solid fuel. The processing of lignocellulosic biomass to ethanol proceeds through a series of operations. The first step is the pretreatment to overcome the natural resistance of plant materials to biological breakdown. The primary function of pretreatment is to open up the lignocellulose's complex structure, so that it becomes accessible for the enzymes. There are several pretreatment methods, such as chemical, physical, biological ones, and combination of these. During acid catalysed steam pretreatment hemicelluloses are partially hydrolysed and solubilised, therefore separation of liquid and solid fraction gives an opportunity of a separate utilisation of hemicellulose sugars. Additionally, fermentation inhibitors formed during pretreatment are also removed with this step. The separated liquid fraction can then be utilised in enzyme production, yeast propagation steps, or converted to products, such as ethanol or biogas.

Plant cell walls are highly recalcitrant to degradation, both microbially and mechanically, and one of the main challenges is concerned with enzymatic conversion of cellulosic plant biomass into fermentable sugars[3][4].

To address this challenge of efficiently hydrolysing cell walls into fermentable sugars - also known as saccharification - two key aspects of cellulosic bioethanol production have been improved upon: Pretreatment and enzyme optimisation. Pretreatment is a balancing act that involves unlocking the cell wall structure without forming inhibitors, which affect hydrolysis and/or fermentation [5].

Being an insoluble and highly heterogeneous substrate, cellulosic materials pose several challenges in enzymatic conversion. However, recent years have shown important advances in understanding, improving and producing synergistic cellulases [6][7].

Currently sewage sludge in the paper industry is still a problem that has not been resolved. Therefore, the required solutions by utilizing the potential of the sludge waste, requiring the availability of technology. Waste management through the use of a management action appropriate, given that change the characteristics of the waste into materials that are not harmful and toxic substances can even transform into high-value products.

Pulp and Paper Industry Sludge is the largest solid waste stream produced by the “pulp and paper industry.” It is an attractive feedstock for emergent technologies that are based on the processing of cellulosic biomass. Disposing of Paper Sludge in landfill or by incineration creates environmental problems, and legislative trends in many countries are restricting the amount and types of materials that are permitted to be disposed of by landfill. In Indonesia, paper sludge is generally of 1-3% by weight of the product for an integrated pulp and paper industry, while for industries that use virgin paper pulp, sewage sludge generated ranged from 0.6 to 0.7% by weight of the product and paper industries that use natural raw waste paper around 0.8 to 1.2% by weight of the product.

Pulp and Paper Industry Sludge consists of 24.5% lignocelluloses (90% cellulose and 10% hemicellulose), 10.5% clay, and 65% water. More than 40% of clay is composed of kaolin and silica. Other minerals such as Si, Ti, Al, Fe, Mn, Na, and K are also present. Some Pulp and Paper Industry Sludge materials also contain non glucan carbohydrate (xylan and mannan). Incineration and on-site landfills used for Pulp and Paper Industry Sludge disposal are running out of storage space and are becoming an environmental concern. Another possible way to utilize Pulp and Paper Industry Sludge based on its high content of polysaccharides (mainly cellulose), it can be further processed to produce cellulase, which can be utilized again to hydrolysis Pulp and Paper Industry Sludge enzymatically [8].

Microorganisms have been used for saccharification of lignocellulosic wastes such as *Aspergillus oryzae* [9] reducing sugar produced 7.53 mg/ml with 9.03% saccharification. *Cellulomonas* sp. [10] with *Acacia auriculiformis* Cunn leaves as a substrate produced reducing sugar of 4.5 g / L.

This study aims to utilize paper sludge into sugar derivatives using cellulase enzymes from *Bacillus* sp. BPPTCC RK2 for saccharifying process.

## 2. MATERIAL AND METHODS

### 2.1. Raw Material.

The Pulp and Paper Industry Sludge (PPIS) was collected from a primary clarifier sludge dewatering process of the production of used paper contained 65% water, 10.5% clay, and 24.5% organic material on a weight basis. Dry PPIS contained 60% organic material consisting of cellulose and hemicellulose.

### 2.2. Microorganism

*Bacillus* sp. BPPTCC RK 2 was isolated from termite body and found in Serpong, Banten. The strain is not identified yet but selection this strain using screening *Bacillus* method.

### 2.3. Inoculum Preparation

A loopful of culture from the nutrient agar slant was transferred to 5 mL of LB (Luria Broth) media. The culture was grown at 37°C with 150 rpm for 24 h. 2% of the culture inoculum was transferred to 250mL Erlenmeyer flask containing 50mL of cellulolytic medium described below. The pH of the medium was adjusted to 7.0 using 1N NaOH before autoclaving. All the experiments were performed in duplicate. The culture broth after 36 h of incubation was centrifuged at 10,000 g for 10min at 4°C to separate the cells. The cell-free supernatant was analyzed for enzyme activity and protein concentration.

### 2.4. Cellulase Production Media And Cultivations

The fermentation medium for *Bacillus* sp. BPPTCC RK2 consisted (per liter) of 10 g Bacto-peptone, 5 g of yeast extract, 10 g NaCl and added 0,5% CMC (pH 7.0). The medium was sterilized at 121°C for 15 min. The inoculated medium was incubated at 37°C for 48 h. The production medium was agitated at 150 rpm for better aeration and growth of the organism. Crude

enzyme preparation was obtained from the supernatant after centrifugation of the broth culture at 5000g for 20 mins and was examined for the total protein content and cellulase activity.

### 2.5. Pretreatment Of Substrates:

The raw substrates were sun dried individually to reduce the moisture content and then crushed into bits. Then the substrates were soaked individually in 1% sodium hydroxide solution (NaOH) in the ratio 1: 10 (substrate: solution) for two hours at room temperature and autoclaved at 121°C for one hour. The treated substrates were then filtered and washed with distilled water until the wash water become neutral [11][12] then dried overnight at 60°C. The dried substrates were packed in polypropylene bags until use.

### 2.6. Cellulase Assay

Cellulase activity was determined by estimating the reducing sugar produced during enzymatic reaction by dinitro salicylic acid (DNS). One milliliter of the enzyme solution was mixed with 0.5% of CMC and incubated at 37°C for 15 min to perform the enzyme substrate reaction. The contents were cooled and 1 ml of DNS was added and heated at 90°C for 5–15 min till slight reddish brown was developed. The contents were cooled and 1 ml of potassium sodium tartrate was added. The absorbency of the contents was measured at 540 nm against reaction mixture prepared using distilled water as blank [13]. One unit of cellulase activity has been taken as the amount of the enzyme required to liberate one micromole of the reducing groups per min as glucose equivalent.

### 2.7. Protein Content

The amount of protein was estimated by Bradford method [14] using Bovine Serum Albumin (BSA) as a standard according to the instruction manual of Quick Start Bradford Protein Assay.

## 3. RESULT

Saccharification process is being derived cellulase processing sugar. The products fermentation on saccharification process indicated by the percent (%) saccharification and sugars produced. One that affects the process of saccharification is the concentration of enzyme and substrate.

To determine the value of percent saccharification, it must first be known reducing sugar content samples. Measurement of glucose level reduction is done by DNS method [13]. 3,5 - dinitrosalisilat acid (DNS) is an aromatic compound that reacts with a reducing sugar samples that have free aldehyde or ketone group to form complex color 3-amino-5 dinitro salicylic acid which can be detected by UV-vis spectrometer at a wavelength of 540 nm [15].

Variations in substrate pretreatment were compared between the treated substrate (pretreatment) and the substrate without treatment (untreatment). Pretreatment process done to change the structure and size of lignocellulosic materials by breaking down and removing lignin content and hemicellulosa, damaging the crystalline structure of cellulose and increase the porosity of the material [16]. Destruction of the cellulose crystal structure will facilitate the disintegration of cellulose to glucose. Furthermore, hemicellulose will help break down into simple sugars such as glucose, galactose, mannose, hexoses, pentoses, xylose and arabinose [17]. The process is done by alkaline pretreatment using NaOH.

Tabel 1: Various incubation time and pretreatment substrate on % saccharification

Incubation time	24 h	48 h	72 h	96 h	120 h
Sample	% Saccharification				
Untreatment	0	0,8154	0,6762	0,2138	0
Pretreatment 6 hours	0,358	0,4325	0,5817	1,1783	1,1783
Pretreatment 12 hours	0,6265	0,7458	0,8353	1,1932	0,9546
Pretreatment 24 hours	1,1485	1,2678	1,417	1,76	1,3722
Pretreatment 36 hours	1,0292	1,1783	1,2976	1,6258	1,3126

From tabel 1 shows that the highest percent saccharification obtained on substrates with substrate pretreatment than without pretreatment process. NaOH can break ester bonds and glycosidic and break down lignin. With the opening of this bond will allow the enzyme to break down cellulose and hemicellulos [18]. It can be shown that by doing pretreatment, saccharification produced greater than untreatment. Percent of Saccharification largest found in samples taken pretreatment for 24 hours is as much as 1.79% with incubation time of 96 hours.

From the table above shows the length of incubation time lead decline in value of percent saccharification, this is because the enzymes used not purely so that the possibility of sugar produced can be turned into other products, for example ethanol [19].

On the variation of the substrate concentration results obtained highest percent saccharification of 1.01%. From the results can be seen that the percent saccharification increased from the lowest substrate concentration of 25 mg and reached the highest value at a concentration of 100 mg. Once the optimum point, the value of percent saccharification decreased. This is because if the substrate concentration was varied, the initial reaction increases until it reaches a maximum and finally decreased. With the increasing concentration of the substrate can be seen in the chart saccharification decreased, it is because of the limited amount of enzyme [20].

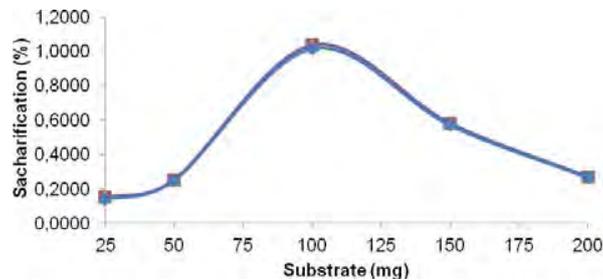


Figure 1: Effect substrate on % saccharification

On the effect of variations in the concentration of the enzyme, showed the highest percent saccharification of 1.80% on Unit enzim12 activity.

Enzymes are catalysts that can speed up the rate of a reaction without participating in the reaction. Enzyme reaction rate influences a variety of factors such as substrate concentration, enzyme concentration, pH, temperature, and inhibitors. Substrate concentration affect the rate of reaction, as more substrate there is the more the bonding that occurs between the enzyme and the substrate.

The product of the reaction between the substrate and enzyme are depended on the condition of the concentration of enzyme and substrate. At the enzyme concentration increases while the fixed substrate concentration, enzyme concentration or number of molecules is lower than the amount that will be catalyzed substrate molecule, the product will be proportional to the amount of substrate converted by enzymes into products.

Saccharification process of pulp and paper industry sludge processing using commercial enzymes and blank (substrate waste paper processing without the addition of cellulase enzymes *Bacillus sp* CC RK2 BPPT) was done.

Tabel 2: Comparison between enzyme commercial and cellulase *Bacillus sp* BPPT CC RK2 on % saccharification

Sampel	Reduction sugar content (mg/ml)	Saccharification (%)
Enzim selulase <i>Bacillus sp</i> BPPT CC RK2	0,4022	1,80
Commercial Enzyme	0,0033	0,0033
Blank (without enzyme)	0	0

Commercial enzyme has optimum conditions at pH 4.5 to 5.5, and a temperature of 55 to 60°C. The process of saccharification followed the optimum conditions of the enzyme, ie pH 5.5 and 60 °C. The substrate used was the result of waste as much as 100 mg pretreatment with NaOH for 24 hours, and the concentration of enzyme used as much as 15.04 units / mg. In the process of saccharification blank, 100 mg of substrate pretreatment with NaOH results for 24 hours plus citrate buffer pH 5.5 and then incubated at 37 °C.

From the results shown that the process of saccharification of PPIS by using the enzyme cellulase *Bacillus sp* CC RK2 BPPT has highest sugar reduction and percent saccharification. This shows that the value of percent saccharification using cellulase enzyme produced from *Bacillus sp*. BPPT CC RK2 is much higher than the commercial enzyme and blank.

After knowing the value of percent saccharification, further identification of the type of sugar used thin layer chromatography comparison with standard sugars using glucose, Xylosa, arabinose, Galactose, Maltose, and Sucrose a concentration of 5 mg / ml. Since this type of sugar saccharification process was not originally known, then spotted various sugar standard comparators to identify the type of sugar produced from saccharification process.

TLC can be used for compound identification standard. Parameters used in the TLC for identification is Rf. If the two compounds identical will have the same Rf value as measured on the same TLC conditions.

Rf values of the ratio between the sample and the reference standard were spotted sugar seen that the value of Rf sample is 0.32 cm, the approximate value of Rf maltose is 0.33 cm, so that based on the analysis of thin-layer chromatography, the final product is expected to contain Maltose.



Note : S= Succrose; A= Arabinose; Ga= Galactose; X= Xylose; M= Maltose; G=Glukose; Su= Sampel; B= Blank (without enzyme)

## ACKNOWLEDGMENT

I would like to thank to Ofa Suzanti Betha, Aam Amelia and Siti Mardiyanti Said from Pharmacy Study Programme, Faculty of Medicine and Health Science, Syarif Hidayatullah State Islamic University for helping us doing this research.

## REFERENCES

- [1] Hodge DB, Karim MN, Schell DJ, McMillan JD: Model-Based Fed-Batch for High-Solids Enzymatic Cellulose Hydrolysis. *Appl Biochem Biotechnol* 2008
- [2] Chinedu, S.N., Yah, S.C., Nwinyi, O.C., Okochi, V.I., Okafor, U.A., Onyegeme- Okerenta, B.M. Plant Waste Hydrolysis by Extracellular Enzymes of *Aspergillus niger* and *Penicillium chrysogenum*: Effect of Ammonia Pretreatment. *Nigerian Journal of Biochemistry and Molecular Biology*. 2008, 23 (1), pp. 1-7.
- [3] Lynd LR, Laser MS, Brandsby D, Dale BE, Davison B, Hamilton R, Himmel M, Keller M, McMillan JD, Sheehan J et al.: How biotech can transform biofuels. *Nat Biotechnol* 2008, 26:169-172.
- [4] Himmel ME, Ding SY, Johnson DK, Adney WS, Nimlos MR, Brady JW, Foust TD: Biomass recalcitrance: Engineering plants and enzymes for biofuels production. *Science* 2007, 315:804-807
- [5] Galbe M, Zacchi G: Pretreatment of lignocellulosic materials for efficient bioethanol production. *Biofuels* 2007, 108:41-65
- [6] Zhang YHP, Himmel ME, Mielenz JR: Outlook for cellulase improvement: Screening and selection strategies. *Biotechnol Adv* 2006, 24:452-481.
- [7] Merino ST, Cherry J: Progress and challenges in enzyme development for Biomass utilization. *Biofuels* 2007, 108:95-120
- [8] Lynd LR, Lyford K, South CR, van Walsum PG, Levenson K. Evaluation of paper sludges for amenability to enzyme hydrolysis and conversion to ethanol. *TAPPI J*. 2001;84:50-55.
- [9] Begum, M.F. & Alimon, A.R.. Bioconversion and saccharification of some lignocellulosic wastes by *Aspergillus oryzae* ITCC-4857.01 for fermentable sugar production. *Journal of Biotechnology*, 2011, ISSN: 0717-3458.
- [10] Sangkharak, Kanokphorn., Samae, Rokeyoh & Wangbua, Chompoonuch. Conversion Of Leafwaste To Sugar And Ethanol By Shf And Ssf Fermentation Using Cellulase From *Cellulomonas* Sp. *International Journal of Advanced Biotechnology*, 2011, Vol 2, pp. 345-349.
- [11] Fan, L. T.; Gharpuray, M. M.; Lee, Y.-H. *Cellulose Hydrolysis*; Biotechnology Monographs; Springer: Berlin; 1987, Vol. 3, p 57
- [12] Solomon BD, Barnes JR, Halvorsen KE: Grain and cellulosic ethanol: history, Economics, and energy policy. *Biomass Bioenerg* 2007, 6:416-425.
- [13] Miller, G.L.,. *Use of Dinitrosalicylic Acid Reagent for Determination of Reducing Sugar*. *Analytical Chemistry*, 1959, 31(3), pp.426-428.
- [14] Bradford, M. *A Rapid and Sensitive Method for the Quantitation of Microgram Quantities of Protein Utilizing the Principle of Protein-Dye Binding*. *Analytical Biochemistry* 1976, (72), p 248-254

- [15] Toledo, V.D.A.A.D., Takasusuki, M.C.C.R., Oliveira, A.J.B.D., Chambo, E.D and Lopes, S.M.S. *Spectrophotometry as a Tool for Dosage Sugars in Nectar of Crops Pollinated by Honeybees*. Dalam *Macro To Nano Spectroscopy* Edited by Dr. Jamal Uddin. Intech. 2012, p 269-290.
- [16] Sun, Ye and Cheng, Jiayang.. *Hydrolysis of Lignocellulosic Materials for Ethanol Production : a Review*. *Bioresource Technology*, 2002, (83) p 1-11.
- [17] Mosier, N., Wyman, C., Dale, B., Elander, R., Lee, Y.Y., Holtzapple and Ladisch, M. *Features of promising technologies for pretreatment of lignocellulosic biomass*. *Bioresource Technology*, 2005, 96 p. 673–686.
- [18] Brodeur, G., Yau, E., Badal, K., Collier, J., Ramachandran, K.B and Ramakhrisnan, S. *Chemical and Physicochemical Pretreatment of Lignocellulosic Biomass: A Review*. SAGE - Hindawi Access to Research Enzyme Research. 2011, p 1-17.
- [19] Prasetyo, J., Kato, T., and Park Enoch.Y. *Efficient Cellulase-Catalyzed Saccharification of Untreated Paper Sludge Targeting for Biorefinery*. *Biomass and Bioenergy*, 2010, 34, p. 1906-1913.
- [20] Ghosh, B and Ray, R.R.. *Saccharification of Raw Native Starches by Extracellular Isoamylase of Rhizopus Oryzae*. *Biotechnology*: 2010, 9 (2) p. 224-228

## Synthesis of Poly (1-vinyl-1,2,4-triazole) and Preparation of Proton Conducting Membrane for High Temperature Operation

Irfan Gustian<sup>1</sup>, Sevim Unugur Celik<sup>2</sup> Ayhan Bozkurt<sup>3</sup>

<sup>1</sup> Universitas Bengkulu, Department of Chemistry-Faculty of Mathematics and Natural Sciences,  
38371 JI, Raya Kandang Limun-Bengkulu, Indonesia

<sup>2</sup> Department of Chemistry, Fatih University, 34500 Buyukcekmece-Istanbul, Turkey <sup>3</sup> Department of Chemistry, Fatih University, 34500  
Buyukcekmece-Istanbul, Turkey <sup>a</sup>unibfan@yahoo.com, <sup>b</sup>sunugur@fatih.edu.tr, <sup>c</sup>bozkurt@fatih.edu.tr

### ABSTRACT

Polymer poly (1-vinyl-1,2,4-triazole) have been synthesized via free radical polymerization using the monomer 1-vinyl-1,2,4-triazole and the initiator azobisisobutyronitrile (AIBN) in toluene as solvent. Proton conducting membranes were prepared by adding nitrilotri (methyl triphosphonic acid) as a dopant into a solution of poly (1-vinyl-1,2,4-triazole) at various molar ratios. The mixture was cast in polished poly (tetrafluoroethylene), PTFE plates and the solvent was evaporated carefully at temperatures of 50 °C for 12 hours. Interaction between the polymer and the dopants have been studied through; FTIR spectrum, thermogravimetric analysis (TG), glass transition temperature using DSC and proton conductivity of membranes made using dielectric-impedance analyzer Novocontrol. Proton conductive membranes with molar ratio of 0.25 was obtained proton conductivity of  $8.52 \times 10^{-4}$  S/cm at 150 °C.

### Keywords

*Poly (1-vinyl-1,2,4-triazole), nitrilotri (methyl triphosphonic acid), proton conducting membrane, high temperature*

**This paper is published in Advanced Materials Research Journal**

# Adsorption of Lead (II) and Copper (II) Ions on Rice Husk Activated Carbon Under Sonication

Muhammad Zakir

Laboratory of Physical Chemistry, Hasanuddin University  
Kampus Tamalanrea 90245, Makassar  
E-mail: muhammadzakir@gmail.com

## ABSTRACT

The effect of sonication on the adsorption of  $Pb^{2+}$  and  $Cu^{2+}$  ions on rice husk activated carbon has been conducted. This study was aimed to removal of  $Pb^{2+}$  and  $Cu^{2+}$  ions from aqueous solution by activated carbon under the influence of sonication. Surface characteristics of activated carbon showed that rice husk based activated carbon prepared at  $400^{\circ}C$  and treated with  $ZnCl_2$  10% has better properties compared to the others prepared with difference conditions. The value of Langmuir model constant,  $b$ , for  $Cu^{2+}$  ion adsorption is -0.0362 (absence of sonication) and 0.1105 (presence of sonication), and for  $Pb^{2+}$  ion adsorption is -5.1508 (absence of sonication) and 1.0745 (presence of sonication). Those values suggest that ultrasonic irradiation positively affects the affinity of  $Pb^{2+}$  and  $Cu^{2+}$  ions towards the adsorbent. Maximum adsorption capacities increase in the presence of sonication. This can be seen on the value of  $a_m$ , Langmuir constant which represents the maximum adsorption capacity of adsorbent. The values of  $a_m$  for  $Cu^{2+}$  and  $Pb^{2+}$  adsorption changed from 1.0464 mg/g (absence) to 6.2775 mg/g (presence) and from 9.7561 mg/g (absence) to 16.5017 mg/g (presence), respectively. Those values suggest an increase in the adsorption capacity of activated carbon under sonication.

## Keywords

Activated carbon, rice husk, adsorption affinity, maximum adsorption capacity, ultrasound

## 1. INTRODUCTION

Environmental pollution due to the disposal of heavy metals and organic pollutants has been causing serious concern for the last few years [1-2]. Heavy metals are non-degradable to harmless end products, unlike organic pollutants, the majority of which are probably biodegradable. Heavy metals are toxic to aquatic ecosystems even in relatively low concentrations. Heavy metals, which are toxic to human beings and ecological environments, include chromium (Cr), copper (Cu), lead (Pb), and mercury (Hg), etc. These metals might be assimilated, stored and concentrated by human body, causing erythrocyte destruction, nausea, salivation, diarrhea, muscular cramps, renal degradation, chronic pulmonary problems and skeletal deformity [3-7].

Lead, which has been used by man for years, can be regarded as an important environmental contaminant. All compounds containing lead are considered as cumulative poisons that affect the gastrointestinal track, nervous system and sometimes both. The sources of lead in water are the effluents of processing industries, storage batteries, insecticides, plastic water pipes, food, beverages, ointments and medicinal concoctions for flavoring and sweetening. Environmental pollution due to copper is originated from mining, printed circuits, metallurgical, fiber production, pipe corrosion and metal plating industries. The other sources of copper pollution are industries of paper and pulp, petroleum refining and wood preserving. Agricultural activities such as fertilizers, fungicidal sprays and animal wastes can cause also copper pollution in water resources [3-7].

Removal of toxic or heavy metals from aqueous solutions can be carried out through several methods, such as chemical precipitation, membrane filtration, ion exchange, biosorption and adsorption [4]. Among those removal techniques of toxic or heavy metals, adsorption is the preferred method and gives the best results as it can be used to remove various types of toxic materials [1-7]. Commercial Activated Carbon (CAC) is the most widely employed adsorbent for the removal of toxic metals due to its effectiveness and high adsorption capacity; however, its use is still limited because of high operating costs. The need for regeneration and difficulty of separation from the wastewater after use are also major concerns associated with CAC. Many researchers have focused on finding non-conventional alternative adsorbents to reduce the cost of pollution treatment. Low-cost adsorbents are generally referred to non-hazardous waste produced from industry, agriculture, and biosorbents. Several lists and reviews of these types of adsorbent for pollutant removal have been made [1-2, 4]. In addition, the use of agricultural waste as adsorbent has attracted some researchers because: (1) it is available abundantly; (2) most of the types of agriculture waste are readily to be utilized and do not need a complex pretreatment step or activation process before applications; (3)

regeneration of these adsorbents may not be necessary (unlike CAC, where regeneration is essential); and (4) less maintenance and supervision are required for the operation of the adsorption process [8-15]. However, use of these cheap alternatives for pollutant treatment is still limited because both insufficient documentation in real wastewater systems and the necessity of post-usage disposal. The employment of rice husk waste for the treatment of wastewater is a win-win strategy because it does not only convert the waste into a helpful material but it also prevents on-site burning of the waste, saves on disposal costs, and reduce CO<sub>2</sub> emission [1-4, 8-9]. Disadvantage of biosorbents, that is often found, is the relatively low adsorbing capacity. However, in some cases, the adsorption capacity can be improved by activation, surface modification, and sonication. The use of activated carbons from plant materials is also often suffered from the low adsorption rate because of their microporous structures and long diffusion path through solid particles of adsorbents [16-18].

The effect of sonication has been studied to exhibit several effects in solid-liquid systems such as the increase of mass transfer rate, the enhancement of the surface area by many micro-cracks formation on the surface of solid and the clean-up of solid particle surfaces [19-28]. The effect of ultrasound on the adsorption/desorption processes has been previously studied and some controversial effects have been found [16, 20-23]. Nevertheless, there is less information in the literature about the removal of heavy metal ions from aqueous solution by adsorption under the influence of ultrasonic irradiation [20-23].

The objectives of the current study was aimed to removal of Cu(II) and Pb(II) ions from an aqueous solution by adsorption onto the activated carbon obtained from rice husk under the influence of sonication. The models of Cu(II) and Pb(II) adsorption will be evaluated to observe the effects of ultrasound on the adsorption of both metals onto the rice husk based activated carbon, and finally to choose optimal adsorption condition.

## 2. MATERIALS AND METHODS

*Materials:* Rice husk (*Oryza satyfum* L.) was supplied from the south part of South Sulawesi (Bontomaero, Kecamatan Bajeng, Kabupaten Gowa). Fresh rice husk were washed several times with distilled water for the removal of surface impurities, dried at 100°C overnight (6h), crushed by a hammer mill and simultaneously carbonized in a muffle furnace at 300 and 400 C for 2h. Carbonized rice husk was then immersed into ZnCl<sub>2</sub> (10%w/v) for 24h. Afterwards, the granular activated carbon was washed three times with distilled water, dried at 110 C for 24h and stored in desiccators. Copper(II) acetate and lead(II)acetate, analytical reagent grade, were purchased from Merck Co. Distilled water was used to prepare aqueous solutions of copper(II) acetate and lead(II)acetate.

*Material characterization:* Surface characteristics of adsorbents were determined by Scanning Electron Microscope (SEM) (JEOL, JSM6510). Crystallinity analysis was carried out through X-Ray Diffraction method (XRD) (Shimadzu, XRD6000). Specific surface area, total pores volume, and pores size distribution were determined by N<sub>2</sub> adsorption method in a Gas Sorption Analyzer (Quantachrome, Autosorb iQ-MP).

*Experimental set-up of sonication:* The set-up consisted of an ultrasonic cleaner (Elmasonic S40H; total nominal power: 250 W; and internal dimensions: 300 x 220 x 155 mm), operating at 40 kHz frequency. The cleaner was filled with distilled water up to 1/3 of its volume (about 3.5 l). The temperature was controlled and maintained by water circulating from a thermostated bath by means of a pump. An Erlenmeyer flask (250 ml) used as adsorption vessel was fixed on a swinger (90 oscillations per minute). The copper(II) acetate and lead(II)acetate solutions (100 ml) and the adsorbent (1.0 g) were put into the flask fixed on the swinger.

*Adsorption experiments:* In these experiments, the initial copper(II) acetate and lead(II)acetate concentrations were in the range between 2 and 50 mg/l. In a preliminary equilibrium test under silent conditions applying the smallest (2 mg/l) and the highest (50 mol/l) copper(II) acetate and lead(II) acetate concentrations, it was established that the equilibrium was reached after 2 h. For sure, all equilibrium experiments lasted 3 h. After establishing equilibrium, a sample was taken from the flask and was centrifuged (1500 rpm for 5 min) for the removal of adsorbent particles. The Cu(II) and Pb(II) concentrations in the supernatant were measured by *Atomic Absorption Spectrophotometer* (AAS) Bulk Scientific Model 205VGP. The amount of Cu(II) and Pb(II) ions adsorbed was calculated from the mass balance equation (Equation 1).

$$q = \frac{(C_0 - C)V}{m_a} \quad (1)$$

Where q is the amount of ions adsorbed at time t; C<sub>0</sub> and C are the initial ions concentration and the ions concentration at time t, respectively; V is the volume of solution (=100 ml); and m<sub>a</sub> is the amount of adsorbent (=1.0 g). For each sample, the ion concentrations were measured in triplicate and the mean value was used as the equilibrium one.

### 3. RESULTS AND DISCUSSION

*Characterization of rice husk based activated carbon (RHAC):* The activated carbon prepared from rice husk by carbonization at elevated temperature (300C and 400C) and salt impregnation ( $ZnCl_2$ ; 10% w/v) for 24 h was characterized by standard methods (Table 1 and Figure 1). The highest specific surface area of RHAC was obtained at carbonization at 400C i.e. 284,963  $m^2/g$ , and the total pore volume was 4,670E-01 cc/g. The active groups were formed due to the dissolution of many chemical bonds initially present in the rice husk through prolonged carbonization at elevated temperature. Immersion of RHAC into  $ZnCl_2$  10% solution for 24h has increased the specific surface area and total pore volume. Based on the SEM results, the surface structure of RHAC (carbonization at 400C and activation with  $ZnCl_2$ ; 10% w/v) has a layered structure and pieces of pores compared to the other RHAC (Fig. 2). Activation can increase the number of pores as can be seen from Fig. 2(a) and 2(b), respectively. The number of pores is available more in Fig. 2(a) than 2(b). This explanation can also be connected to information from the specific surface area and total pore volume, where RHAC produced and activated at 400 C has the highest value of both parameters. Activation can also increase the values of specific surface area from 38,248  $m^2/g$  to 115,282  $m^2/g$ , and from 55,074  $m^2/g$  to 284,963  $m^2/g$  at 300 C and 400 C of activation, respectively.

Table 1: Specific surface area, pores radius and total pores volume of activated carbon. 300 A and 400 A were activated by  $ZnCl_2$  (10% w/v) at 300C and 400C, respectively. 300 TA and 400 TA means without activation at the same temperature.

No	Sample name	Specific surface area ( $m^2/g$ )	Pore radius ( $\text{\AA}$ )	Total pore volume (cc/g)
1	300 TA	38,248	1,735E+01	3,318E-02
2	300 A	<b>115,282</b>	1,821E+01	1,050E-01
3	400 TA	55,074	8,040E+01	2,214E-01
4	400 A	<b>284,963</b>	3,278E+01	<b>4,670E-01</b>

Table 2: Parameters of adsorption isotherms and linear correlation coefficient of both presence and absence of ultrasonic irradiation experiments.

Isotherm	Parameter	Absence ( $Cu^{2+}$ )	Presence ( $Cu^{2+}$ )	Absence ( $Pb^{2+}$ )	Presence ( $Pb^{2+}$ )
Langmuir	$a_m (q_{max})$	1,0464	6,2775	9,7561	16,5017
	b (adsorption affinity)	-0,0362	0,1105	-5,1508	1,0745
	R	<b>0,7612</b>	<b>0,9906</b>	<b>0,9988</b>	<b>0,9927</b>
Freundlich	$k_F$ (adsorption capacity)	10,4372	2,0086	7,1717	9,4595
	n (adsorption intensity)	-2,6385	4,3497	13,1926	8,4459
	R	0,5614	0,9054	0,7864	0,7972

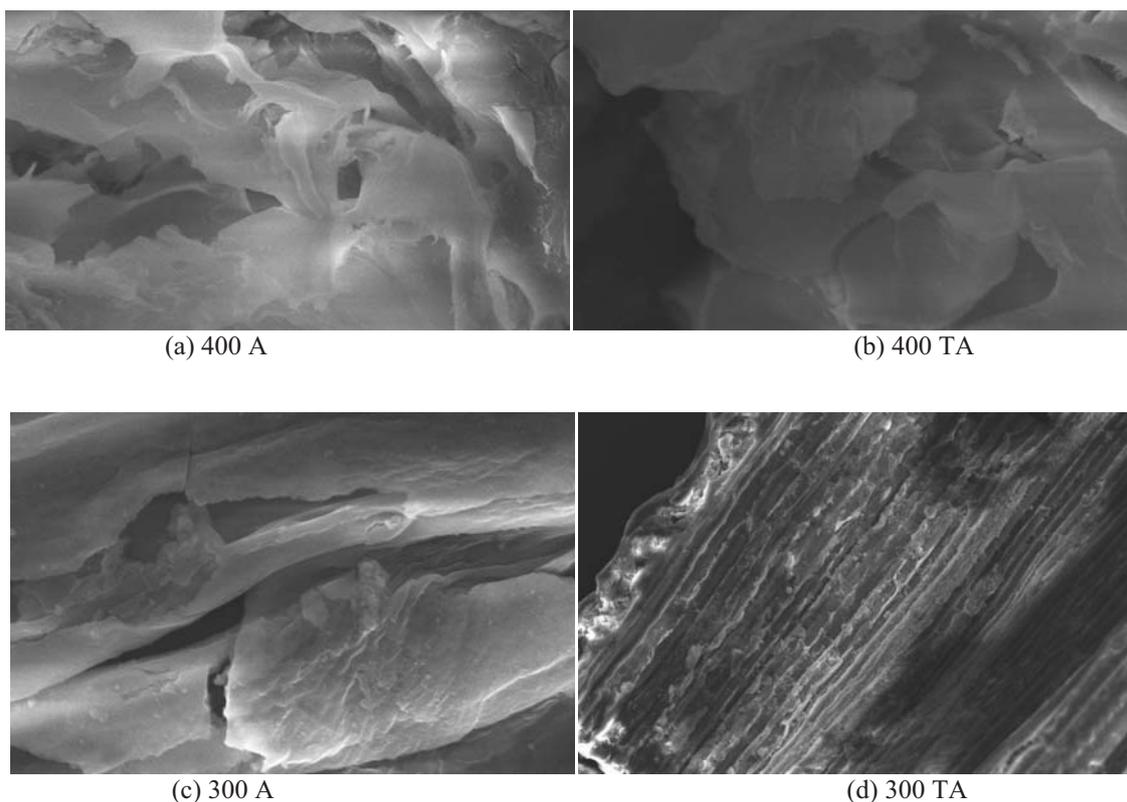


Figure 1: Surface characteristics of adsorbent determined by Scanning Electron Microscope (SEM). 300 A and 400 A were activated by  $ZnCl_2$  (10% w/v) at 300C and 400C, respectively. 300 TA and 400 TA means without activation at the same temperatue.

In addition, as seen from Fig. 2, both adsorption isotherms for both metals are non-linear and seem to approach to the maximum values, except Pb(II) adsorption under sonication. Indication from the shape of the curves can be understood that several well-known models reported in the literature could be employed to explain the adsorption isotherms. Both Langmuir and Freundlich models are the most frequently used isotherms for adsorption studies [3-7, 10-16]. The Langmuir model can be applied to homogeneous sorption, where the sorption of each molecule is carried out onto monolayer surface and has equal sorption activation energy. The Freundlich model is an empiric isotherm model in nature. In this study, both adsorption isotherms were used to model the relationships between the amount of Cu(II) and Pb(II) ions adsorbed onto RHAC and its equilibrium concentration in solution in the absence and the presence of ultrasonic irradiation. Table 2 shows parameters of both adsorption isotherm models that were obtained in the presence and absence of ultrasonic irradiation. Nevertheless, when the Langmuir isotherm model was utilized in our experimental data, this model better fits both in the presence of ultrasound and its absence than with the Freundlich isotherm model. This can be seen in Table 2 when the corresponding linear correlation coefficients (R) are compared. The higher R-value for the Langmuir isotherm model than for the Freundlich isotherm model might be caused by homogeneous distribution of active sites of RHAC surface as it was explained in the case of Cu(II) ions removal by activated carbon from hazelnut shells under sonication [16].

The Langmuir constants  $a_m$  and  $b$  as well as the Freundlich constants  $k_F$  and  $n$  are also shown in Table 2. The Langmuir adsorption constant  $b$  defines the ratio of adsorption and desorption rate constants and is related to the free energy of adsorption. Its value represents the affinity of Cu(II) and Pb(II) ions to the adsorbent. When both values are compared, the values of  $b$  for the silent and the ultrasound-assisted adsorption, it can be concluded that ultrasound positively affected the affinity of Cu(II) and Pb(II) ions to the granular activated carbon as it was previously found for the adsorption of Cu(II) ions by activated carbon of hazelnut shell under sonication [16].

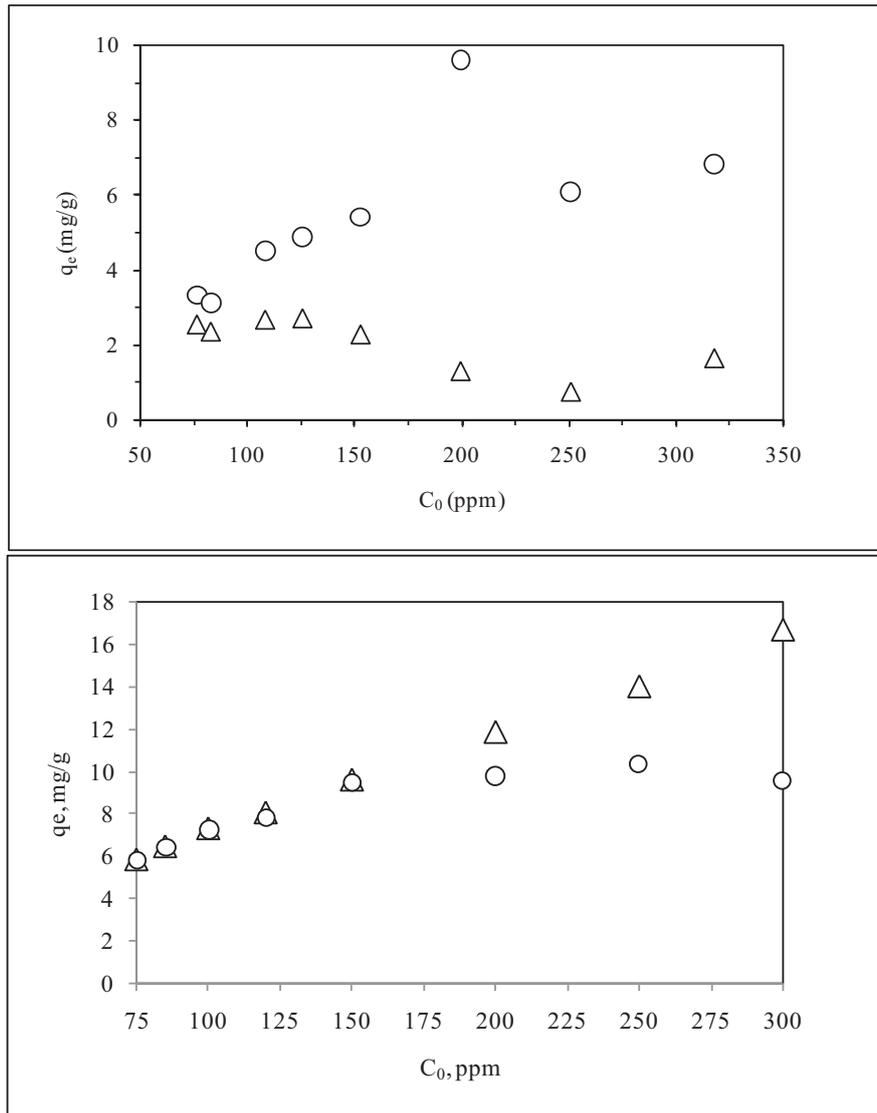


Figure 2. Adsorption isotherms of (upper)  $Cu^{2+}$  ions and (lower)  $Pb^{2+}$  ions on rice husk based activated carbon (O = presence of sonication, Δ = absence of sonication).

The difference conclusion was withdrawn from values of the Freundlich constant  $k_F$ , related to the adsorption capacity. The increase of  $k_F$  was only observed in adsorption of  $Pb(II)$  ions under sonication, while in the case of  $Cu(II)$  ions adsorption, sonication was decreasing the adsorption capacity of RHAC. The corresponding linear correlation coefficients (R) of  $Cu(II)$  adsorption in the absence of sonication, however, is lower than the presence of sonication. The adsorption capacity of  $Cu(II)$  ions by activated carbon of hazelnut shell was also greater in the presence of ultrasound than in the silent conditions [16]. This can be attributed to the cavitation effects which can increase the capability of the porous particle structure for  $Cu(II)$  and  $Pb(II)$  ions adsorption and/or the appearance of new sites of sorption by disruption of sorbent particles [16-28].

Maximum adsorption capacities for removal of  $Cu(II)$  and  $Pb(II)$  ions from aqueous solution by the granular activated carbon achieved in silent and ultrasound-assisted adsorption are 1.0464, 6.2775, 9.7561 and 16.5017 mg/g (calculated from the Langmuir isotherm model), respectively. Those values are much higher than that reported for the activated carbon obtained by steam activation of hazelnut shells under sonication [16]. This might be attributed to the specific surface area of the granular activated carbon of rice husk used in the present experiment.

## 5. CONCLUSION

Surface characteristics of RHAC prepared at 400C then impregnated with ZnCl<sub>2</sub> 10% are better than the other activated carbon prepared with the other conditions. When the values of *b* for the silent and the ultrasound-assisted adsorption are compared, it can be concluded that ultrasound positively affected the affinity of Cu(II) and Pb(II) ions to the surface of RHAC. The values for Cu<sup>2+</sup> adsorption are 1.0464 mg/g and 6.2775 mg/g for the absence and presence of sonication, respectively, which suggests an increase (83%) in the adsorption capacity of activated carbon due to the ultrasonic irradiation. The values for Pb<sup>2+</sup> adsorption are 9.7561 mg/g and 16.5017 mg/g for the absence and presence of sonication, respectively, which also suggests an increase (41%) in the adsorption capacity of activated carbon due to the ultrasonic irradiation. Langmuir adsorption isotherm model is better fits than the Freundlich model based on the values of corresponding linear correlation coefficients (R), both in the presence and absence of ultrasonic irradiation.

## ACKNOWLEDGMENT

The author acknowledges for the financial support provided by Hasanuddin University (a Grant-in-Aid for Study Program Research DIPA Unhas No: 64/un4-lk.26/2012).

## REFERENCES

- [1] Babel, S. Kurniawan, T.A. "Low-cost Adsorbents for Heavy Metals Uptake from Contaminated Water: a Review". *J. Hazard. Mater. B*, vol. 97, pp. 219–243, 2003.
- [2] Crini, G. "Non-Conventional Low-Cost Adsorbents for Dye Removal: A Review". *Bioresour. Technol.*, vol. 97, pp. 1061–1085, 2006.
- [3] Babel, S. Kurniawan, T.A. "Cr(VI) removal from synthetic wastewater using coconut shell charcoal and commercial activated carbon modified with oxidizing agents and/or chitosan". *Chemosphere*. vol. 54, pp. 951–967, 2004.
- [4] Febrianto, J. Kosasih, A.N. Sunarso, J. Ju, Y.H. Indraswati, N. Ismadji, S. "Equilibrium and Kinetic Studies in Adsorption of Heavy Metals using Biosorbent: a Summary of Recent Studies". *J. Hazard. Mater.* vol. 162, pp. 616–645, 2009.
- [5] Kadirvelu, K., Thamaraiselvi, K., Namasivayam, C. "Adsorption of nickel(II) from aqueous solution onto activated carbon prepared from coirpith". *Sep. Pur. Technol.* vol. 24, pp. 497–505, 2001.
- [6] Sudarmaji, Mukono, J. Corie, I.P. "Toksikologi Logam Berat, Zat B3, dan dampaknya terhadap kesehatan". *Kesehatan Lingkungan*. vol. 2, no. 2, pp. 129-142, 2006.
- [7] Weng, C.H. Tsai, C.Z. Chu, S.H. Sharma, Y.C. "Adsorption Characteristics of Copper (II) onto Spent Activated Clay". *Sep. Purif. Technol.* vol.54, pp. 187–197, 2007.
- [8] Daifullah, A.A.M. Girgis, B.S. Gad, H.M.H."Utilization of Agro-Residues (Rice-Husk) in Small Waste Water Treatment Plants". *Mater. Lett.* vol. 57, pp. 1723-1731, 2003.
- [9] Deptan RI (Departemen Pertanian Republik Indonesia), 2006, Produksi padi Indonesia dalam ton pada tahun 2000-2006, in Purwono dan Purnamawati H., *Budidaya 8 jenis tanaman pangan unggul*, Ed.3, 2008, Penerbit Swadaya, Jakarta, pp. 9-29.
- [10] Chandrasekhar, S. Pramada, P.N. "Rice husk ash as an adsorbent for methylene blue—effect of ashing temperature". *Adsorption*, vol. 12, pp. 27–43, 2006.
- [11] Guo Y. Zhao J. Zhang H. Yang S. Qi J. Wang Z. "Use of rice husk-based porous carbon for adsorption of Rhodamine B from aqueous solutions". *Dyes Pigments*, vol. 66, pp. 123-128, 2005.
- [12] Gupta, V. K. Mittal, A. Jain, R. Mathur, M. and Sikarwar, S. "Adsorption of Safranin-T from wastewater using waste materials—activated carbon and activated rice husks". *J. Colloid Interface Sci.* vol. 303, pp. 80–86, 2006.
- [13] Hameed, B.H. "Spent Tea leaves: A New Non-Conventional and Low-Cost Adsorbent for Removal of Basic Dye From Aqueous Solutions". *J. Hazard. Mater.* vol. 161, pp. 753–9, 2009.
- [14] Mane, V.S. Mall, I.D. Srivastava, V.C. "Kinetic and equilibrium isotherm studies for the adsorptive removal of Brilliant Green dye from aqueous solution by rice husk ash". *J. Environ. Manage.* vol. 84, pp. 390–400, 2007.
- [15] Ponnusami, V. Kritika, V. Madhuram, R. Srivastava S.N. "Biosorption of reactive dye using acid-treated rice husk: factorial design analysis" *J. Hazard. Mater.* vol. 142, pp. 397–403, 2007.
- [16] Milenkovic, D.D. Dasic, P.V. Veljkovic, V.B. "Ultrasound assisted adsorption of Copper (II) ions on hazelnut shell activated carbon. *Ultrason. Sonochem.* vol. 16, pp. 557-563, 2009.
- [17] Ramirez, O.H. Holmes, S.M. "Novel and Modified Materials for Wastewater Treatment Application". *J. Mater. Chem.* vol. 18, pp. 2751-2761, 2008.
- [18] Zakir, Maming, and Achmad, A. "Adsorption of Methylene Blue and Eosin on Rice Husk Based Activated Carbon". Dalam *Indo. Chim. Acta.* vol. 4, no. 2, pp. 1-6), 2011.
- [19] Hoffmann, M. R. Hua, I. Hochemer, R. "Application of Ultrasonic Irradiation for the Degradation of Chemical Contaminants in Water". *Ultrason. Sonochem.* vol. 3, pp. S163-S172, 1996.
- [20] Sekine, T. dan Zakir, M. "Oxidative Dissolution of Tc(IV)O<sub>2</sub> · nH<sub>2</sub>O Colloids by Sonolysis". *Radiochim. Acta.* vol.96, no. 9-11, pp. 625-9, 2008.
- [21] Zakir, M. dan Sekine, T. "Oxidation Reaction of Tc(IV)O<sub>2</sub> · nH<sub>2</sub>O Nanocolloid Induced by Ultrasonic Wave". *Indo. Chim. Acta.* vol. 2, no. 1, pp. 46-7, 2009.
- [22] Zakir, M. dan Sekine, T. "Sonolytic Oxidation of Tc(IV)O<sub>2</sub> · nH<sub>2</sub>O Nanoparticles to Tc(VII)O<sub>4</sub><sup>-</sup> in Aqueous Solution". *Atom Indonesia.* vol. 36, no.1, pp.17-22, 2010.

- [23] Zakir, M. "Sonochemical Dissolution of  $TcO_2 \cdot nH_2O$  Nanocolloids in Aqueous Solution: A New Heterogeneous Kinetics Model Taking into Account The Local Concentration of OH Radicals and  $TcO_2 \cdot nH_2O$  Nanoparticle". Dalam Seminar Nasional Himpunan Kimia Indonesia (SNHKI). Makassar, 2-3 Agustus 2010.
- [24] Flint, E. B. dan Suslick, K. S. "The Temperature of Cavitation". *Science*. vol. 253, pp.1397-9, 1991.
- [25] McNamara III, W. B. Didenko, Y. T. Suslick, K. S. "Sonoluminescence Temperatures during Multi-bubble Cavitation". *Nature*. vol. 401, pp. 772-5, 1999.
- [26] Suslick, K. S. "Sonochemistry". *Science*. vol. 247, pp. 1439-45, 1990.
- [27] Suslick, K. S. Didenko, Y. Fang, M. M. Hyeon, T. Kolbeck, K. J. McNamara III, W. B. Mdeleleni, M. M. dan Wong, M. "Acoustic Cavitation and Its Chemical Consequences. *Phil. Trans. R. Soc. Lond. A*. vol. 357 pp, 335-353, 1999.
- [28] Thompson, L. H. Doraiswamy, L. K. "Sonochemistry: Science and Engineering". Dalam *Ind. Eng. Chem. Res.* vol. 38, pp. 1215-1249, 1999.

# Synthesis and adsorption characteristics of activated carbons originated from banana peel waste for dye removals

Arenst Andreas, Evelyn Natalia and Gisela Giovanni

Department of Chemical Engineering  
Faculty of Industrial Technology  
Parahyangan Catholic University  
Ciumbuleuit 94 Bandung 40141 Indonesia  
Tel : (022) 2032700 ext 601. Fax : (022) 2032700  
E-mail : arenst@unpar.ac.id

## ABSTRACT

Activated carbon is the most commonly used adsorbent for wastewater treatment and water purifications. The main characteristics of activated carbon are its high surface area and high adsorption capacity with certain adsorbates. In this work, activated carbons were synthesized using banana peel wastes. The samples were activated chemically using zinc chloride as the activating agent. These samples were then activated at 600 °C in nitrogen flow respectively. The activated carbons were characterized by Scanning Electron Microscopy (SEM) and nitrogen adsorption at 77 K. Results indicated that activation processes improved the uptake of methylene blue (MB) with respect to adsorption results obtained for raw precursors. Overall, activated carbons obtained from banana peel wastes showed good performance for the removal of MB dyes. The activated carbon prepared from banana peel wastes exhibits good surface characteristics and porosity properties. This indicates that banana peel can be one of a promising precursor for the production of commercial activated carbon.

## Keywords

Activated carbons, dyes, banana peel, chemical activation

## 1. INTRODUCTION

Recently, adsorption has shown to be one of well-established and cheap pollutant removal process among other purification techniques. From various type of adsorbents, activated carbons (ACs) are one of the most popular for both liquid and gas purification [1] since they own unique properties such as porous structure, high specific surface areas and large adsorption capacities. The surface properties of ACs are determined by both the precursor material and the method used for their synthesis [2–4]. On the other hand the adsorption capacity is highly dependent on its specific surface area, pore size distribution and surface functional groups, with the latter affecting their behaviour during interaction with polar, non-polar, anionic and cationic adsorbates [5].

A main drawback in the application of ACs, in commercial scale, is the production cost. In the last years, a lot of research has been concentrated on the utilisation of new carbon precursors, cheap and abundant with great valorisation potential, such as agricultural residues and waste biomass [6,7]. A variety of starting materials have been already used for the preparation of AC, such as jackfruit peel, orange peel, coconut shell, nut-shells, bituminous coal, coffee ground etc [8-12].

One method to prepare such kind of carbon material is the chemical activation route that might improve the pore structure with tunable structural characteristics. This method involves the impregnation of the carbon precursor by a chemical agent, usually  $H_2SO_4$ ,  $H_3PO_4$  or  $ZnCl_2$ , and then followed by the heat-treatment at moderate temperatures (673–873 K). From the available activating agents, Zinc chloride is preferably used for the activation of lignocellulosic materials as it causes the decomposition of the cellulose structure and, on carbonization, causes dehydration process that results in charring and aromatization of the carbon structure and formation of the pore structure [13].

The focus of the research is to investigate the adsorption potential of banana peel-based activated carbon for methylene dye based on the fact that the banana peel is a very abundant waste in Indonesia and never exploited for commercial use. Methylene blue (MB) was selected in this study because it has a very strong adsorptive capability on the solids and is often serves as a model compound for removing organic contaminants and colored bodies from aqueous solutions. The kinetic data and equilibrium data of adsorption studies were then examined to understand the adsorption mechanism of the dye molecules onto the activated carbon.

## 2. EXPERIMENTALS

### 2.1 Preparations of activated carbons

Raw material (banana peel) used for preparation of activated carbon was collected locally, washed, dried, crushed to desired mesh size of +100/-200. The raw material was then carbonized at 450°C under nitrogen atmosphere for 1 h (first pyrolysis). A certain amount of produced char then was soaked with zinc chloride (ZnCl<sub>2</sub>) at various impregnation ratio of 1:1, 2:1, 4:1, 1:2 and 1:4 (ZnCl<sub>2</sub> pellets: char). The mixture was dehydrated in an oven overnight at 105 °C; then pyrolysed in a furnace under nitrogen flow (second pyrolysis) to a final temperature of 450°C and activated for 1 h. Once the final temperature was reached, the gas flow was switched to carbon dioxide and activation was continued for 2 h. The activated product was then cooled to room temperature under nitrogen flow and washed with deionized water to remove remaining chemical. Textural characterization of the activated carbon (AC) was carried out by N<sub>2</sub> adsorption at 77K. The BET (N<sub>2</sub>, 77K) is the most usual standard procedure used when characterizing an activated carbon. The morphology of carbon samples was observed using scanning electron microscope and its elemental compositions was estimated by Energy Dispersive x Ray (EDX) Spectroscopy.

### 2.2 Analysis of methylene blue

Methylene blue (MB) was used as an adsorbate and was not purified prior to use. Double distilled water was employed for preparing all the solutions and reagents. The concentration of methylene blue in the supernatant solution after and before adsorption was determined using a double beam UV spectrophotometer (Shimadzu, Japan). It was found that the calibration curve was very reproducible and linear over the concentration range used in this work.

### 2.3 Batch equilibrium studies

Adsorption isotherms were performed in a set of Erlenmeyer flasks (250 ml) where solutions of dye (200 ml) with different initial concentrations were placed in these flasks. Equal mass of 0.5 g of particle size activated carbon was added to dye solutions and kept in an isothermal shaker (30 °C) for 48 h to reach equilibrium of the solid-solution mixture. The pH was adjusted to 7 by adding either few drops of diluted hydrochloric acid or sodium hydroxide. The flasks were then removed from the shaker and the final concentration of dye in the solution was analyzed. The samples were filtered prior to analysis in order to minimize interference of the carbon fines with the analysis. Each experiment was duplicated under identical conditions. The amount of adsorption at equilibrium,  $q_e$  (mg g<sup>-1</sup>), was calculated by:

$$q = \frac{(C_0 - C_e)V}{W} \quad (1)$$

where  $C_0$  and  $C_e$  (mg l<sup>-1</sup>) are the liquid-phase concentrations of dye at initial and equilibrium, respectively.  $V$  is the volume of the solution (l), and  $W$  is the mass of dry adsorbent used (g).

### 2.4 Batch kinetic studies

The procedures of kinetic experiments were basically identical to those of equilibrium tests. The aqueous samples were taken at preset time intervals, and the concentrations of dye were similarly measured. The amount of adsorption at time  $t$ ,  $q_t$  (mg g<sup>-1</sup>), was calculated by:

$$q = \frac{(C_0 - C_t)V}{W} \quad (2)$$

where  $C_0$  and  $C_t$  (mg l<sup>-1</sup>) are the liquid-phase concentrations of dye at initial and any time  $t$ , respectively.  $V$  is the volume of the solution (l), and  $W$  is the mass of dry adsorbent used (g).

## 3. RESULTS AND DISCUSSION

### 3.1. Structural and morphological characteristics of the activated carbons

Figure 1 shows the SEM images indicating the differences in the external surfaces of the carbon samples produced by various impregnation ratio. It can be observed from the SEM that all samples contain porous structure and, in general, exhibits an uneven distribution of particle sizes. The activation procedure caused a significant structural change.

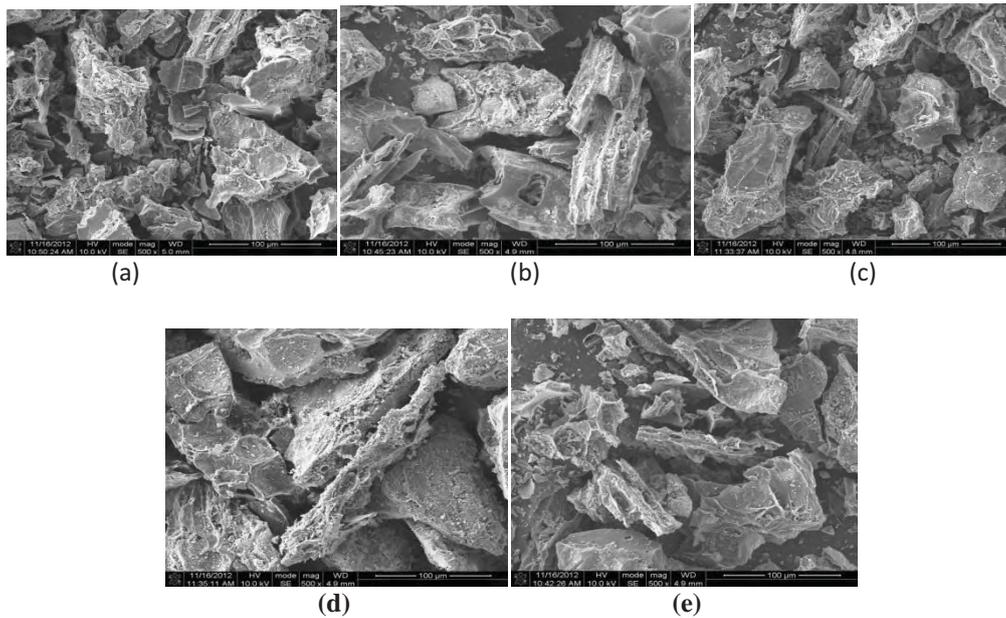


Figure 1: SEM images of activated carbons produced by various impregnation ratio (banana powder :  $ZnCl_2$  : (a) 1:1 (b) 1:2 (c) 1:4 (d) 2:1 (e) 4:1

The  $N_2$  adsorption–desorption isotherms as shown in Fig.21 are usually used to determine the surface area of the banana peel based activated carbons. The isotherm of carbon samples exhibits type I characteristics exhibited by a well-defined plateau, according to IUPAC classification, which confirms its microporosity. An obvious hysteresis loop for the samples is detected between the relative pressures ( $P/P_0$ ) of 0.45 to 1.

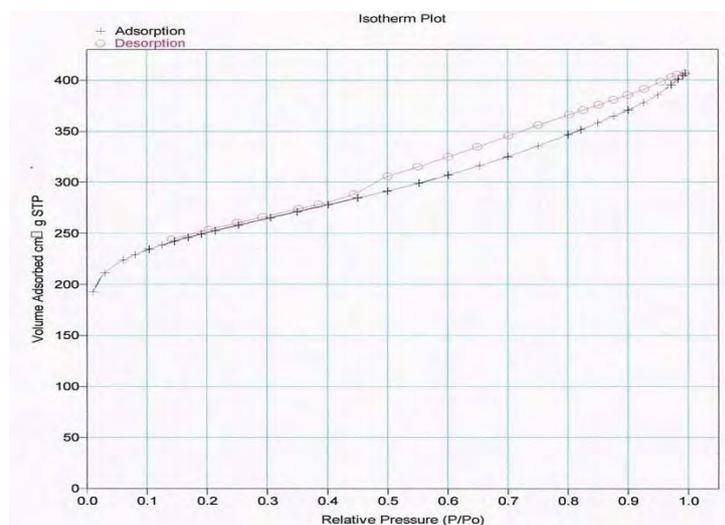


Figure 2: Adsorption/Desorption Isotherm of  $N_2$  gas on the banana peel based activated carbons

Table 1 summarizes the textural properties of the carbon samples obtained by various impregnation ratio. It can be seen that the highest surface is shown by the sample activated at ratio of 4:1. It seems that higher ratio of impregnation leads to the higher surface area generated during activation process using  $ZnCl_2$ .

Table 1: Textural characteristics of banana peel based activated carbons

Samples	Impregnation ratio (banana powder: ZnCl <sub>2</sub> )	BET Surface Area (m <sup>2</sup> /g)
1	1:1	553.66
2	1:2	555.75
3	1:4	601.54
4	2:1	612.78
5	4:1	632.65

### 3.2 Adsorption isotherm of batch adsorption of MB onto the banana peel based activated carbons

The adsorption isotherm shows the distribution of adsorption molecules between the liquid phase and the solid phase when the adsorption process reaches an equilibrium state. The analysis of the isotherm data by fitting them to different isotherm models is an important step to find the suitable model that can be used for design purpose [17]. Fig. 3 typically shows the adsorption isotherms of MB dye on the activated carbon. Adsorption isotherm is basically important to describe how solutes interact with adsorbents, and is critical in optimizing the use of adsorbents.

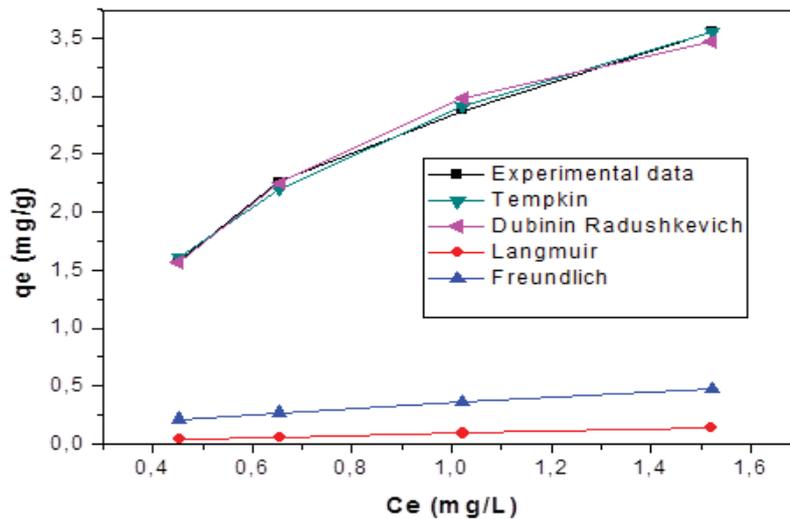


Figure 3: Equilibrium adsorption isotherm of methylene blue onto activated carbon

Adsorption isotherm study is carried out on the four type of isotherms, Langmuir, Freundlich, Tempkin and Dubinin Radushkevich model. The applicability of the isotherm equation is compared by judging the correlation coefficients.

#### 3.2.1 Langmuir adsorption

Langmuir isotherm assumes monolayer adsorption onto a surface containing a finite number of adsorption sites of uniform strategies of adsorption with no transmigration of adsorbate in the plane of surface [14]. The linear form of Langmuir's isotherm model is given by the following equation:

$$\frac{C_e}{q_e} = \frac{1}{q_0 b} + \frac{1}{q_0} C_e \quad (3)$$

where  $C_e$  is the equilibrium concentration of the adsorbate (MB) (mg/l),  $q_e$  the amount of adsorbate adsorbed per unit mass of adsorbate (mg g<sup>-1</sup>), and  $q_0$  and  $b$  are Langmuir constants related to adsorption capacity and rate of adsorption, respectively. When  $C_e/q_e$  was plotted against  $C_e$ , straight line with slope  $1/q_0$  was obtained. The Langmuir constants ' $b$ ' and ' $q_0$ ' were calculated from this isotherm and their values are given in Table 2.

Table 2: Langmuir, Freundlich, Tempkin dan Dubinin R isotherm constants for MB

Langmuir		Tempkin	
q <sub>o</sub> (mg/g)	7.168	β	1.606
b (L/mg)	0.657	α	6.014
R <sup>2</sup>	0.974	R <sup>2</sup>	0.997
Freundlich		Dubinin-Radushkevich	
n	1.527	K (mol <sup>2</sup> .J <sup>2</sup> )	1.129 x 10 <sup>-7</sup>
K <sub>f</sub>	0.358	Q <sub>m</sub> (mg/g)	4.166
R <sup>2</sup>	0.977	R <sup>2</sup>	0.994
		E (J/mol)	2104.26

The essential characteristics of the Langmuir isotherm can be expressed in terms of a dimensionless equilibrium parameter ( $R_L$ ) [14], which is defined by:

$$R_L = \frac{1}{1 + bC_0} \quad (4)$$

where  $b$  is the Langmuir constant and  $C_0$  the highest dye concentration ( $\text{mg l}^{-1}$ ). The value of  $R_L$  indicates the type of the isotherm to be either unfavorable ( $R_L > 1$ ), linear ( $R_L = 1$ ), favorable ( $0 < R_L < 1$ ) or irreversible ( $R_L = 0$ ). Value of  $R_L$  was found to be less than 1 and confirmed that the activated carbon is favorable for adsorption of MB dye under conditions used in this study.

### 3.2.2 Freundlich adsorption

While, Freundlich isotherm model assumes heterogeneous surface energies, in which the energy term in Langmuir equation varies as a function of the surface coverage [14]. As implied, its derivation is characterized by a uniform distribution of binding energies (up to some maximum binding energy). The well-known logarithmic form of Freundlich model is given by the following equation:

$$\ln(q_e) = \ln(K_F) + \frac{1}{n} \ln(C_e) \quad (5)$$

where  $q_e$  is the amount adsorbed at equilibrium ( $\text{mg g}^{-1}$ ),  $C_e$  the equilibrium concentration of the adsorbate (MB) and  $K_F$  and  $n$  are Freundlich constants,  $n$  giving an indication of how favorable the adsorption process and  $K_F$  ( $\text{mg g}^{-1} (\text{l mg}^{-1})^n$ ) is the adsorption capacity of the adsorbent.  $K_F$  can be defined as the adsorption or distribution coefficient and represents the quantity of dye adsorbed onto activated carbon adsorbent for a unit equilibrium concentration. The slope  $1/n$  ranging between 0 and 1, is a measure of adsorption intensity or surface heterogeneity, becoming more heterogeneous as its value gets closer to zero [14]. A value for  $1/n$  below one indicates a normal Langmuir isotherm while  $1/n$  above one is indicative of cooperative adsorption [14]. The Freundlich constant is given on Table 2.

### 3.2.3 Tempkin adsorption

Tempkin isotherm contains a factor that explicitly taking into the account of adsorbent-adsorbate interactions. By ignoring the extremely low and large value of concentrations, the model assumes that heat of adsorption (function of temperature) of all molecules in the layer would decrease linearly rather than logarithmic with coverage [14]. The Tempkin isotherm has been used in the following linearized form:

$$q_e = \beta \ln(\alpha) + \beta \ln(C_e) \quad (6)$$

The adsorption data can be analyzed according to Eq. (13). A plot of  $q_e$  versus  $\ln C_e$  enables the determination of the constants A and B.

### 3.2.4 Dubinin Radushkevich (D-R) adsorption

The D-R model, which does not assume a homogeneous surface or a constant adsorption potential as the Langmuir model, was also used to test the experimental data. It was applied to distinguish between physical and chemical adsorption of MB. The following form of D-R model is used :

$$\ln(q_e) = \ln(q_m) - K \varepsilon^2 \quad (7)$$

Where K = coefficient related to the mean free energy of adsorption ( $\text{mol}^2/\text{J}^2$ ) and  $\varepsilon$  = Polanyi potential [ $\text{J}/\text{mol}$ ] , which is equal to  $RT \ln(1+1/C_e)$  where R = gas constant ( $8.314 \text{ J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ ); and T = temperature (K)]. The values of constants  $q_m$  and  $\beta$  thus obtained from linear regression, along with the error functions, are given in Table 2.. Therefore, in all the cases, the D-R equation represented the most fit to experimental data than the other isotherm equations. The constant  $\beta$  gives an idea of the mean sorption energy, E, which is defined as the free energy transfer of 1 mol of solute from infinity of the surface of the sorbent and can be calculated using the relationship :

$$E = \frac{1}{\sqrt{2K}} \quad (8)$$

The magnitude of E was less than  $8 \text{ kJ}\cdot\text{mol}^{-1}$  indicating that the adsorption mechanism was physical adsorption.

### 3.3. Adsorption Kinetics

Two kinetic models such as pseudo-first-order and pseudo-second-order kinetic were applied for the experimental results. The pseudo-first-order kinetic model proposed by Lagergren and Svenska [15] was usually used to predict sorption kinetic and was defined as:

$$\ln(q_e - q_t) = \ln(q_e) - k_1 t \quad (9)$$

where  $q_e$  and  $q_t$ (mg/g) are the amounts of adsorbate adsorbed at equilibrium and at any time,  $t$  (h), respectively and  $k_1$  (1/h) is the adsorption rate constant.

The pseudo-second-order equation [12] is expressed by :

$$\frac{t}{q_t} = \frac{1}{k_2 q_e^2} + \frac{t}{q_e} \quad (10)$$

where  $k_2$  (g/mg h) is the rate constant of second-order adsorption.

The values of all constants  $R^2$  obtained from the plots for adsorption of MB dye on the adsorbent at  $25^\circ\text{C}$  are reported in Table 3. It was observed that the  $R^2$  values obtained for the pseudo-second-order model was higher than that of first order model. This shows that the adsorption of MB dye on the adsorbent follows a pseudo second-order kinetic model.

Table 3: Adsorption kinetic models and their parameters

Models	Parameters	Values
1st Order	$k_1$	0.012
	$q_e$	2.339
	$R^2$	0.892
2nd Order	$k_1$	0.009
	$q_e$	3.826
	$R^2$	0,989

## 4. CONCLUSIONS

The present investigation showed that banana peel can be effectively used as a raw material for the preparation of activated carbon for the removal of methylene blue dye from aqueous solution. Methylene blue is found to adsorb strongly on the surface of activated carbon. Adsorption behaviour is described by a Dubinin Radushkevich type isotherm. Kinetic data follows pseudo second-order kinetic model.

## ACKNOWLEDGMENT

The first author acknowledged the financial support provided by Parahyangan Catholic University

## REFERENCES

- [1] K.R. Ramakrishna, T. Viraraghavan, "Dye removal using low cost adsorbents", *Water Sci. Technol.* 36 (2-3), 1997, 189-196.
- [2] P.N. Cheremisinoff, F. Ellerbusch (Eds.), *Carbon Adsorption Handbook*, Ann Arbor Science, Ann Arbor, Michigan, 1980.
- [3] R.T. Yang, *Adsorption*, John Wiley & Sons Inc., Hoboken, New Jersey, 2003.
- [4] D.M. Ruthven, *Principles of Adsorption and Adsorption Process*, Wiley, New York, 1984.
- [5] P. Chingombe, B. Saha, R.J. Wakeman, Surface modification and characterisation of a coal-based activated carbon, *Carbon* 43 (2005) 3132-3143.
- [6] P. Nigam, G. Armour, I. Banat, D. Singh, R. Marchant (2000). *Physical removal of textile dyes and solid state fermentation of dye adsorbed agricultural residues*, *Bioresour. Technol.* 72 p. 219.
- [7] C. Lee, K. Low, P. Gan. *Removal of some organic dyes by acid treated spent bleaching earth*, *Environ. Technol.* 1999, 20 p. 99
- [8] A. Khaled, A. Nemr, A. Sikaily, O. Abdelwahab. *Treatment of artificial textile dye effluent containing Direct Yellow 12 by orange peel carbon*, *Desalination*, 2009, 238, 210-232
- [9] Md.Z. Alam, E.S. Ameen, S.A. Muyibi, N.A. Kabbashi, The factors affecting the performance of activated carbon prepared from oil palm empty fruit bunches for adsorption of phenol, *Chem. Eng. J.* 155 (2009) 191-198.
- [10] R. Gottipati, S. Mishra, Process of adsorption of Cr(VI) on activated carbons prepared from plant precursors by a two-level full factorial design, *Chem. Eng. J.* 160 (2010) 99-107.
- [11] El-Hendawy, A. A.; Samra, S. E.; Girgis, B. S. Adsorption characteristics of activated carbons obtained from corncobs. *Colloids Surf., A* 2001, 180, 209-221.
- [12] El-Hendawy, A. A. Surface and adsorptive properties of carbons prepared from biomass. *Appl. Surf. Sci.* 2005, 252, 287-295.
- [13] Tseng, R. L.; Tseng, S. K. Pore structure and adsorption performance of the KOH-activated carbons prepared from corncob. *J. Colloid Interface Sci.* 2005, 287, 428-437.
- [14] K.Y. Foo, B.H. Hameed (2010) "Insights into the modeling of adsorption isotherm systems", *Chemical Engineering Journal* 2010, 156, 2-10.
- [15] S. Langergren, B.K. Svenska *Zur theorie der sogenannten adsorption gelöster stoffe*, *Veternskapsakad Handlingar*, 1998, 24 (4) p. 1-39.

## Synthesis of pH-Dependant ZnO Nanoparticle by Sol-Gel Method

Radyum Ikono<sup>b,e</sup>, Putri Riskia Akwalia<sup>c</sup>, Siswanto<sup>c</sup>, Wahyu Bambang W.<sup>d</sup>, Agus Sukarto<sup>d</sup>,  
Lusi Susanti<sup>b</sup>, Nurul Taufiqu Rochman<sup>a\*</sup>

<sup>a</sup>Research Center for Metallurgy  
Indonesian Institute of Science (LIPI)  
Tangerang Selatan  
Email : nurul@nano.or.id

<sup>b</sup>Nano Center Indonesia  
Tangerang Selatan 15320

<sup>c</sup>Department of Physics  
University of Airlangga  
Surabaya

<sup>d</sup>Research Center for Physics  
Indonesian Institute of Science (LIPI)  
Tangerang Selatan

<sup>e</sup>Department of Metallurgy and Materials  
University of Technology Sumbawa, Sumbawa

### ABSTRACT

In recent years, there have been many methods developed to synthesize Zinc Oxide (ZnO) nanoparticles. Nevertheless, a simple yet cheap method to prepare single crystal with high purity nano ZnO was still yet to be established. In this research, nano Zinc oxide (ZnO) was prepared by sol-gel method. The pH variation effect to the resulting ZnO product was also observed.  $(\text{CH}_3\text{COOH})_2\text{Zn}\cdot 2\text{H}_2\text{O}$  powder and NaOH solution were used as precursors. NaOH solution was added to  $(\text{CH}_3\text{COOH})_2\text{Zn}\cdot 2\text{H}_2\text{O}$  solution by titration until colloids with different pH were obtained, then precipitates of nano ZnO were formed. From the precipitation profile, it can be observed that increasing pH led to shortened precipitation time, which also means increasing particle size. It was also further confirmed that particle size at pH 7 and pH 12 was 1.3 nm and 73.8 nm, respectively. XRD profile showed that increasing pH led to increasing purity of nano ZnO: 42.9%, 62.2%, 64.7%, and 100% at pH 7, pH 8, pH 10, and pH 12, respectively. To conclude, nano ZnO synthesized by Sol-Gel method was highly affected by pH of the working solution. Increasing pH led to increasing particle size, however led to higher purity of nano ZnO produced.

### Keywords

*Nano ZnO; sol-gel; pH variation*

### 1. INTRODUCTION

Zinc Oxide (ZnO) ceramics have gained much attention due to their distinct properties and characteristics. ZnO ceramics in various forms are used extensively in electronic applications, such as LED, sensor, or solar cells [1]. In recent years, it has also been found that ZnO can be used in other potential applications like photocatalysis and anti-bacterial substance, thus making them exciting commodities for industries [2].

At the same time, nanotechnology becomes much more popular nowadays. Scientists believe that by engineering material size into nanoscale, there will be an enhancement on properties of the material. In many literatures, it can also be learned that nano ZnO offers better performance compared to that of in bulk size [3].

There have been many methods to synthesize nano ZnO. Some of the widely used methods are, for instance, Chemical vapor deposition (CVD), dip coating, or mechanical alloying [4,5,6]. Those methods have their own advantages and disadvantages. For example, CVD and dip coating, they can produce nano ZnO with high purity, however high growth temperature is needed in their system. Also, the preparation scheme is quite complex and can be very expensive [7]. Mechanical alloying is another interesting method where it can synthesize nano ZnO in relatively simple manner [8]. Nevertheless, to date, there has been no reports on mechanical alloying method that can yield pure nano ZnO. Another possible method is sol-gel method. The good

thing about this method is that, it is relatively simple and cheap in process, and it does not need to be treated in high growth temperature [9]. However, to date, there is still a little knowledge on the effect of pH variation on sol-gel working solution, also whether high purity of nano ZnO can be achieved by this method.

In this research, nano ZnO was synthesized by sol-gel method, in an attempt to find the optimum condition to produce single crystal ZnO with relatively small size. The pH condition would be varied for this optimization process.

## 2. EXPERIMENTAL PROCEDURE

4.39 gram  $(\text{CH}_3\text{COOH})_2\text{Zn}\cdot 2\text{H}_2\text{O}$  (Merck) powder was dissolved in 100 mL methanol. It was then sonicated at 750 Watt for 30 minutes to obtain homogenous solution of 0.2 M. Separately, 1.0 M NaOH was dissolved in 500 mL distilled water. After that, optimization for titration was conducted to find the optimum condition of the time, temperature, and stirring speed.

The optimized condition was used for titration of NaOH solution dropped to  $(\text{CH}_3\text{COOH})_2\text{Zn}\cdot 2\text{H}_2\text{O}$  solution. Titration was continued until 5 pH variations were obtained: pH 7, pH 8, pH 9, pH 10, pH 11, and pH 12. After the color of the solution become milky white, the solution was sonicated for another 30 minutes. It was then idled for several days to observe the precipitation of nano ZnO in the solution.

After the precipitation could be clearly seen through, solution was centrifuged at 3000 rpm for 30 minutes. The supernatant was then removed, and the precipitation which contains nano ZnO was obtained. Nano ZnO precipitates was first treated in  $80^\circ\text{C}$  oven to remove the remaining water. Finally, nano ZnO was grinded with mortar to be shaped into powder.

To find out the particle size, Particle Size Analyzer (Delsa<sup>TM</sup> Nano C Beckman Coulter) was used. Briefly, nano ZnO was dissolved in distilled water in 1:10 concentration. It was then stirred until ZnO suspension in water was formed. 1 mL of the suspension was then tested to obtain the average particle size.

The solution was then centrifuged, and the supernatant was removed to obtain the nano ZnO. Finally, nano ZnO powder was achieved after heat treatment at  $80^\circ\text{C}$ . The X-ray diffraction (XRD) pattern of the final ZnO nanoparticles was obtained with Cu K $\alpha$  radiation (Shimadzu, Japan). The peak positions and relative intensities were characterized by comparison with the Joint Committee for Powder Diffraction Standards (JCPDS). Williamson-Hall plot was used to analyze the crystal size at different pH.

The preparation scheme was shown in Figure 1.

## 3. RESULTS AND DISCUSSIONS

The time for nano ZnO to precipitate from solution was observed. It can be seen from Figure 2 that time to precipitate decreased over increasing pH. The range from pH 7 condition which needed 72 hours to pH 12 condition which needed only 120 minutes to precipitate showed that pH plays a very significant role in sol-gel experiment.

One of the prominent characteristics of nanoparticles are that they tend to float in solution and they need much longer time to be precipitated inasmuch as the gravitation force exerting them is very small, or even almost negligible [10]. It was hypothesized that by varying the pH condition, the size of the particle obtained would also be varied, and this would affect the precipitation profile of the ZnO nanoparticles.

To test above hypotheses, size of the particles at lower and upper pH (pH 7 and pH 12) were measured by PSA machine. Results showed that the size of nanoparticles at pH 7 and pH 12 were 1,3 nm and 73,8 nm, respectively. It is in agreement with hypotheses above that as pH of the solution increased, the size of the nanoparticle increased as well.

Finally, XRD graph in Figure 4 gave us information about the elements of the particles formed at pH 7, 8, 10 and 12. From the graph, it can be inferred that the purity of nano ZnO produced increased as pH increased. Only at pH 12 the 100% ZnO without any contaminants or mixture with other compounds were obtained. The quantitative data of ZnO purity at pH 7, 8, 10, and 12 was as follows: 42.9%, 62.2%, 64.7%, and 100%, respectively.

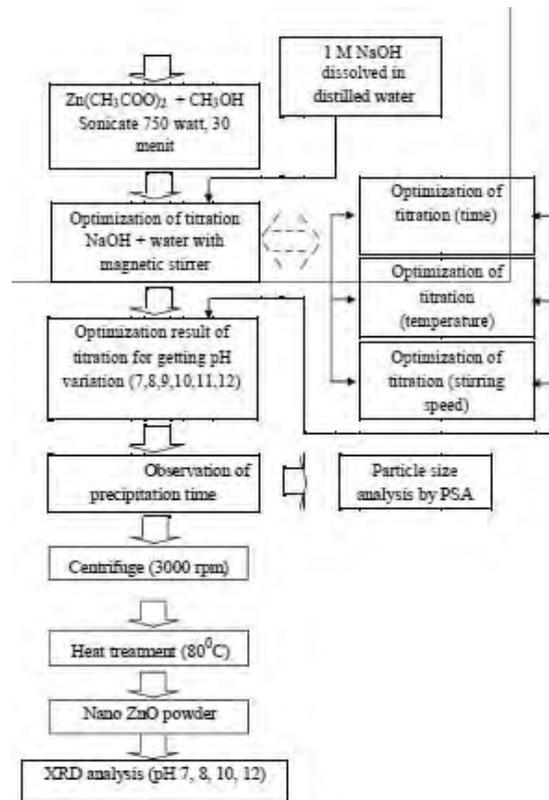


Figure 1: Experiment Scheme

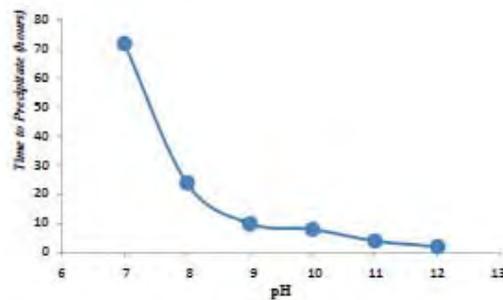


Figure 2: The graph of precipitation time over pH of working solution

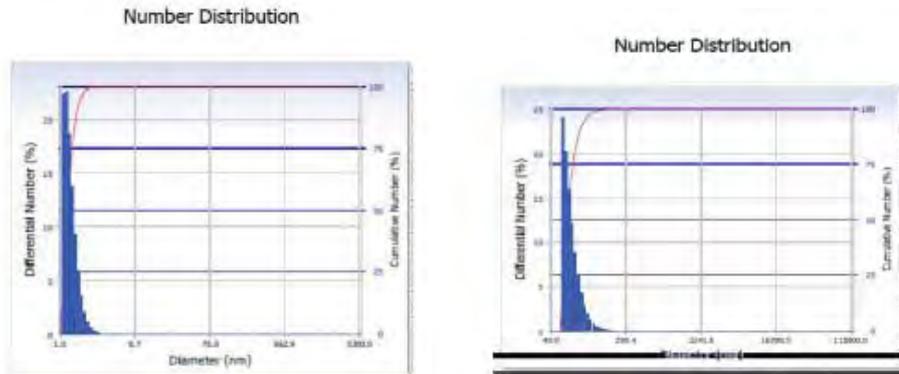


Figure 3: Size distribution of ZnO nanoparticle at pH 7 (top) and pH 12 (bottom)

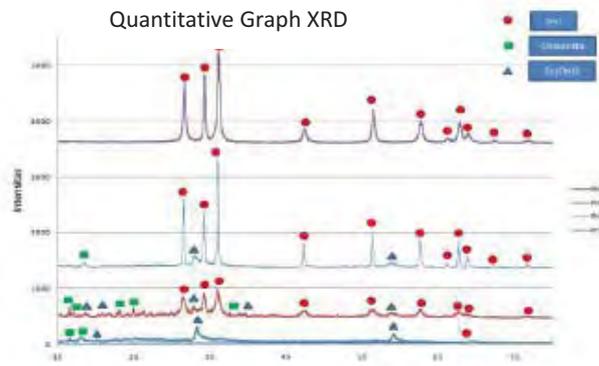


Figure 4: XRD graph of nano ZnO at pH 7, pH 8, pH 10, and pH 12

This phenomenon was well explained by Sunandan, *et al.* that the growth of ZnO is normally enhanced in basic medium. The final growth of ZnO depends upon the competition between growth and etching [10]. The size became significantly bigger at basic condition maybe because high purity ZnO nanoparticles tend to bind each other and agglomerate. In lower pH, although the particle was much smaller in size, the ZnO obtained was still in mixture with other compounds, such as  $\text{CH}_3\text{COONa}$  and  $\text{Zn}(\text{OH})_2$ , therefore they tend to be separated, hence each has small size. Interestingly, at pH 7 there was almost no ZnO particles could be observed. It can be understood that at pH 7, the growth of ZnO was suppressed. It can be predicted that at pH lower than 7, there might be no ZnO produced by sol-gel method using protocol implemented in this research.

Another interesting finding was observed from measurement of crystal size using Williamson-Hall plot analysis as shown in Table 1. From those data, it can be seen by comparing the particle size (before heat treatment) and crystal size (after heat treatment), there was a tendency for the particle to grow in size. This might be due to recrystallization happened due to heat treatment effect. Nevertheless, it can be deduced that the size increment was not significant.

Table 1: Crystal size analyzed by williamson-hall plot

pH	Crystal size (nm)
7	10,94±0,99
8	17,44±5,36
10	38,27±2,14
12	74,04±41,77

#### 4. CONCLUSIONS

Nano ZnO was synthesized successfully from precursor  $(\text{CH}_3\text{COOH})_2\text{Zn}\cdot 2\text{H}_2\text{O}$  and NaOH. pH of the working solution was varied to see the different resulting nano ZnO produced. Nano ZnO precipitation time increased over increasing pH, while the size of the nanoparticle also increased over increasing pH. The XRD data showed that from pH 7 to pH 12, there was significant improvement of the nano ZnO purity. Interestingly, 100% purity of nano ZnO could be obtained at pH 12. This research showed that pH condition in sol-gel reaction plays a very significant role to control the characteristics of nano ZnO produced.

#### REFERENCES

- [1] Shen, L., Bao, N., Yanagisawa, K., Domen K., Gupta A., Grimes C.A. "Direct synthesis of ZnO nanoparticles by a solution-free mechanochemical reaction", *Nanotechnology* 17 (2006) 5117-5123.
- [2] Puckett S.D., Taylor E., Raimondo T., et al. "The relationship between the nanostructure of titanium surfaces and bacterial attachment", *Biomaterials* 31 (2010) 706-713.
- [3] Salah N., Habib S.S., Khan Z.H., Memic A., Azam A., Alarfaj E., Zahed N., Al-Hamed S. "High-energy ball milling technique for ZnO nanoparticles as antibacterial material", *Intl. J. Nanomed.* 6 (2011) 863-869.
- [4] Wang J.R., Ye Z.Z., Huang J.Y., et al. "ZnMgO nanorod arrays grown by metal-organic chemical vapor deposition", *Mater. Lett.* 62 (2008) 1263-1266.
- [5] Sasani G.M., Vafaei M. "Sol-gel derived zinc oxide buffer layer for use in random laser media", *Mater. Lett.* 62 (2008) 1754-1756.
- [6] Ye, X.Y., Zhou, Y.M., Chen, J., Sun, Y.Q., Wang Z.Q., et al. "Coating of ZnO nanorods with nanosized silver particles by electroless plating process", *Mater. Lett.* 62 (2008) 666-669.
- [7] Damonte L.C., Mendoza Z.L.A., Mari S.B., Fenollosa H.M.A. "Nanoparticles of ZnO obtained by mechanical milling", *Powder Technol.* 148 (2004) 15-19.
- [8] Yan, J., Liu, Y., Peng, A., Lu, Q. "Fabrication of nano-crystalline W-Ni-Fe pre-alloyed powders by mechanical alloying technique", *Trans. Nonferrous. Met. Soc. China* 19 (2009) s711-s717.
- [9] Ansari A.A., Singh R., Sumana G., Malhotra B.D., "Sol-gel derived nano-structured zinc oxide film for sexually transmitted disease sensor", *Royal Soc. Chem.* 134 (2009) 997-1002.
- [10] Sunandan B., Joydeep D. "pH dependent growth oxide nanorods", *J. Crystal Growth* 318 (2009) 8 2549-2554

## Improvement of Zinc Oxide Nanoparticle Dispersion Stability With Polyelectrolyte Stabilization Mechanism

Radyum Ikono<sup>b,d</sup>, Nofrizal<sup>b</sup>, Tanti Dewingih<sup>c</sup>, Mukhtar Effendi<sup>c</sup>, Lusi Susanti<sup>b</sup>, Nurul Taufiq Rochman<sup>a\*</sup>

<sup>a</sup>Research Center for Metallurgy  
Indonesian Institute of Science (LIPI)  
Tangerang Selatan  
Email : nurul@nano.or.id

<sup>b</sup>Nano Center Indonesia  
Tangerang Selatan 15320

<sup>c</sup>Department of Physics  
University of Jenderal Soedirman  
Purwokerto

<sup>d</sup>Department of Metallurgy and Materials  
University of Technology Sumbawa, Sumbawa

### ABSTRACT

Zinc Oxide (ZnO) possesses high tendency to agglomerate in dispersion system, thus making it difficult to be stable. This research is intended to find out the effect of addition of polyelectrolyte Polyacrylic Acid (PAA) to improve the stability of nano ZnO dispersion. Two parameters that will be observed here are particle size and zeta potential. 5% nano ZnO was dispersed with different condition of stirring (1 hour and 5 hour) with different concentration of PAA (0.5%, 1% dan 3%) also with different temperature (27°C and 57°C). Results showed that in all conditions, PAA addition gave significant effect in particle size and zeta potential, compared to control without PAA addition. Most optimum condition for PAA addition was obtained on PAA addition of 0.5%, 1 hour stirring duration and temperature of 57°C with particle size in range of 193.4 – 253.8 nm and zeta potential of -74.86 mV. From all results and discussions, it can be concluded that PAA addition could improve the stability of nano ZnO dispersion.

### Keywords

*ZnO; Dispersion stability; Particle size; Zeta Potential*

### 1. INTRODUCTION

In recent years, Nano *Zinc oxide* (ZnO) was used in enormous applications, such as photocatalysis [1], coating [2], food packaging [3], and many more. One of the way of utilization of nano ZnO is by dispersing it in the solution. However, nano ZnO is not stable in the solution, and possesses high tendency for agglomeration.

One of the mostly used dispersion solution for nano ZnO is ethanol. Nevertheless, ethanol is easily vaporized, flammable, and poisonous, thus making it limited in this application [4]. On the other hand, water can also be used as a dispersion media for nano ZnO. Water is safe, though is difficult to obtain stable dispersion. In some researches, it was found that Nano ZnO agglomerated much faster in water than in ethanol [1].

The stability of the dispersion can be controlled by adding electrolyte in the form of surfactants or polymers [5]. Polyelectrolyte is a type of polymer that has many charges surrounding its surface and has electrolytic characteristics [6,7]. This charged polymeric chain has an essential role to decide dispersion system's stability. In this research, the dispersion stability of nano ZnO in water will be studied by adding polyelectrolyte Polyacrylic acid (PAA) that hypothesized to be able to neutralize excessive cations in the dispersion system. The effect of PAA concentration, stirring time, and stirring temperature will also be studied. Two parameters that will be analyzed are particle size and zeta potential.

## 2. EXPERIMENTAL PROCEDURE

Materials used in this experiment are Zinc Oxide (Nanotech Indonesia Ltd.), and Polyacrylic acid (Foton Prima Perkasa Ltd.).

ZnO was first analyzed by Scanning Electron Microscopy (SEM) (JEOL) with 10,000 and 20,000 times magnification. ZnO was then dispersed in distilled water, with or without PAA addition. 5% ZnO was dispersed in distilled water and stirred using magnetic stirrer in 700 rpm. Concentration of PAA, stirring time, and stirring temperature were varied as follows: 0.5%, 1%, and 3%; 1 hour and 5 hour; 27°C and 57°C, respectively.

The particle size and zeta potential of dispersed ZnO was then analyzed by Particle Size Analyzer (Delsa™ Nano C Beckman Coulter) and Zeta Potential Analyzer (Delsa™ Nano C Beckman Coulter), respectively.

## 3. RESULTS AND DISCUSSIONS

From the SEM image of nano ZnO shown in figure 1, particle size of nano ZnO can be obtained by manual observation. The particle size was predicted to be in range of 142.8 – 809.2 nm as shown in Figure 2. This particle size can be assumed as the real particle size of nano ZnO.

The complete data of particle size and zeta potential at varied PAA concentration, stirring time, and stirring temperature is shown in Table 1.

Particle size in dispersed ZnO in water without PAA addition has minimum particle size at 1 hour stirring time at 57°C, which is in range of 3.758 nm – 13.049 nm. Physically, stirring time and stirring temperature did not give significant effect towards ZnO particle size in control group (without PAA addition).

The ZnO particle size in PAA added group has relatively smaller size compared to those without PAA addition, and much nearer to predicted real size of ZnO as analyzed earlier by SEM. It can be inferred that PAA can improve the stability of the dispersion system, most likely due to its ability to neutralize excessive positive charges in the dispersion system, which also relates to particle size of ZnO. The complete graph of the effect of PAA addition to ZnO particle size can be seen in Figure 3.

As shown in figure 3, PAA addition, stirring time, and stirring temperature have significant effects towards ZnO particle size. Generally, by increasing the PAA concentration, the ZnO particle size became relatively smaller, also prolonged stirring time tends to make particle size smaller. However, this phenomenon only occurred during stirring temperature of 27°C. Increasing stirring temperature can give an effect towards decreasing particle size, nevertheless, still, most significant variable that affects the particle size is PAA addition. 3% PAA addition is much more effective to obtain particle size with narrow distribution. Meanwhile, ZnO particle size with PAA addition that has smallest particle size was obtained at 1% PAA addition, stirring time of 5 hours and stirring temperature of 57°C, which led to size of 88.3 nm – 350.5 nm.

The graph of effect of PAA addition to ZnO zeta potential is shown in Figure 4. ZnO without PAA addition could not be analyzed by Zeta Potential Analyzer because during the characterization, the light scattering intensity was not enough for measurement.

Figure 4 shows that as the PAA added more and more, the zeta potential of ZnO will shift towards positive axis. This zeta potential increase made the dispersion system becomes unstable, close to  $\pm 30$  mV that is usually considered as the limit of dispersion stability. In the other words, increasing PAA concentration leads to decreasing ZnO stability. The highest ZnO dispersion stability was obtained at PAA addition of 0.5% with 5 hour stirring time and at stirring temperature of 27°C, which gave the zeta potential of -76.06 mV. At the very last, the correlation of zeta potential and particle size of nano ZnO can be observed in figure 5. It can be inferred that generally, increasing zeta potential leads to decreasing ZnO particle size. Also, it can be concluded that the most optimum sample of all experiments, which compromises the particle size and zeta potential value was obtained at PAA addition of 0.5% with stirring time of 1 hour and at 57°C which gave the zeta potential value of -74.86 mV and particle size with narrow range of 193.4 – 253.8 nm.

## 4. CONCLUSIONS

Based on results above, it can be concluded that the predicted real size of ZnO in this experiment is 142.8 nm – 809.2 nm as characterized by SEM. PAA addition that gave smallest particle size was obtained PAA addition of 1% with 5 hour stirring time at 57°C, with size range of 88.3 nm – 350.5 nm. The ZnO dispersion with highest stability was obtained at PAA addition of 0.5% with 5 hour stirring time at 27°C, which gave the zeta potential value of -76.06 mV. While the most optimum that compromises the particle size and zeta potential of ZnO was obtained at PAA addition of 0.5% with 1 hour

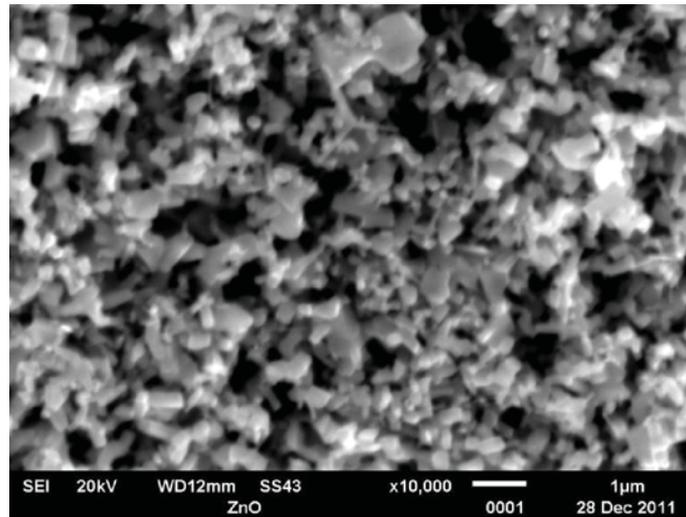
stirring time at 570C, with particle size in range of 193.4 nm – 253.8 nm. At the very last, PAA addition in ZnO dispersion was proven to be able to improve the system's stability significantly.

## REFERENCES

- [1] H. Wang et al., "Effect of Polyelectrolyte Dispersants on the Preparation of Silica-Coated Zinc Oxide Particles in Aqueous Media," *American Ceramic Society*, vol. 85, pp. 1937-1940, 2002.
- [2] F. L. Duivenvoorde, C. F. van Nostrum, J. Laven, dan R. Van der Linde, "Improving Pigmen Dispersing in Powder Coatings with Block Copolymer Dispersants," *J. Coat. Technol*, vol. 72, no. 52, p. 145, 2000.
- [3] Armin reindl, "Dispersing and Stabilizing Semiconducting Nanoparticle for Application in Pirantable Electronics," Erlangen University, Nurnberg, Tesis 2009.
- [4] Prof. Shakhashiri, "Ethanol," *Chemical of Week*, Pebruari 2009.
- [5] "Sample Preparation," in *Zeta Sizer Nano Series.*, ch. 6.
- [6] Jingyu Shi, *Steric Stabilization*. United States of America: Center for Industrial Sensors and Measurements, Departemen Materials Science & Engineering, Group Inorganic Materials Science, The Ohio State University, 2002.
- [7] Fred W. Billmeyer, *Polymer Science*, 3rd ed. New York: A wiley-Interscience, 1984.
- [8] Andrey V. Dobrynina dan Michael Rubinsteinb, "Theory of polyelectrolytes in solutions and at surfaces," *Prog. Polym. Sci.* , vol. 30, pp. 1049–1118, Juli 2005.

Table 1. Experimental variables

PAA concentration	Stirring time (hour)	Stirring temperature (°C)
0 %	1	27
0.5 %	1	27
1 %	1	27
3 %	1	27
0 %	5	27
0.5 %	5	27
1 %	5	27
3 %	5	27
0 %	1	57
0.5 %	1	57
1 %	1	57
3 %	1	57
0 %	5	57
0.5 %	5	57
1 %	5	57
3 %	5	57



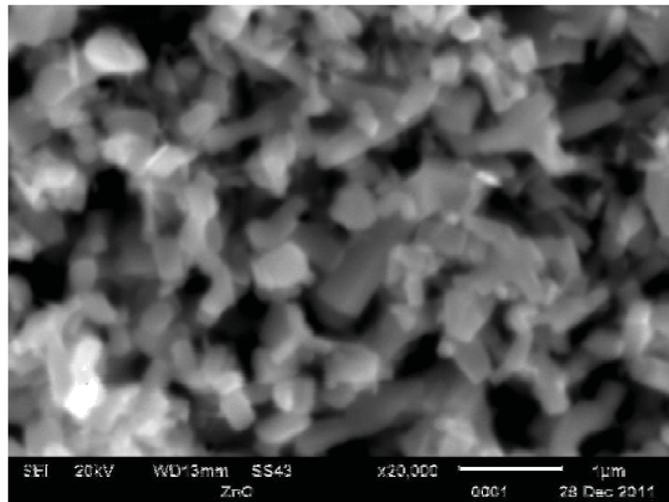


Figure 1. Nano ZnO characterization at 10,000 and 20,000 times magnification

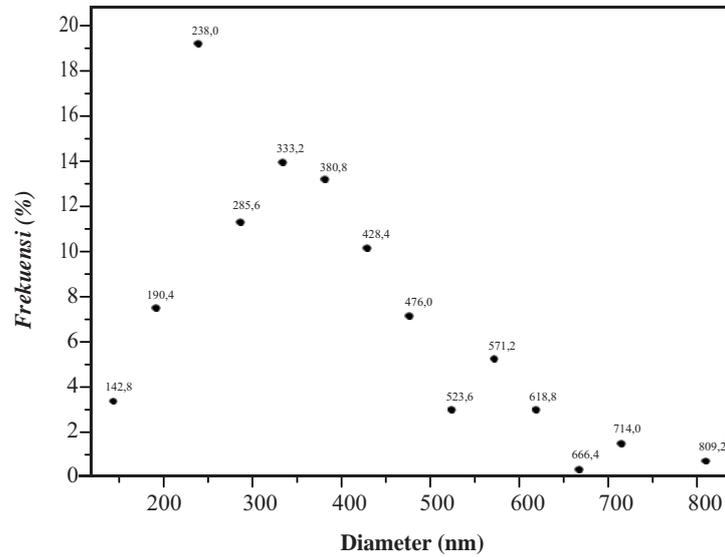
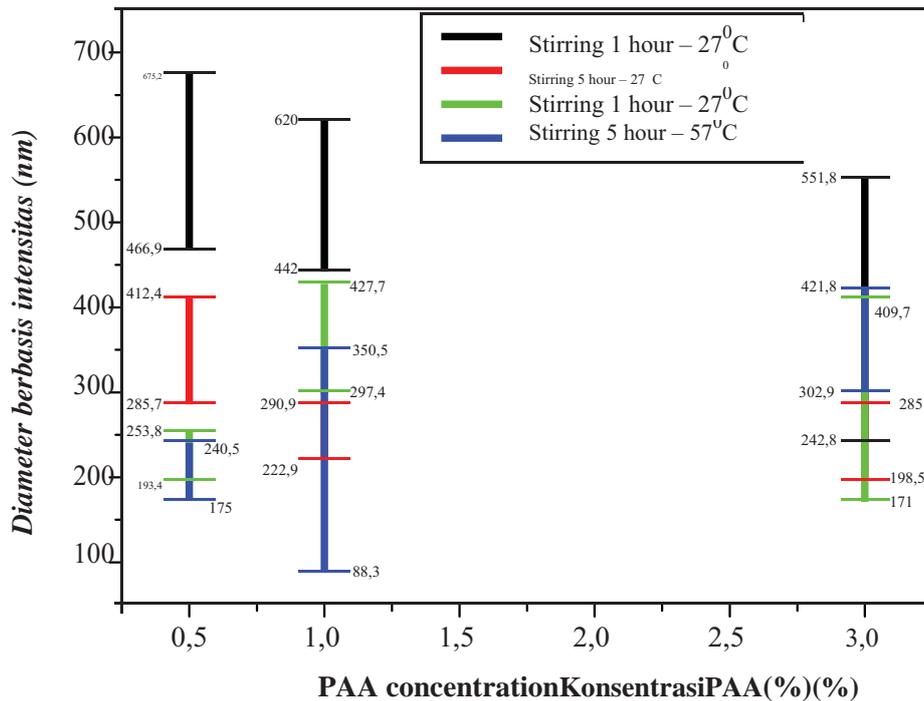


Figure 2. Distribution profile of ZnO particle size analyzed from SEM image 10,000 times magnification

**Table 2. Complete data of the experiment**

PAA (%)	Stirring time (hour)	Stirring temperature (°C)	Particle size (nm)	Zeta Potential(mV)
0	1	27	10,731.0 – 25,977.8	-
0.5	1	27	466.9 – 675.2	-69.69
1	1	27	442.0 – 620.0	-63.18
3	1	27	242.8 – 551.8	-34.62
0	5	27	33.621.0 – 89.700.0	-
0.5	5	27	285.7 – 412.4	-76.06
1	5	27	222.9 – 290.9	-65.62
3	5	27	198.5 – 285.0	-51.92
0	1	57	3.758.3 – 13,049.0	-
0.5	1	57	193.4 – 253.8	-74.86
1	1	57	297.4 – 427.7	-63.52
3	1	57	171.0 – 409.7	-51.94
0	5	57	35.947.9 – 173.761.3	-
0.5	5	57	175.0 – 240.5	-52.51
1	5	57	88.3 – 350.5	-59.68
3	5	57	302.9 – 421.8	-46.65



**Figure 3. Graph of effect of PAA addition to ZnO particle size**

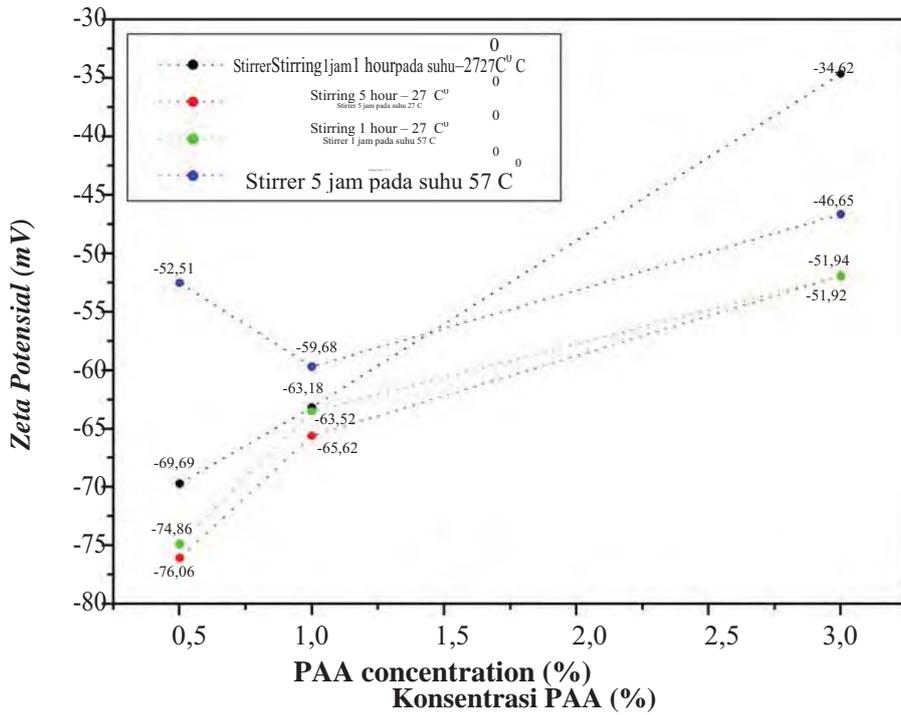


Figure 4. Graph of effect of PAA addition to ZnO zeta potential

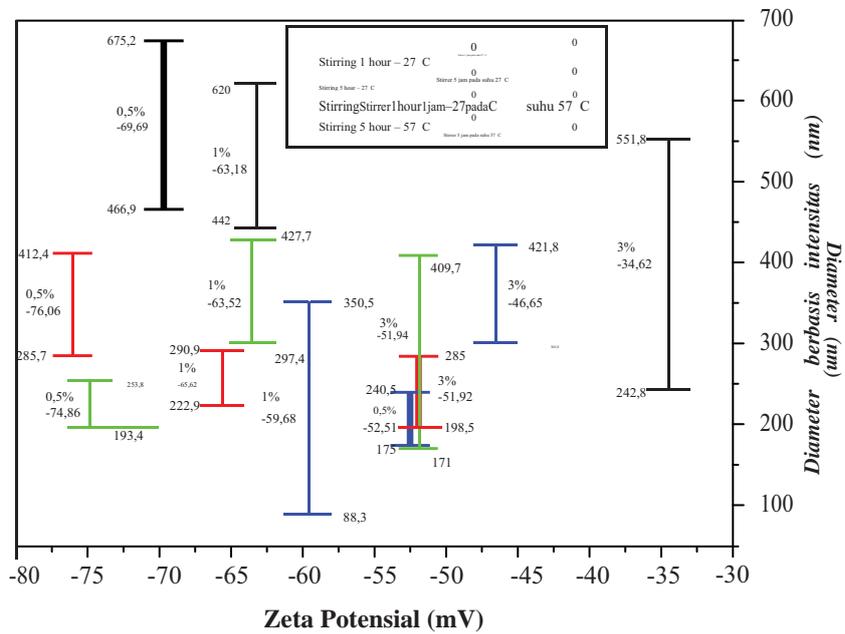


Figure 5. Graph of correlation between zeta potential and particle size in ZnO dispersion system

# Kinetics of Carbon Nanotubes Growth on Ni-Cu-Al Catalyst by Catalytic Decomposition of Methane

Praswasti PDK Wulan<sup>a</sup>, Widodo W. Purwanto<sup>b</sup>, Yuswan Muharam<sup>c</sup>

<sup>a</sup> Department of Chemical Engineering Faculty of Engineering  
 University of Indonesia, Depok 16424  
 Tel : (021) 7863516 Fax : (021) 7863515  
 E-mail : wulan@che.ui.ac.id

<sup>b</sup> Department of Chemical Engineering Faculty of Engineering  
 University of Indonesia, Depok 16424  
 Tel : (021) 7863516 Fax : (021) 7863515  
 E-mail : widodo@che.ui.ac.id

<sup>c</sup> Department of Chemical Engineering Faculty of Engineering  
 University of Indonesia, Depok 16424  
 Tel : (021) 7863516 Fax : (021) 7863515  
 E-mail : muharam@che.ui.ac.id

## ABSTRACT

The objective of this research is the application of a phenomenological kinetic model to the analysis associated with measuring the carbon formed using a thermobalance. The Ni-Cu-Al catalyst was prepared using the co-precipitation method and then calcined at 800°C. Direct decomposition of the methane reaction was performed in a 15 mm quartz thermobalance reactor at atmospheric pressure in the temperature range of 500-750°C. The reaction mechanism and the identification of rate-controlling steps were attempted in the present study following the mechanism proposed by Snoeck et al. Methane adsorption on the catalyst surface was identified as the limiting step for the reaction rate when activation energy was 67.76 kJ/mol and the frequency factor of decomposition was  $5.15 \times 10^{18}$ . Results also demonstrate that there was catalyst deactivation during the reaction due to deposits of carbon on the catalyst surface, and it was therefore considered in the kinetics model with the order of decay rate being first. This result would be valid for reaction temperatures of 500 - 750 °C. At 500-600 °C, deactivation was rapid and led to a complete loss of catalyst activity. The second process that dominated above 650 °C involved a slow decrease in the decomposition rate.

## Keywords

*Deactivation, Kinetic model, Ni-Cu-Al catalyst, Thermo balance*

## 1. INTRODUCTION

Natural gas (methane) in Indonesia is directly used for fuel consumption or export with selling value lower than domestic. Advanced processing of methane is expected to increase its economical value. Methane could be processed into more valuable products, such as nanocarbons and hydrogen. There are some methane manufacturing processes developed to produce both products with great benefit. One alternative to produce nanocarbons and hydrogen economically and simultaneously is by using methane catalytic decomposition as follows  $CH_4 \rightarrow C + 2H_2$   $\Delta H = +75 \text{ kJ/mol}$  [1].

Carbon nanotubes (CNTs) are tubular carbon molecules with superior mechanical, chemical, optical, and electrical properties. These unique properties make CNTs potentially valuable for hydrogen storage, superconducting, drug delivery, and other end-use applications. Catalytic decomposition of methane is a promising method for producing hydrogen and CNTs simultaneously. In the future, this process represents a potential alternative to infuse small-scale natural gas reserves with methane as their main component in order to produce high value products, i.e., hydrogen as an energy source for the future and carbon nanotubes, which have many applications. This kind of energy may also prevent the formation of greenhouse gases that contribute to global warming. [2, 3]

According to Snoeck et al. and Rahman et al. [4, 5], the catalytic decomposition of methane proceeds through four steps (for a nickel catalyst): surface reaction, dissolution/segregation, diffusion of carbon through nickel, and precipitation/dissolution of carbon. Surface reactions involve the adsorption of methane, followed by a series of dehydrogenation steps, and finally hydrogen desorption. The dehydrogenation steps are followed by the dissolution/segregation of carbon into the Ni. After dissolution/segregation, the carbon dissolved in the nickel particle at the front end diffuses to the rear interior of the particle

(i.e., metal/carbon filament interface). Opinion is divided concerning the driving force for the bulk diffusion of carbon through the metal particle.

To carry out the catalytic decomposition of methane, many researchers have measured the conversion of methane while others have measured the production of hydrogen [5]. Research has been conducted on the kinetics of catalytic decomposition of methane, but studies have been limited to fluidized bed reactors and fixed bed reactors [2, 3]. Other experimental studies have been performed to gain a better understanding of the kinetics of methane decomposition. The majority of the studies focused on the reaction mechanisms and identification of primary decomposition products [6].

Catalytic activity can be measured in various ways depending on the chosen approach. Some researchers have measured the catalytic activity of 16.4% wt Ni/SiO<sub>2</sub> by measuring the conversion of diluted CH<sub>4</sub> streams (20% CH<sub>4</sub> + 80% He) in connection with time-on-stream (min) in a fixed-bed, plug-flow reactor at 550 °C [5]. Others have been monitoring the outlet concentration of hydrogen as a function of reactor temperature in the range of 500-750 °C using different combinations of catalysts in a plug-flow reactor [5, 7]. Another method utilizes a thermobalance to obtain the level of methane cracked by monitoring the mass gain with time. This method appears to overcome the problem of space limitations that interfere with the fixed-bed technique for measuring the activity, as discussed by several researchers [5]. Therefore, we selected the thermobalance for this study. In this research, an intrinsic kinetics study of catalytic decomposition of methane was performed on the Ni-Cu-Al catalyst with a microkinetics analysis method, in which the reaction rate is determined by the reaction mechanism.

## 2. EXPERIMENTAL

Methane decomposition experiments were conducted in a thermobalance. At atmospheric pressure, the thermobalance can operate up to 1100 °C. The system consists of three main sections: the hardware [Sartorius T-214 S micro balance, data acquisition, furnace, gas chromatography with thermal conductivity detector (Shimadzu GC-8A)]; the software (electronic components and displays); and the external flow, pressure, and temperature controllers. The loading and unloading of the sample was accomplished by opening the sample holder and lowering the furnace. The temperature inside the reaction chamber was measured and controlled by a 1/8-inch Chromel–Alumel thermocouple located just inside the sample holder. The sensitivity of the balance was 100 µg, the data were recorded at thermobalance reached constant.

The catalyst used for catalytic decomposition of methane was prepared by the coprecipitation method with a molar ratio of 2:1:1 for Ni:Cu:Al. An aqueous solution of nitrates salts, which include nickel nitrate hexahydrate, copper nitrate trihydrate, and aluminum nitrate nonahydrate from Merck, was used. After stirring 1 h at about 50°C, the solution was dissolved with sodium carbonate at the rate of 10ml/min until it reach the desired pH. The viscous solution was then stirred for another 1 h at the same temperature and left to age overnight. The precipitate was filtered out and washed with deionized water in order to remove ammonium nitrate; washing was repeated five times. Wetcake was then dried at 120°C for 5 h in a vacuum furnace and calcined at 800°C for 5 h in an atmospheric furnace.

### Activity Measurement

The specific rate of carbon formation,  $r'_C$ , relative to the initial amount of nickel in the catalyst is defined as follows [5]:

$$r'_C = \frac{\text{rate formation of carbon (g}_C/\text{min)}}{\text{Mass of Ni (g}_{Ni})} \quad (1)$$

$$= \frac{1}{W_{Ni}} \frac{dm}{dt} \left( \frac{g_C}{g_{Ni} \cdot \text{min}} \right) \quad (2)$$

where  $W_{Ni}$  is the mass of nickel in the catalyst ( $g_{Ni}$ ),  $t$  is the time on stream (min) and  $m$  is the mass gain as recorded by the balance ( $g_C$ ).

The activity is defined as [5]:

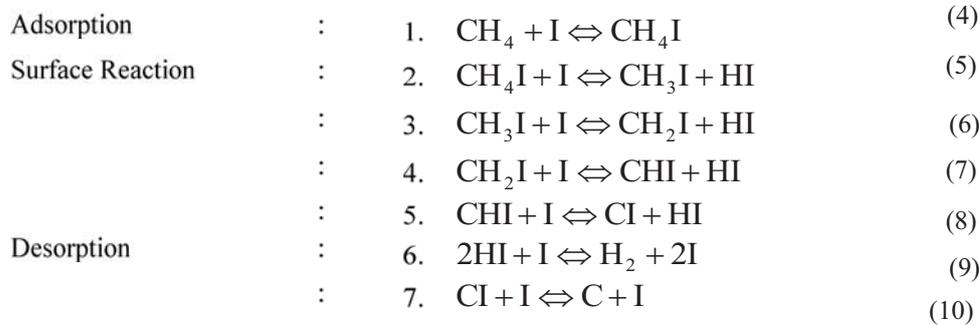
$$a = \frac{r'_{C(t)}}{r'_{C(\max)}} \quad (3)$$

Where  $r'_{C(\max)}$  is the maximum specific rate, usually occurring at the early stage of the cracking reaction.

### 3. RESULTS AND DISCUSSION

#### 3.1 Intrinsic Kinetic Model and Estimation of Parameter

The reaction mechanism and identification of rate-controlling steps were attempted in the present study following the mechanism model for methane decomposition proposed by Snoeck et al. [4], which is outlined below.



The Langmuir-Hinshelwood-Hougen-Watson model was chosen as the intrinsic kinetic model for the reaction. This model is based on the assumption that each stage of the reaction mechanism model can be the rate limiting step (RLS).

Surface concentrations of methane and hydrogen can be replaced by partial pressure respectively by the Langmuir isotherm, so that:  $[CH_4] = P_{CH_4}$  and  $[H_2] = P_{H_2}$ . The following rate equation is derived for the mechanism:

$$r_{C,M} = \frac{k_M^+ \cdot K_{CH_4} \cdot p_{CH_4} - \frac{k_M^- \cdot K_H^2 \cdot K_C}{K_3 \cdot K_4 \cdot K_5} \cdot [c_{Ni,T}] \cdot p_{H_2}^2}{\left( 1 + K_C \cdot [c_{Ni,T}] + K_H^{1/2} \cdot \left( 1 + \frac{K_C \cdot [c_{Ni,T}]}{K_5} \right) \cdot p_{H_2}^{1/2} + \frac{K_H \cdot K_C \cdot [c_{Ni,T}]}{K_4 \cdot K_5} \cdot p_{H_2} + \frac{K_H^{3/2} \cdot K_C \cdot [c_{Ni,T}]}{K_3 \cdot K_4 \cdot K_5} \cdot p_{H_2}^{3/2} + K_{CH_4} \cdot p_{CH_4} \right)^2} \quad (11)$$

Where,  $r_{C,M}$  is Rate of carbon filament formation by the methane cracking (g/gNi min);  $k_M^+$  and  $k_M^-$  are Rate coefficients of the forward and the reverse reaction of the rate-determining step; K is symbol used for equilibrium coefficients and  $p_i$  is partial pressure of component i.

When the surface concentrations of H-I, CH-I and CH<sub>2</sub>-I are negligible, the rate equation is simplified to :

$$r_{C,M} = \frac{k_M^+ K_{CH_4} p_{CH_4} - \frac{k_M^- K_C K_H^{1/2}}{K_3 K_4 K_5 / K_H^{3/2}} \cdot [c_{Ni,T}] \cdot p_{H_2}^2}{\left( 1 + K_C \cdot [c_{Ni,T}] + \frac{K_C \cdot [c_{Ni,T}]}{K_3 K_4 K_5 / K_H^{3/2}} p_{H_2}^{3/2} + K_{CH_4} p_{CH_4} \right)^2} \quad (12)$$

Where :  $k_M^- = k_M^+ \cdot K_H^{1/2}$   
 $K_r' = K_r / K_H^{3/2} = K_3 \cdot K_4 \cdot K_5 / K_H^{3/2}$  and equation (12) into

$$r_{C,M} = \frac{k_M^+ \cdot K_{CH_4} \cdot p_{CH_4} - \frac{k_M^-}{K_r'} \cdot K_C \cdot [c_{Ni,T}] \cdot p_{H_2}^2}{\left( 1 + K_C \cdot [c_{Ni,T}] + \frac{1}{K_r'} \cdot K_C \cdot [c_{Ni,T}] \cdot p_{H_2}^{3/2} + K_{CH_4} \cdot p_{CH_4} \right)^2} \quad (13)$$

It is assumed that the concentration of carbon dissolved in nickel is almost uniform (uniform) across the Ni particles and equal to the concentration of carbon on the catalyst support. This implies that the closure of the surface by carbon occurs constantly [10, 11], so  $[c_{Ni,T}] \approx [c_{Ni,r}] \approx [c_{Ni,sat}]$ . Assumptions  $K_C \cdot [c_{Ni,T}]$  can be combined with the coefficient  $K_r'$  so

$K_r'' = K_r' / (K_C \cdot [c_{Ni,T}]) = K_r' / (K_C \cdot [c_{Ni,T}])$ . Dividing the numerator and denominator by  $(1 + K_C \cdot [c_{Ni,T}])$  and incorporating this group in the other parameters leads to the following simplified form for the rate equation:

$$r_{C,M} = r_{CH_4} = \frac{k_M^+ \cdot K_{CH_4} \cdot p_{CH_4} - \frac{k_M^-}{K_r''} \cdot p_{H_2}^2}{\left(1 + \frac{1}{K_r''} \cdot p_{H_2}^{3/2} + K_{CH_4} \cdot p_{CH_4}\right)^2}$$

Thus, seven kinetic models were obtained that represent the rate-limiting steps of this mechanism: Model 1 is the adsorption model; Model 2 represents the first step of hydrogenation in the surface reaction; Models 3-5 are the second, third, and fourth steps of hydrogenation in the surface reaction; Model 6 represents hydrogen desorption; and Model 7 represents carbon desorption [12].

The best kinetic model is closer to the line equation  $Y = X$ . In addition, kinetic models are close to the line equation  $Y = X$  on Figure 1 will be the rate-limiting step reaction. From the statistical point of view and calculation of error percentages for the seven models [12] for all of the reaction temperatures, we observed that Model 1, the adsorption model, had the higher  $R^2$  value and the lowest error percentage. Thus, Model 1 is the most representative model, statistically, based on the reaction rate equation of carbon growth via methane catalytic decomposition.

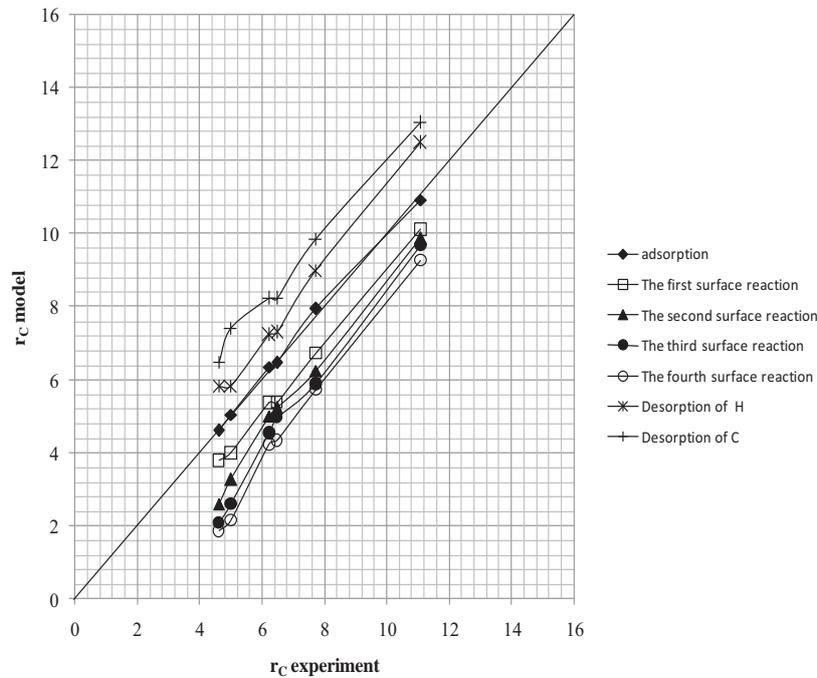


Figure 1: Rate of Carbon Growth,  $r'_C$  (experiment) vs.  $r'_C$  (model)

The kinetics equation for methane catalytic decomposition with adsorption as the reaction rate-limiting step is as follows. This result would be valid for reaction temperatures of 500-750 °C. Then, the determination of the activation energy is conducted by using Arrhenius equation as follows:

$$\ln\left(\frac{k}{T}\right) = \ln A - \frac{E_a}{R} \left(\frac{1}{T}\right) \quad (15)$$

The applicability of Eq. (12) is tested by plotting  $\ln\left(\frac{k}{T}\right)$  vs  $\left(\frac{1}{T}\right)$  as in Figure 1. If the plot is linear, where the slope of the plot is  $E_a/R$ , then  $E_a$  value can be calculated. An Arrhenius plot of the deactivation methane decomposition rates is given in Figure 2. Fitting the data with a straight line, we calculated activation energy of about 67.76 kJ/mol and the frequency factor of  $5.15 \times 10^{18} \text{ s}^{-1}$ .

The Ea value obtained from this calculation is between the energy activation value in several reported literatures, i.e. 60 – 236 kJ/mol. In addition, this value is similar to the results obtained with the value of 60 kJ/mol for the adsorption step ( $\text{CH}_4 + \text{I} \rightarrow \text{CH}_4\text{I}$ ) [11] where I is the active site. This supports the view that the adsorption model step may be rate-determining, at least in the early stage of the decomposition process.

The resultant parameter estimates were subjected to a statistical analysis and checked with the statistical test from the L-H type intrinsic kinetic model [6]. Normally, this model is suitable for application when  $\rho^2 > 0.9$ ,  $F > 10F_T$  [6].  $\rho^2$  is the key parameter, calculated by:

$$\rho^2 = 1 - \frac{\sum_{i=1}^M (y_{i,e} - y_{i,c})^2}{\sum_{i=1}^M y_{i,e}^2} \quad (16)$$

where M is the number of experiments,  $y_{i,e}$  is specific mass gain of experimental data, and  $y_{i,c}$  is the specific mass gain of simulation value.

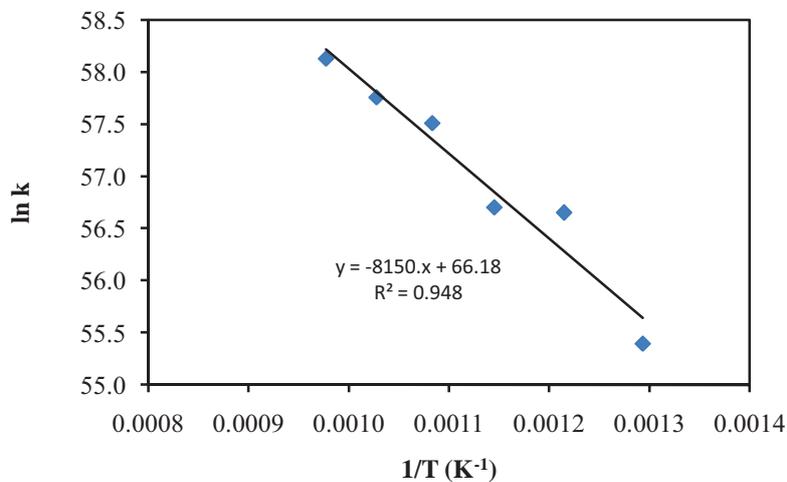


Figure 2: Arrhenius plot for the maximum specific rate of carbon formation

F is the proportion of the regression sum of the mean square to residual error sum of the mean square,  $F_T$  is a value of F Table corresponding to 5% significant level, and  $M_p$  is the number of parameters in the equation of models shown below.

$$F = \frac{\left[ \frac{\sum_{i=1}^M y_{i,e}^2}{M} - \frac{\sum_{i=1}^M (y_{i,e} - y_{i,c})^2}{M} \right] / M_p}{\frac{\sum_{i=1}^M (y_{i,e} - y_{i,c})^2}{(M - M_p)}} \quad (17)$$

The values calculated by the Langmuir-Hinshelwood intrinsic kinetic model agree with the experiment results for Model 1. The average relative errors of the specific mass gain for each temperature in Model 1 are 1.13 % and 3.96 %, respectively.

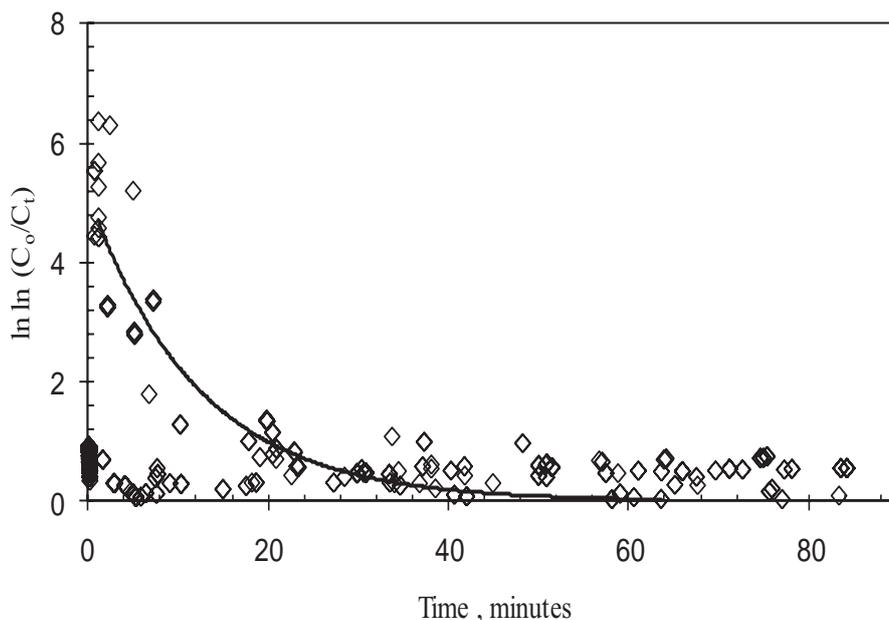
### 3.2 Catalyst Deactivation

The main causes of catalyst deactivation are fouling by encapsulating coke, sintering (or thermal aging), and poisoning [13]. Therefore, the deactivation rate,  $r_d = -\frac{da}{dt}$ , must be described according to an appropriate deactivation kinetic model related to the deactivation cause [13, 14]. Thus, if the formation of encapsulating coke is partially reversible, the catalyst does not suffer complete deactivation, maintaining a residual level of activity at steady state [6]. As shown in Figure 3, the profile corresponds with Empirical Decay Laws from Fogler [14], where the catalyst activity decreases as the function of time due to the presence of catalyst decay (deactivation of catalyst).

Profile of the graphic in this research more to exponential which is the characterization of first order reaction. The bigger the deactivation reaction order, the greater the decrease in the reaction rate because catalyst deactivation will decrease significantly.

The exponential data enables the first deactivation reaction order, where  $a(t)$  value can be obtained by using Eq. (18) as follows [14], where  $\beta_1$  is reaction order.

$$a = e^{\beta_1 t} \quad (18)$$



**Figure 3** Profile of time versus  $\ln \ln(C_{c,t}/C_{c,i})$

Deactivation mechanism is due to the encapsulation of metal particles by carbon layers of graphite. Through EXAFS and Mössbauer Spectroscopies, Shah et. al., 2001, said that in the form of encapsulation, the catalyst remains in a state of the metal. It is postulated that the metallic catalyst deactivated not due to poisoning or a change in surface structure but was isolated from  $\text{CH}_4$  by encapsulation and could not catalyze the decomposition of methane.

## 7. CONCLUSION

The following conclusions summarize findings from this research is the reaction kinetics equation model of methane catalytic decomposition with adsorption as the reaction rate limiting step is more accurate than the equation model with surface reaction and desorption as reaction rate limiting step. The activation energy required is 67.76 kJ/mol with frequency factor of  $5.15 \times 10^{18}$ . Based on the result of this research, the catalyst deactivation during the reaction due to deposits of carbon on the catalyst surface, and it was therefore considered in the kinetics model with the order of decay rate being first.

## ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support provided by The Directorate General of Higher Education Ministry of National Education, Republic of Indonesia under Hibah Pasca 2010. The authors would also like to thank Susalit and Wilda for their valuable cooperation

## NOMENCLATURE

$r_{C,M}$	=	Rate of carbon filament formation by the methane cracking ( $\text{gC/gNi min}$ )
$k_M^+$ and $k_M^-$	=	Rate coefficients of the forward and the reverse reaction of the rate-determining step
K	=	symbol used for equilibrium coefficients
$p_i$	=	partial pressure of component $i$
Ea	=	the activation energy, $\text{kJ.mol}^{-1}$
A	=	the frequency factor, (-)
$a$	=	catalyst activity factor, (-)
$\beta$	=	reaction order, (-)
$-r_C(t)$	=	reaction rate of carbon formation, $\text{mol.gr catalyst}^{-1}.\text{minutes}^{-1}$
$-r_{C,max}$	=	maximum reaction rate of carbon formation, $\text{mol.gr catalyst}^{-1}.\text{minutes}^{-1}$
M		the number of experiments
$y_{i,e}$		specific mass gain of experimental data
$y_{i,c}$		the specific mass gain of simulation value
$F_T$		a value of F Table corresponding to 5% significant level
Mp		the number of parameters in the equation of models

## REFERENCES

- [1] Grujicic M., C.G., Gersten B., *An Atomic-Scale Analysis of Catalytically-Assisted Chemical Vapor Deposition of Carbon Nanotubes*. Materials Science and Engineering, 2002. B94:247-259.
- [2] Muradov, N., *Thermocatalytic CO<sub>2</sub>-free Production of Hydrogen from Hydrocarbon Fuels*. Proceedings of the DOE Hydrogen Program Review, 2001.
- [3] Purwanto, W.W., et.al. *Utilization Of Very Small Field Of Natural Gas By Methane Catalytic Decomposition. Effect Of Nickel Catalyst Diameter And Acidity On Nanocarbon And Hydrogen Quality And Methane Activation*. in *International Energy Conference, 5-7 August*. 2005. Jakarta.
- [4] Snoeck, J.W., Froment, G. F. & Fowles, M., *Kinetic Study of The Carbon Filament Formation by Methane Cracking on A Nickel Catalyst*. Journal Of Catalysis, 1997. 169: p. 250-262.
- [5] Rahman, M., et.al (2006) *Catalytic Decomposition of Methane for Hydrogen Production*. Topics in Catalysis 37, Nos. 2-4 April DOI: 10.1007/s11244-006-0015-8.
- [6] Benzhen Yao, et al., *Intrinsic kinetics of methane aromatization under non-oxidative conditions over modified Mo/HZSM-5 catalysts*. Journal of Natural Gas Chemistry 2008. 17: p. 64–66.
- [7] Shah, N., D. Panjala, and a.G.P. Huffman, *Energy & Fuels* 2001. 15 p. 1528.
- [8] Shuanglin Zhan, Y.T., Yanbin Cui, Hao Wu, Yonggang Wang, Shufeng Ye, Yunfa Chen, *Effect of Process Conditions on the Synthesis of Carbon Nanotubes by Catalytic Decomposition of Methane*. Journal China Particuology, 2007. 5: p. 213-219.
- [9] Reyhan KOC, et al., *Partial Regeneration of Ni-Based Catalysts for Hydrogen Production via Methane Cracking*. , Turk J Chem 2008. 32 (@ TUBITAK): p. 157 – 168.
- [10] Snoeck, J.W., G.F. Froment, and M. Fowles, *Kinetic Study of the Carbon Filament Formation by Methane Cracking on a Nickel Catalyst*. Journal of Catalysis, 1997. 169(1): p. 250-262.

- [11] Zein, S.H.S., A.R. Mohamed, and P.S.T. Sai, *Kinetic Studies on Catalytic Decomposition of Methane to Hydrogen and Carbon over Ni/TiO<sub>2</sub> Catalyst*. Ind. Eng. Chem. Res., 2004. 43: p. 4864-4870.
- [12] Praswasti PDK Wulan, Y.M., and Widodo Wahyu Purwanto, *Kinetics Study on Catalytic Decomposition of Methane Using Parallel Flat Plate Structured Catalyst Reactor*. International Journal of Chemical Engineering Research, 2010. ISSN 0975 – 6442, 2(2): p. 231–241.
- [13] N. Latorre, E.R., J.I. Villacampa, F. Cazaña, C. Royo, A. Monzón, *Kinetics of Carbon Nanotubes Growth on a Ni–Mg–Al Catalyst by CCVD of Methane: Influence of Catalyst Deactivation*. Catalysis Today 2010. xxx p. xxx-xxx.
- [14] Fogler, H.S., ed. *Elements of Chemical Reaction Engineering, 4th edition*. 2006, Upper Saddle River: Prentice-Hall, Inc.

## **Disinfection of Bacteria *Escherichia Coli* Using Hydrodynamic Cavitation**

**Eva FathulKaramah<sup>a</sup>, IndikaSunarko**

*<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : eva@che.ui.ac.id*

### **ABSTRACT**

*This study brings out a disinfection process of bacteria *Escherichia coli* using hydrodynamic cavitation method. The method used different contactors, orifice plate and venturi injector. The experiment result shows that orifice plate with initial concentration of  $10^4$  CFU/mL has decreased into 0 CFU/mL after 20 minutes, while venturi injector has decreased into 0 CFU/mL after 30 minutes. The orifice plate gave a better, more effective and faster disinfection than the venturi injector.*

### **Keywords**

*Disinfection, *Escherichia coli*, Hydrodynamic Cavitation, Venturi Injector, Orifice Plate*

**This paper is published in International Journal of Technology (IJTech)**

# Performance of a Biomass-Gas Stove using Fuel of Rubber Wood Pellets

Dijan Supramono<sup>a</sup> dan Farah Inayati<sup>b</sup>

<sup>ab</sup>Department of Chemical Engineering, Faculty of Engineering,  
Universitas Indonesia, Depok – 16424, Indonesia  
Ph : (021) 7863516. Facs : (021) 7863515  
<sup>a</sup>Email: dsupramo@che.ui.ac.id

## ABSTRACT

Conventional biomass stoves, which currently use direct combustion of biomass pellets or briquettes, have still a problem of emitting much higher CO gas emission compared to LPG stoves at the level of 100's ppm. These values are well above the minimum allowable CO gas emission of 25 ppm and therefore the emission is not safe for the stove users.

In this research, a biomass-gas stove was designed using a method of *top-lit updraft gasification* where the combustion of pyrolysis gas evolving from the bed of rubber wood pellets by adding secondary air occurs at the top of the stove. The primary air is delivered upward the bed, while the secondary air flows through the annulus of the stove and bends horizontally towards a series of holes at the top of the stove. This research has an objective to obtain optimum value of flowrate ratio of the secondary air to the primary air (air flow ratio) where the stove produces minimum emission of CO and maximum thermal efficiency. The ratio was varied at 2.44, 6.29, 13.43, and 20.6.

This work concluded that the lowest CO emission and the highest average flame temperature occur at the air flow ratio of 6.29, while the highest thermal efficiency at 2.44.

## Keywords

*Rubber wood pellets, biomass-gas stove, top-lit updraft gasification, CO emission, pyrolysis*

## 1. INTRODUCTION

Indonesia has abundant potential of biomass waste, which is currently not utilised massively. The production of the waste is estimated to reach 123.5 million tons per year and is equivalent to 1,455.97 million GJ/year. The main resources are rice waste of 705 million GJ/year, rubber plantation waste of 46.45 million GJ/year, bagasse waste of 70.65 million GJ/year, palm plantation waste of 247.15 million GJ/year, and coconut plantation waste of 162.3 million GJ [1-2]. If the biomass waste is directly burnt as solid fuels for stoves in the forms of briquettes or pellets, CO emission resulting from the combustion is expected to be high, well above the minimum allowable CO emission of 25 ppm [3]. This occurs due to heat absorption by solid fuels through conduction during the combustion causing the surface temperature of briquettes or pellets to drop and consequently increasing CO emission. This condition encourages the research on the biomass waste fuel which utilises its gas phase to allow the combustion to produce low CO emission. This may be substantiated by pyrolysing the solid biomass waste to produce biomass gas and burning the gas. This is expected to produce much lower CO emission similar to that produced by LPG stoves.

The combustion occurs due to oxidation reactions between gases (CO, H<sub>2</sub>, CH<sub>4</sub> and hydrocarbons) produced by pyrolysis of the biomass material. This pyrolysis is carried out in limited air environment and combustion uses a separate flow of air. The air used for pyrolysis is usually termed as primary air, whereas that for combustion secondary air. This pyrolysis is usually called oxidative pyrolysis. Senneca *et al* [4] found that this type of pyrolysis results in much higher weight loss of solid fuels at certain range of temperature compared to the loss using inert-gas pyrolysis. The pyrolysis is initiated by heat radiation of the gas combustion at the top of the pellet bed. The gas produced by oxidative pyrolysis may subsequently be completely oxidised to produce CO<sub>2</sub> and H<sub>2</sub>O [5][6]. Stoves utilising gas produced by oxidative pyrolysis of biomass material as a fuel is usually called biomass-gas stoves. Figure 1 describes the schematic diagram of the stove. Fuel, in the current research of rubber wood pellets, is ignited at the top of the pellet bed. The ignition forms flaming pyrolysis front which moves downward. During its passage, the biomass pellets are pyrolysed (gasified) from the top to the bottom of the fixed bed [7]. Primary air is supplied from the bottom of the pellet bed at strictly limited amount to sustain flaming pyrolysis front. Biomass gas produced moves upward and after mixing with the secondary air supplied radially from the top side of the stove, it burns over the top of the fixed bed with high heat release. The gasification process is entirely autothermal and does not need any external heat. Part of the pellet bed left behind by flaming pyrolysis front forms biochar after releasing biomass gas. The char may be oxidised by

remaining oxygen from the flaming pyrolysis front to form  $\text{CO}_2$  [8].  $\text{CO}_2$  and  $\text{H}_2\text{O}$  produced in the flaming pyrolysis front may react with biochar to form gases  $\text{CO}$  and  $\text{H}_2$  [7]. The pyrolysis-combustion of biomass material using this method was first introduced by using a principle of *top-lit updraft (TLUD) gasification* by Reed [9].

The present research is aimed to investigate the  $\text{CO}$  emission resulting from the combustion of the gas phase of the pyrolysis products of rubber wood pellets and the stove efficiency subject to the variation of ratio of the secondary to primary air flowrates. Although some researches relating to the  $\text{CO}$  emission has been conducted, but in general the emission figures were published in terms of grams as cumulative emissions [9]. None present in terms of the ppm during the combustion. Effect of  $\text{CO}$  emission to human being depends on the concentration of  $\text{CO}$  emission in ppm and the duration to which the human being is exposed [10]. Besides, the  $\text{CO}$  emission may also depend on the type of biomass used as fuel because different biomass types have different compositions of cellulose, hemicellulose and lignin part of which under pyrolysis environment will decompose to volatile matter and subsequently to smaller molecules [11]. The threshold  $\text{CO}$  emission stipulated by Ministry of Workforce Indonesia is 25 ppm. According to the result of proximate analysis by Energy Technology centre, BPPT, the content of volatile matter of the rubber wood sample was 68.32%. This gives indication that the rubber wood if used as fuel in TLUD stove will produce much volatile matter and therefore it is potential for biomass-gas stove.

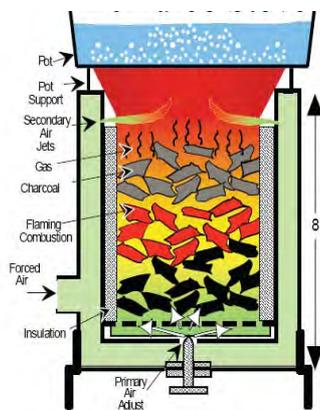


Figure 1a: Schematic description of TLUD stove [8].

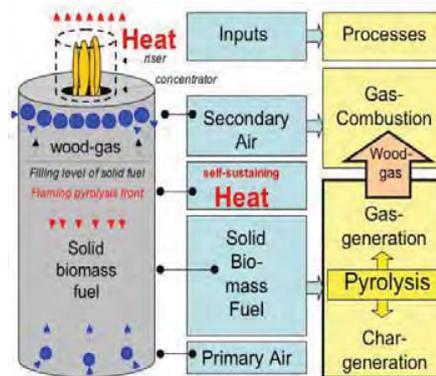


Figure 1b: Mechanisms of biomass pellet pyrolysis and wood gas combustion [9].

## 2. EXPERIMENT

The experiment consists of biomass pellet preparation, and biomass pellet pyrolysis and combustion. Rubber wood pellets were prepared by first grinding the rubber wood branches to powder, drying the powder to reach moisture content of 10%. Subsequently, the dry powder was moulded to form pellets. During the pyrolysis-combustion, measurements of  $\text{CO}$  emission and flame temperature were conducted. Main measurement tools used were biomass-gas stove where the pyrolysis-combustion of pellets was undertaken, some thermocouples type K, a temperature data logger to log data of flame temperature, a gas analyzer to measure  $\text{CO}$  concentration in flue gas, and an anemometer to measure velocity of air to the primary and secondary air blowers, and a water pot of 17cm diameter. The water pot was used for determination of the stove thermal efficiency using water boiling test method. Pellets made of rubber wood were of cylindrical shape with 1.5cm diameter and 3cm length.

The stove prepared has inside diameter of 15cm and height of 58cm (see Figure 2). These sizes were to accommodate the loading of rubber wood pellet of 1.4 kg. The stove consists of 2 concentric cylinders with an annulus in between the cylinders. The pellets were laid in the inner cylinder of the stove. Through the annulus, the secondary air is flowing to fulfil the need for the combustion of wood-gas produced by the pyrolysis. The construction material is made of mild steel. The outer side of the stove was lined with ceramic fibre and enclosed with an aluminium plate. A grate of stainless steel 314 was installed at the lower side of the stove to support the pellet bed to resist corrosion. Two centrifugal blowers have been used to deliver primary and secondary air respectively (see Figure 2). The first blower has diameter of 2 inches and input electricity ampere of 1A, while the second blower 2.5 inches and input ampere of 1.6A. The primary air was delivered to the base of the bed, while the secondary air flowed through the annulus of the stove and bent towards a series of holes at the circumference of the top of the stove. This design allows the crossflow between pyrolysis gas and combustion air, which intensifies mixing. For each run, the stove used 1.4 kg of the pellets and primary air flowrate set about  $0.0038 \text{ m}^3/\text{sec}$ . The ratio of the secondary air to the primary air flowrates (air flow ratio) as the free variabel for this experiment was varied at 2.44, 6.29, 13.43 and 20.6 and its effect on

flame temperature, CO emission and thermal efficiency were observed. The measurements of CO emission, flame temperature and water temperature in the water boiling test were carried out simultaneously.



Figure 2: Fabricated biomass-gas stove for experiment with 2 blowers for primary air and secondary air respectively.

### 3. RESULTS AND DISCUSSION

#### 3.1. Flame temperature and CO emission

Figure 3 shows that at the air flow ratio equal to 2.44, the flame temperature is nearly constant during the course of the combustion. At this ratio, the use of the secondary air to oxidise the pyrolysis gas is limited and may be not sufficient (see Table 1). As a result, the concentration of CO as an indicator of the incomplete combustion is high as described in Figure 4. The heat radiated from the combustion flame to the flaming pyrolysis front to enhance the pyrolysis may be not high due to low temperature driving force between both flames. This weakens the rate of pyrolysis and consequently, the rate of pyrolysis gas production is low and the pyrolysis-combustion lasts longer to produce and oxidise all the pyrolysis gas compared to that at higher air flow ratios. This also affects the CO emission, where its level of emission is high at low flame temperature (see Figure 4) [10]. At higher air flow ratio of 6.29, Figure 3 shows that most of the time, the flame temperature is higher than that at air flow ratio of 2.44. This may happen due to more complete oxidation as a result of sufficient supply of secondary air. In terms of the CO emission, this favours the low production of CO as described by Figure 4 and achieves the lowest average CO emission (see Table 1). Due to higher temperature driving force between combustion flame and flaming pyrolysis front at the air flow ratio of 6.29, the pyrolysis may occur at higher temperature and lasts shorter.

Pyrolysis-combustion operation at air flow ratio of 13.43 where the supply of the secondary air is higher than that at flow ratio of 6.29 exhibits opposite trend compared to the trend if the air flow ratio is increased from 2.44 to 6.29. The flame temperature is lower (see Figure 3) and consequently the CO emission during the course of the pyrolysis-combustion is higher (see Figure 4) and its average value is also higher (see Table 1). This may happen due to excessive supply of the secondary air which cools the combustion flame. The temperature driving force between combustion flame and pyrolysis flame is lower at the air flow ratio of 13.43 and thus extending the pyrolysis time as shown in Figure 3.

At the air flow ratio of 20.6, at times after 9 minutes, the flame temperature is lower than that at air flow ratio of 13.43 as expected due to excessive supply of the secondary air to the combustion flame. However, at times before 9 minutes, the flame temperature is slightly higher than that at air flow ratio of 13.43. The temperature fluctuation at the air flow ratio of 13.43 at initial stage of pyrolysis-combustion operation where the position of the thermocouples was kept at the combustion flame indicates that there may be non-uniformity of the secondary air supply because the secondary air inlet at the base of the stove is at one side of the stove. Consequently, this creates non-uniformity of the secondary air supply and forms lacking and excess air regions in the combustion flame front. The regions where the air supply is lacking form soot which intensifies radiation heat transfer [10]. At higher air flow ratio of 20.6, which means higher secondary air supply, turbulence inside the annulus becomes more rigorous and results in redistribution of inlet flow of the secondary air across the circumference of the top side of the stove [12]. As a result, the inlet flow is more uniform and flame temperature at this ratio is relatively unchanged from time to time. This also causes the portion of heat radiation is less than that at the air flow ratio of 13.43. The less flame temperature at initial stage of the combustion using the air flow ratio of 13.43 is due to non-uniformity preheating of the secondary air in the annulus. With the time proceeds, the wider region of the pellet bed with higher temperature allows expansion of the preheated

secondary air and intensified turbulence which gives effect similar to that which happens in the case of the air flow ratio of 20.4 where the flame temperature is less turbulent (see Figure 3). This comparison between flame temperature profile for the combustion using the air flow ratio of 13.43 and that of 20.6 gives consequences on the CO emission profile of both air flow ratio. At initial stage of the combustion, the CO emission at the air flow ratio of 13.43 is higher than that at the ratio of 20.6. Contrary to that, at later stage of the combustion, the CO emission at air flow ratio of 13.43 is less than that at the ratio of 20.6 (see Figure 4).

Table 1. shows that the average CO concentration in the flue gas reaches the minimum value, i.e. 14 ppm, when the air flow ratio was set 6.29. This implies that using controlled air flows both of primary air and secondary air, we can make the stove healthy to the users in domestic kitchens because the CO emission can be kept low. However, the stove fabricated for this experiment is considered too high to be practical, so the next research should be directed to fabricate a shorter stove with longer operation to suit the needs in the kitchens.

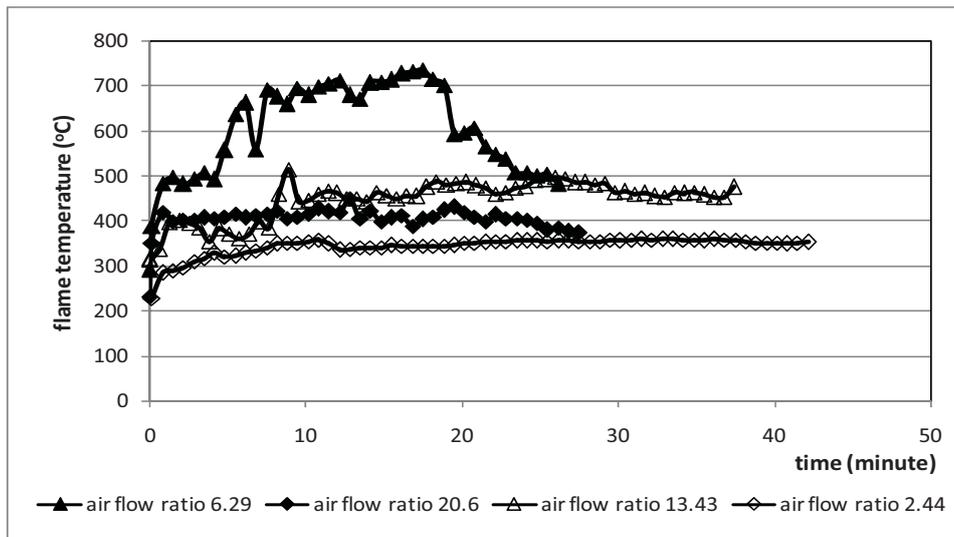


Figure 3: Flame temperature measured during the course of the combustion

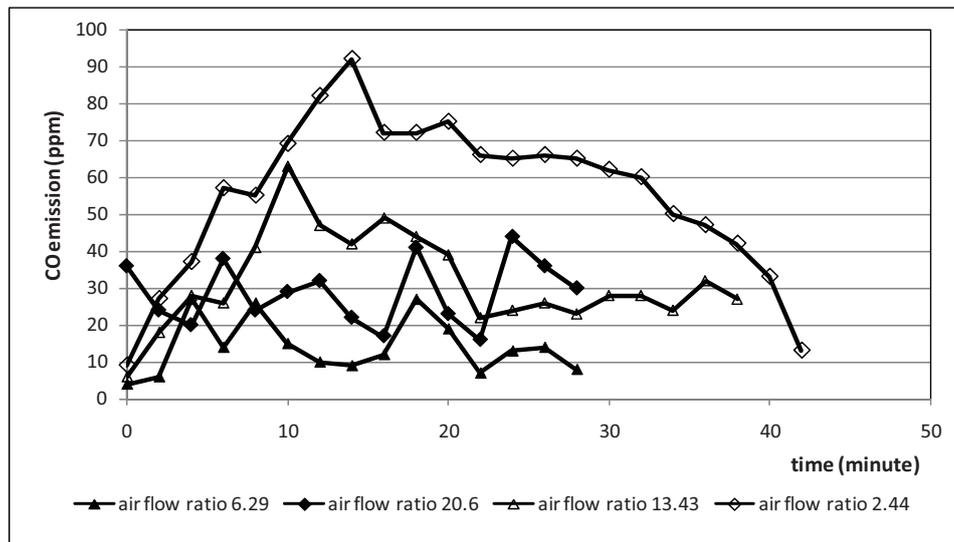


Figure 4: CO emission during the course of the combustion

Table 1. Average CO emission, maximum flame temperature and maximum water temperature at different values of ratio of secondary air to primary air flowrates (air flow ratio)

Primary air flow rate (m <sup>3</sup> /s)	Secondary air flow rate (m <sup>3</sup> /s)	Air flow ratio	Average CO emission (ppm)	Maximum flame temperature (°C)	Maximum water temperature (°C)
0.00038	0.0024	6.29	14	739.3	87.1
0.00038	0.0078	20.6	29	441.7	86.4
0.00035	0.0047	13.43	32	516.8	96.0
0.00038	0.00093	2.44	52	360.8	133.0

### 3.2. Stove thermal efficiency

Thermal efficiency is calculated using the following equation

$$\eta = \frac{M \times c_{p1} \times (T_b - T_a) + M_1 \times c_{p2} \times (T_b - T_a) + M_2 \times H_L}{H_c \times W} \quad (1)$$

where  $M$  is the initial mass of water in the water pot,  $M_1$  is the mass of the water pot,  $C_{p1}$  is the heat capacity of water,  $C_{p2}$  is the heat capacity of the water pot,  $M_2$  is the mass of evaporated water,  $H_L$  is the latent heat of evaporation,  $H_c$  is the high heating value of the rubber wood (3771 cal/gram),  $W$  is the mass of the rubber wood pellets in the stove,  $T_a$  is the initial temperature of the water in the water pot and  $T_b$  is the end temperature of the water in the water pot before the water is evaporated at constant temperature. The values of the thermal efficiency for all runs based on varied air flow ratio are shown in Table 2.

The highest efficiency (58.05%) is achieved by the stove using air flow ratio of 2.44. Even though in average the flame temperature at this ratio is low, insufficient supply of the secondary air forms soot particles in large number. These particles make the emissivity of the flame high which favours the heat radiation from the combustion flame to the base of water pot. In turns, this heat radiation intensifies the heat transfer to the water in the water pot and therefore the water temperature. Because the lack of secondary air supply uniformly occurs across the circumference of the top of the stove, the water temperature is higher than those measured at other air flow ratios (see Figure 5). In terms of the efficiency, this is desired, but as far as the CO emission is concerned, the stove at this ratio is not favourable because it produces high CO emission with the average value of 52 ppm (see Table 1).

The highest thermal efficiency (56.98%) with appropriate CO emission of 32 ppm in average is achieved at air flow ratio of 13.43. This is slightly higher than that achieved by the ratio of 6.29, i.e. 52.8% though the maximum flame temperature at the ratio of 13.43 was lower, i.e. 516.8°C. As discussed previously in Section 6.1 there may be non-uniformity of the secondary air supply on the circumference of top of the stove which exerts the formation of soot at circumferential positions where the air primary flow is low indicated visually by the yellow flame and intensifies heat radiation [10]. The high thermal efficiency was the result of the combined effect of heat convection and radiation, but at the ratio of 13.43, the heat radiation seems more predominant which intensifies the water temperature above the water temperature measured at the air flow ratio of 6.29 (see Figure 5). At the air flow ratio of 20.6, as discussed in Section 3.1, due to the uniformity of the secondary air supply across the circumference of the top of the stove, the soot formation can be lessened and the combustion flame is engulfed with excessive air. As a result, the thermal efficiency at this ratio is less than that at the ratio of 13.43 (see Table 2).

Table 2. Thermal efficiency at different values of ratio of secondary air to primary air flowrates (air flow ratio)

Air flow ratio	Thermal efficiency (%)	Maximum flame temperature (°C)
6.29	52.8	739.3
20.6	36.32	441.7
13.43	56.98	516.8
2.44	58.05	360.8

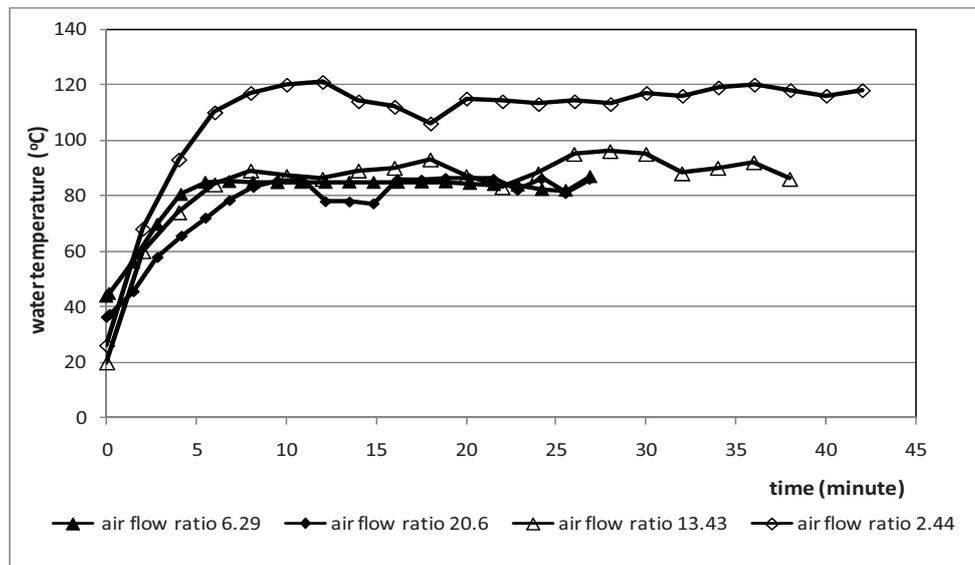


Figure 5: Water temperature measured during the course of the combustion

#### 4. CONCLUSIONS

This experiment gives some conclusions as follows:

1. The stove operating with air flow ratio of 6.29 results in the lowest CO emission which reaches 14 ppm in average.
2. The stove operating with air flow ratio of 6.29 results in the highest average flame temperature which reaches the peak temperature of 739°C.
3. The stove operating with air flow ratio of 2.44 results in the highest efficiency of 58.05%.
4. It seems that by exploiting a condition where the formation of soot is intensified, the thermal efficiency may be improved.

#### REFERENCES

- [1] Milbrandt, A and Overend, R.P., "Survey of biomass resource assessments and assessment capabilities in APEC economies", National Renewable Energy Laboratory (NREL), Colorado, 2008.
- [2] Zentrum für Rationell Energieanwendung und Umwelt GmbH, "Biomass in Indonesia-business guide", 2000.
- [3] Purwanto, W.W., Supramono, D., Nugroho, Y.S., and Rizqiardihatno, R.F., "Designing biomass pellet stove of high efficiency and environmental friendly using heat recovery principle", International Seminar on Sustainable Biomass Production and Utilisation, University of Lampung, 2009.
- [4] Senneca, O., Chirone, R., and Salatino, P., "Oxidative pyrolysis of solid fuels", *J. Anal. Appl. Pyrolysis*, 71, 2004, p. 959–970
- [5] Belonio, Alexis T, "Risk husk gas stove handbook", Department of Agricultural Engineering and Environmental Management, Central Philippine University, 2005.
- [6] Reed, T.B., "Biomass gasification principles and technology", New Jersey : Noyes Data Corp, 1981.
- [7] Saravanakumar, A., Haridasan, T.M., Reed, T.B., and Bai, R.K., "Operation and modelling of an updraft long-stick wood gasifier", *Energy for Sustainable Development*, Vol. IX, No. 4, p.25-39, December 2005
- [8] Reed, T.B., Das, A., and Anderson, P.S., "Gasification: A process common to all biomass stoves", ETHOS meeting, 2004.
- [9] Christa, Roth, "Micro-gasification: cooking with gas from biomass", 1<sup>st</sup> edition GIZ HERA – Poverty-Oriented Basic Energy Service, 2011.
- [10] Turns, Stephen R., "Introduction to combustion: concepts and applications", 2<sup>nd</sup> edition, McGraw Hill, 2000
- [11] Basu, Prabir, "Biomass gasification and pyrolysis, practical design and theory", Elsevier, 2010.
- [12] McNair, J. N., Newbold, J. D., and Hart, D. D., "Turbulent transport of suspended particles and dispersing benthic organisms: How long to hit bottom ?.", *J. Theoretical Biology.*, 188, 1, pp.29–52, 1997.

## Enhancement of Biogas Production from Capsule Husk *Jatropha curcas* Linn Substrates Using Urea and Crude *Jatropha* Oil as Additive

Praptiningsih G. Adinurani<sup>a</sup>, Ahmad Wahyudi<sup>b</sup>, Satriyo K. Wahono<sup>c</sup>, Roy Hendroko<sup>d</sup>, Salafudin<sup>e</sup>,  
and Tony Liwang<sup>f</sup>

<sup>a</sup>Faculty of Agrotechnology University of Merdeka, Madiun 63131  
Tel : (062)8155505260  
E-mail : praptiningsih.ga@gmail.com

<sup>b</sup>Faculty of Agriculture and Animal Husbandry University of Muhammadiyah, Malang 65144  
Tel : (062)8113609227  
E-mail : wahyudi\_biotek@yahoo.co.id

<sup>c</sup>Technical Implementation Unit for Development of Chemical Engineering Processes – Indonesian Institute of Sciences, Yogyakarta 55861  
Tel : (062)8157741020  
E-mail : dna\_tqim@yahoo.com, satriyo.krido.wahono@gmail.com

<sup>d</sup>Graduate Student – Renewable Energy University of Darma Persada, Jakarta 13450  
Tel : (062)8159555028  
E-mail : roy\_hendroko@hotmail.com

<sup>e</sup>Faculty of Chemical Engineering, ITENAS, Bandung 40123  
Telp (062) 81322326381  
E-mail : salafudin2004@yahoo.com

<sup>f</sup>PT Sinarmas Agresources and Technology Tbk., Jakarta 10350  
Telp (062)8811230417  
E-mail : tony-liwang@smart-tbk.com

### ABSTRACT

Processing of crude *Jatropha* oil (CJO) for biodiesel produced waste, one of them was capsule husk about 30-80% weight of the *Jatropha curcas* Linn (JcL) fruit. Utilization of dried capsule husk (DH-JcL) for organic fertilizer directly was not recommended due to high C/N ratio value (40-69). Fermentation process could be solved these problems. This paper reports the study of culture enrichment to increase microbes present on JcL substrate with some additives. The study was conducted at the research garden of PT Bumimas Ekapersada, Bekasi, West Java in November - December 2012 using DH-JcL of JatroMas cultivars in toxic category as material. There were three variable, they were the control, 3% urea and 5% CJO as additive. Observation variables were biogas production volume, pH and temperature in the effluent. The results showed that effluent pH average about 5 and daily average biogas production showed that 56.64, 43.13 and 32.63 cc biogas/g VS for 3% urea, 5% CJO and the control respectively. The study concluded that urea and CJO was appropriate as additive for culture enrichment due to they could increase the biogas production of DH-JcL with the best result was achieved by 3% urea as additive.

### Keywords

Biogas, capsule husk, *Jatropha curcas* Linn, urea, Crude *Jatropha* Oil (CJO)

## 1. INTRODUCTION

*Jatropha curcas* Linn (JcL) was believed as biofuel crops renewable energy. In the other side, the facts show that the process of making Crude *Jatropha* Oil [CJO – Oil] (the biodiesel raw materials) were not environmental friendly. There are a number of waste, namely sludge CJO (S-CJO), seed cake (*Jatropha curcas* press cake, *Jatropha curcas* defatted waste), and capsule husk (*Jatropha* fruit coat, fruit husk, hulls, shell, fruit shell, peel, fruit encapsulation) that were stacked in the field and / or thrown into the river. Stacking JcL waste on land would have negative impact on global warming due to greenhouse gases (GHG). Similarly with discharging to rivers would pollute the environment, one of them was negative impacts on fish life. As an agricultural waste for recycling soil nutrients and minerals, JcL seed cake (SC-JcL) was used as organic fertilizer [1, 2].

However capsule husk (DH-JcL) was not recommended as organic fertilizer with direct application (fresh). The quality standards of organic fertilizer according to the Minister of Agriculture number 28/Permentan/OT.140/2/2009 said that C/N ratio for organic fertilizer was 15-25, whereas the DH-JcL C/N ratio was 40-69 [3]. Fermentation is one of the threatment to reduce the C/N ratio. Anaerobic fermentation is more efficient than aerobic, besides producing organic fertilizer (solid and liquid), it will produce gaseous bio-fuels, namely biogas.

SC-JcL was also recommended as biogas substrate due to the biogas production was made from seed cake higher than cow dung [4, 5], but DH-JcL utilization as substrate having a number of constraints. DH-JcL float as biogas substrate due to its density is relatively low, so the fermentation process was imperfect. DH-JcL residual fibers fermentation also clogs at the inlet and outlet of biogas digester [6, 7]. DH-JcL does not suitable as biogas substrate due to slow degradation [8, 9]. DH-JcL volume is relatively large which is about 30-80% of the weight of fresh fruits [10, 11] or 8-15% of the dry weight [12]. In consideration to increase revenue of JcL farmer and to push JcL development as biodiesel feedstock, the series of study has been done which use DH-JcL as biogas substrate. The study was conducted in the laboratory and field scale with 6 m<sup>3</sup> digester capacity [3, 13]. The series of studies were expected to push the development of two bio-fuels types, biogas and non-edible oil-based biodiesel.

This paper reports one part of the series to increase the biogas production from DH-JcL with enrichment culture which conducted by increasing number of existed microbial at the waste by adding some of the required microbial nutrients for growth [14]. One of required biogas substrate is contains the C/N ratio of 16-25 [15] or 20-30 [16, 17] or 25-32 [18]. Based on these requirements, DH-JcL with the C/N ratio of 40-69 [3] was not suitable as a substrate. On the substrate with high C/N ratio (low nitrogen) will occur reduce biomass growth and reduce degradation [18], unstable pH and easy of pH decreasing [19], imperfect conversion of carbon to methane which indicated by high CO<sub>2</sub> of biogas content [19, 20, 21], and insufficient microbial growth for methane production [22]. Urea was suggested as nitrogen source [23, 24]. Using 0.04-6% urea result positive impacts in single substrate cassava tubers, rice straw, cattle dung and / or substrate mixtures of meal waste, mixture of chicken feces and corn stalks, wood ash and poultry droppings, cattle slurry and pressed sugar cane stalk [25, 26, 27]. Another study proposed that 3% urea was better than 6% [28, 29]. Culture enrichment action is also called co-digestion technology which is different types of wastes are treated together [30, 31]. Because of urea is not waste and it is deliberately added to substrate for increasing the biogas production, it is called as additive [32, 33, 34, 35] or supplement [36, 37] or amendment [38]. Mixtures substrate is identical with enrichment culture because it adds co-substrate for nutrient addition in the substrate. Some of study suggest a number of studies on the co-digestion positive impacts [36, 39]. The materials are rich in fat, can help to improve the quality and quantity of the biogas [40, 41, 42, 43, 44, 45]. Related JcL and CJO, a preliminary study reported that DH-JcL and 10% S-CJO as a co-digestion can increase biogas production [46].

## 2. METHODS

The preliminary study was conducted at the research garden of PT Bumimas Ekapersada, Bekasi, West Java in November - December 2012. On this laboratory scale, a liter glass laboratory digester was used as one-stage digester which was compiled completely randomized design (CRD) with three replications in water bath on 32 °C as in Figure 1. The materials are DH-JcL of JatroMas cultivars in toxic category as substrate which mixed with water in 1: 8 as the control treatment. The 1<sup>st</sup> treatment was using 3% urea (w/w) and the 2<sup>nd</sup> was using 5% CJO (w/w) as additives. As the starter was used semi-artificial inoculum [47] from the DH-JcL digester slurry. Hydraulic retention time was set for five weeks. Every day 4 g DH-JcL and 32 cc water as a feed was added and removed from the digester based on draw and fill method [48]. Observation variable were biogas production volume (water displacement method) [49], pH (pH meter) and temperature (digital thermometer) in the effluent.

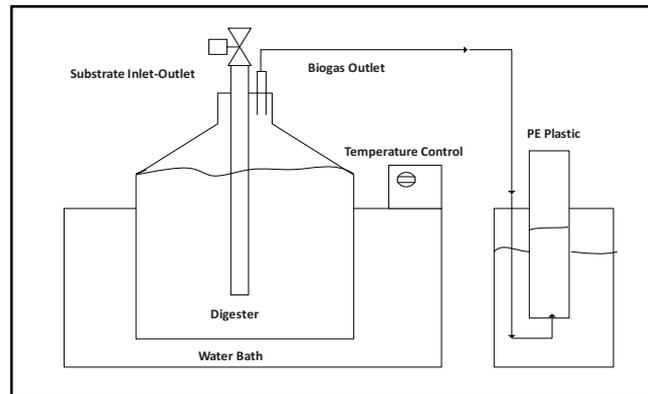


Figure 1: Schematic Research Digester

### 3. RESULTS AND DISCUSSION

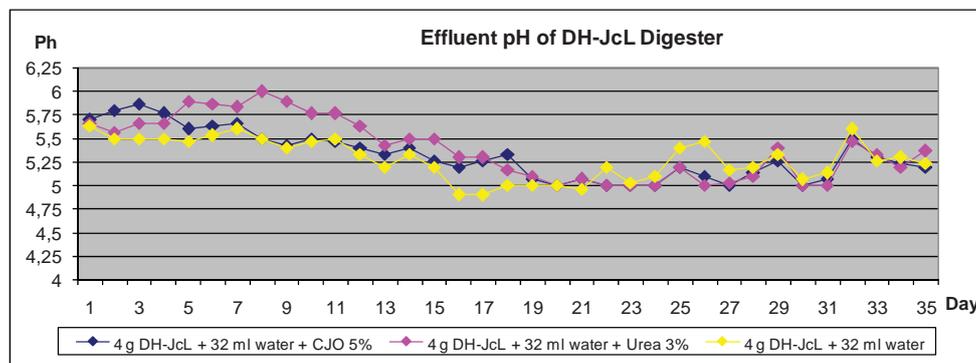


Figure 2: pH curves of DH-JcL digester effluent with three treatments

Observations of 3rd pH treatment for 5 weeks were presented in Figure 2. Figure 2 shows that the average pH in the effluent with three treatments tended to decrease from 2<sup>nd</sup> week to 5<sup>th</sup> week. The average pH for five weeks, the treatment 1 (CJO as an additive), treatment 2 (urea as an additive), and controls were 5.32, 5.43 and 5.23 respectively. These data support previous studies which showed pH at one stage DH-JcL digester is not ideal conditions for biogas microbial growth, especially methanogenic bacteria [46]. Optimal pH for methanogenic bacteria is 6.7 to 7.5 [40], so pH conditions in Figure 2 was marginal category [50]. This is one issue on utilization DH-JcL substrate due to DH-JcL properties is very high buffering capacity such as another JcL waste (SC-JcL) [46]. The pH average of urea treatment was relatively higher than the others, especially in 5<sup>th</sup> – 17<sup>th</sup> day. It was similarly with the pH average of CJO treatment in 2<sup>nd</sup> – 5<sup>th</sup> day. These data indicate that urea and CJO able to provide better conditions than the controls. The daily production average of biogas on weekly recapitulated was shown in Table 1.

Table 1. Daily biogas production (cc/g VS) of DH-JcL digester with three treatments

Treatment	1 <sup>st</sup> week	2 <sup>nd</sup> week	3 <sup>rd</sup> week	4 <sup>th</sup> week	5 <sup>th</sup> week	Average
5% CJO	81.40	29.53	51.11	31.57	22.03	43.13
3% Urea	106.77	46.19	59.82	41.27	29.15	56.64
Control	52.24	21.96	21.2	35.97	31.8	32.63

Table 1 shows that the urea treatment produces the highest number of biogas production average at 56.64 cc/g VS. At weekly biogas production details, it appears that the urea treatment is always the highest except at 5<sup>th</sup> week. CJO treatment generate 2<sup>nd</sup> rank of production average at 43.13 cc/g VS. CJO additives were able to produce biogas in 2<sup>nd</sup> rank, especially in 1<sup>st</sup> – 3<sup>rd</sup>

week. The data in Table 1 support the Figure 2, the urea treatment pH effect of biogas production is relatively higher than the others. The nitrogen addition through urea as enrichment culture action is useful to add nutrients for microbial growth which impacting for increase biogas production. The same conclusions were obtained at Sri Lanka in the urea treatment of rice straw which decrease C/N ratio from 80 to 30 [33]. The high C/N ratio has negative impact on the protein formation which needed for microbial growth due to the low nitrogen in the substrate [40].

Table 1 shows that the CJO treatment is the 2<sup>nd</sup> rank of the biogas average production, especially in the 3<sup>rd</sup> week which producing two times higher than the control. It has similarity with the addition of 5% fish oil which will double the biogas productions from manure or sewage sludge [45] and the addition of 5% oil bleaching earth (which has high lipids content) in hog manure substrate [44]. The correlation graph between biogas methane content and carbon chain length reveals that the higher C atoms in the substrate, then the higher the methane content of the biogas substrate [51]. Lipids C<sub>57</sub>H<sub>104</sub>O<sub>6</sub> potentially CH<sub>4</sub> yield on 1.014 l/g VS with CH<sub>4</sub> levels at 70% was compared to the potentially CH<sub>4</sub> of Carbohydrate C<sub>6</sub>H<sub>10</sub>O<sub>5</sub> on 0.415 l/g VS with CH<sub>4</sub> levels at 50% [43]. Fats will produce biogas on 1300 l/kg TS with CH<sub>4</sub> levels at 72% was compared to the carbohydrate that produces 746 l/kg TS with CH<sub>4</sub> levels at 50% [52]. Typical gas compositions for carbohydrate feeds are 55% methane and 45% carbon dioxide, while the gas contains as much as 75% methane for fats [53].

However, there are problems such as reduction in daily average biogas production. Daily biogas production is decrease from the 1<sup>st</sup> week to the 5<sup>th</sup> week with CJO, urea, and control treatment on 72.94%, 72.70%, and 39.15% respectively. Production decrease on additive treatment is greater than control. This is presumably due to the enrichment culture treatment impact to the accumulation of organic acids. The accumulation will form a weak acid buffer that will cause the pH became lower as shown in Figure 2. It show that the additive urea and CJO are more stimulate the development of fermentative bacteria which not balanced by the rate of growth and development of methanogenic bacteria. With fats, the hydrolysis (the first stage of biogas fermentation) proceeds more rapidly with increasing emulsification (bioavailability), so that the acetogenesis (third stage of biogas fermentation) is limiting [40]. Addition of urea in cattle dung digesters at various organic loadings has been reported to be beneficial but has certain limitations, i.e. continuous addition of urea leads to decrease in biogas production and also ammonia toxicity [54]. pH decrease affects to the majority of methanogenic bacteria, are very sensitive with low pH, will die [55]. At pH < 6.5, only one genus of methanogenic bacteria (from 7 genus of methanogenic bacteria) is able to life namely Methanosarcina [40]. This affects the biogas production decreased from week to week as shown in Table 1. Further examination Figure 1 and Table 1 indicate other problems of DH-JcL substrate as shown on Table 2.

Table 2. pH values and daily biogas production (cc/g VS) average of DH-JcL digester with three treatments in the 1<sup>st</sup> week

Treatment	pH	Biogas Production
5% CJO	5.71	81.4
3% Urea	5.73	106.77
Control	5.63	52.44

Table 2 shows that the observed pH and average daily production in the first week. pH values show flat at about 5, but the average biogas productions show relatively different. The urea treatment produces biogas at 2.03 times higher than the control in average. It show that, the pH value is not the appropriate properties for monitoring biogas fermentation especially for those containing highly buffered substrates such as agricultural wastes [50, 56.57, 58].

#### 4. CONCLUSION

This preliminary study concluded that 3% urea (w/w) and 5% CJO (w/w) was able to used as additives due to it could increase the biogas production of DH-JcL for each 132% and 173%. More research/study is needed to solve the decrease in the biogas production of DH-JcL as a result of the organic acids accumulation. At the other side, it was taken a cheap and easy way tool to monitor the biogas fermentation process as a replacement or companion of pH values.

#### REFERENCES

- [1] Wouter A., "Sustainability Evaluation of Biodiesel from *Jatropha curcas* L. A Life Cycle Oriented Study", Dissertation, Katholieke Universiteit Leuven België, 2010.
- [2] Mkoma, S.L and F. P. Mabiki., "Jatropha as Energy Potential Biofuel in Tanzania", International Journal of Environmental Sciences, Volume 2, No.3, 2012, pp 1553 – 1564.

- [3] Salafudin, Praptiningsih G.A., T. Liwang, L. O. Nelwan, Y. Sakri and Hendroko, R., "Study Bio-refinery Capsule Husk from *Jatropha curcas* L. Waste Crude *Jatropha* Oil as Source for Biogas", World Renewable Energy Congress Indonesia, International Conference and Exhibition on Renewable Energy and Energy Efficiency, Nusa Dua, Bali, October 17<sup>th</sup> – 19<sup>th</sup>, 2011.
- [4] Singh, R.N., D.K. Vyas, N.S.L. Srivastava, and M. Narra, "SPRERI Experience on Holistic Approach to Utilize All Parts of *Jatropha curcas* Fruit for Energy", *Renewable Energy*, 33, 2008, 1868–1873.
- [5] Nafisa Ali, A.K., Kurchania, dan Swati Babel, "Bio-Methanisation of *Jatropha curcas* Defatted Waste", *Journal of Engineering and Technology Research*, 2010, 2(3), 38-43.
- [6] O. Lopez, G. Foidl, N. Foidl, "Production of Biogas from *J. curcas* Fruitshells", in Gubitz, Mitielbach, Train : Biofuel and Industrial Products From *J. Curcas*,. Down load from Gubitz et sl.-2008-05-29 (4)-chapter 3-Biofuel.pdf-Adobe Reader.
- [7] Hendroko, R., Praptiningsih, G.A., T. Liwang, Salafudin, L.O. Nelwan, and Y.Sakri, "Kajian Pemanfaatan Daging Buah *Jatropha curcas* L. Sebagai Pembangkit Biometana di Pencernaan Anaerobik Dua Tahap", Seminar Semester Genap Universitas Darma Persada 2010/2011, Jakarta, 13 Juli 2011.
- [8] Makkar, H. P. S. and Becker, K., "*Jatropha curcas*, A Promising Crop For The Generation of Biodiesel and Value-added Coproducts", *Eur. J. Lipid Sci. Technol*, 2009, 111, 773–787.
- [9] Becker, K., "Biofuels from *Jatropha curcas* Oil – Perspectives for Tropical Regions", *OCL VoL. 16 No. 4 Juillet – Decembre 2009*.
- [10] Sotolongo J. A., Beatón P., Diaz A., de Oca, S. M. del Valle, Y. Pavón, S. G. and Zanzi R., "*Jatropha curcas* L. as a Source for The Production of Biodiesel : A Cuban Experience", Download from <http://hem.fyristorg.com/zanzi/paper/W2257.pdf>, 2009.
- [11] Hasanudin, U. and A. Haryanto, "Sustainability Assesment of Biomass Utilization for Bioenergy Case Study in Lampung Indonesia", The 7<sup>th</sup> Biomass Workshop Asia, Jakarta. November 29 – December 1, 2010.
- [12] Praptiningsih G. A., R. Hendroko, T. Liwang, and Salafudin, "Pengamatan Awal Pertumbuhan dan Produktivitas Provenan Jarak Pagar (*Jatropha curcas* L.) Non Toksik Dibandingkan Kultivar Harapan Jatromas", The I Seminar of Renewable Energy (SNETI-I), Jendral Soedirman University, Purwokerto, 18 – 19 Desember, 2010.
- [13] Hendroko, R., T. Liwang, Salafudin, Praptiningsih, G. A., L. O. Nelwan, Y. Sakri, and Satriyo K. W., "The Modification for Increasing Productivity at Hydrolysis Reactor with *Jatropha curcas* Linn Capsule Husk as Bio-Methane Feedstocks at Two Stage Digestion", International Conference on Sustainable Energy Engineering and Application, Yogyakarta, November 6<sup>th</sup> – 8<sup>th</sup>, 2012.
- [14] He Fang, Hu Wenrong and Li Yue Zhong, "Biodegradation Mechanisms and Kinetics of Azo dyes 4BS by a Microbial Consortium", *Chemosphere*, 2004, 57:293-301.
- [15] D. Doublein and A. Steinhäuser, "Biogas from Waste and Renewable Resources an Introduction", Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2008.
- [16] Karki, A. B. and K. Dixit, "Biogas Fieldbook", Sahayogi Press, Khatmandu, Nepal, 1984.
- [17] Marti. I. F., "Study of The Effect of Process Parameters on The Thermophilic Anaerobic Digestion of Sewage Sludge, Evaluation of Thermal Sludge Pre-treatment and Overall Energetic Assessment", PHD Thesis of Escola University, Barcelona, 2008.
- [18] Angelidaki, I., Ellegaard, L. and Ahring, B. K., "Applications of The Anaerobic Digestion Process", In: Ahring, B.K. (ed.) *Biomethanation II*, Springer, Berlin, 2003, pp.1- 33.
- [19] Anonim, "Biogas", down load from <http://www.geocities.com/tiper01ugm/BIOGAS.HTM>.
- [20] Laksana, Y. P., "Air Lumpur Lapindo untuk Produksi Biogas?", *Kompasiana*, 4 Juli 2011.
- [21] Angelidaki, I. and L. Ellegaard, "Co-digestion of Manure and Organic Wastes in Centralized Biogas Plants, Status and Future Trends", *Applied Biochemistry and Biotechnology*, 2003, 109: 95-105.
- [22] Kasmidjo, R. B., "Penanganan Limbah Pertanian, Perkebunan dan Industri Pangan", Inter University Center of Food and Nutrition, UGM, Yogyakarta, 1990.
- [23] Sarwono, R., "Pengendalian Proses Biogasifikasi Limbah Organik", *IPT Bulletin*, No. 1 Vol III., April/Mei 1997.
- [24] Luthfianto, D., E. Mahajoeno and Sunarto, "Pengaruh Macam Limbah Organik dan Pengenceran Terhadap Produksi Biogas dari Bahan Biomassa Limbah Peternakan Ayam", *Bioteknologi 9* (1) : 18-25, Mei 2012.
- [25] Audra A. O. and V. D. Aryati, "Biogas Production Using Anaerobic Bioreactor from Cassa Starch Effluent with Ruminant Bacteria as Biocatalyst", Thesis, Chemical Engineering Department, Technical Faculty, Diponegoro University, Semarang, 2010.
- [26] B. Pound, Done F. and T. R. Preston, "Biogas Production from Mixtures of Cattle Slurry and Pressed Sugar Cane Stalk, With and Without Urea", *Trop. Anim. Prod.*, 1981, 6:1.
- [27] Anunputtikul, W., Rodtong, S., "Investigation of The Potential Production of Biogas from Cassava Tuber", Abstracts of the 15th Annual Meeting of The Thai Society for Biotechnology and JSPSNRCT Symposium, Thailand, 2004.
- [28] Indarto, K. E., "Produksi Biogas Limbah Cair Industri Tapioka Melalui Peningkatan Suhu dan Penambahan Urea pada Perombakan Anaerob", Thesis, Sebelas Maret University, Surakarta, 2010.
- [29] Santoso, A. A., "Produksi Biogas dari Limbah Rumah Makan Melalui Peningkatan Suhu dan Penambahan Urea pada Perombakan Anaerob", Thesis, Sebelas Maret University, Surakarta, 2010.
- [30] Agunwamba, J. C., "Waste Engineering and Management Tool", Immaculate Publication Limited, Enugu, 2001.
- [31] Ahring, B. K., Angelidaki, I., and Johansen, K., "Co-digestion of Organic Solid Waste, Manure and Organic Industrial Waste", *Waste Management International*, K. J. Thim'ekozmiensky (Eds.), EFVerlag fur Energieund Umwelttechnik GmbH 1: 661–666, 1992.
- [32] Rongyu, H. E., Liu Xiao Feng, Yuan Yue Xiang, "Review on Enhancing Biogas Production by Additives", Down load from [http://en.cnki.com.cn/Article\\_en/CJFDTOTAL-ZGZQ200705005.htm](http://en.cnki.com.cn/Article_en/CJFDTOTAL-ZGZQ200705005.htm)
- [33] Jayasinghe, G. Y., S. I. Abegunwardana and K.D.N Weerasinghe., "Studies on Improvement of Rice-Straw Biomethanation - A Case Study from Srilangka", 7<sup>th</sup> World Congress on Recovery, Recycling and Re-integration, Peking, China, 25<sup>th</sup> – 29<sup>th</sup> September 2005.
- [34] Wate, S. R., "Studies on Anaerobic Digestion Process as Applied to Organic Matter in Presence of Some Additives", PhD Thesis, Nagpur University, Nagpur, India, 1982.
- [35] Yadvika, Santosh, T. R. Sreerishnan, S. Kohli, and V. Rana, "Enhancement of Biogas Production from Solid Substrates Using Different Techniques – A Review", *Bioresource Technology*, 95, 2004.

- [36] Onwosi, C. O., "Effect of Water Dilution and Nutrient Supplements (Wood Ash, Urea and Poultry Droppings) on Biogas Production from Brewers Spent Grain", Down load from [http://www.worldscientific.com/doi/abs/10.1142/9789812837554\\_0048](http://www.worldscientific.com/doi/abs/10.1142/9789812837554_0048)
- [37] Satyanarayana, S., P. Murkutea, and Ramakantb, "Biogas Production Enhancement by *Brassica campestris* Amendment in Cattle Dung Digesters", *Biomass and Bioenergy* 32, 2008, 210 – 215.
- [38] Oswald, W., "Co-digestion of Hog Manure with Glycerol to Boost Biogas and Methane Production", Thesis, The University of Manitoba, Winnipeg, Manitoba, 2009.
- [39] Iyagba, E. T., I. A. Mangibo and Y. S. Mohammad, "The Study of Cow Dung as Co-substrate with Rice Husk in Biogas Production", *Scientific Research and Essay*, Vol.4 (9), pp. 861-866, September 2009.
- [40] D. Deublein and A. Steinhauser, "Biogas from Waste and Renewable Resources an Introduction", Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2008.
- [41] Al Setiadi, T. and C. Lukehurst, "Quality Management of Digestate From Biogas Plants Used as Fertilizer", *IEA Bioenergy*, May 2012.
- [42] Angelidaki, I. and B. K. Ahring, "Co-digestion of Olive Oil Mill Wastewaters with Manure, Household Waste or Sewage Sludge", *Biodegradation*, 8: 221–226, 1997.
- [43] Angelidaki, I., Ellegaard, L., and B.K. Ahring, "Applications of The Anaerobic Digestion Process", *Advances in Biochemical Engineering/Biotechnology*, 2003, 82: 1-33.
- [44] Campos, E., Palatsi, J. and X. Flotats, "Co-digestion of Pig Slurry and Organic Wastes from Food Industry", In *Proceedings of the II International Symposium on Anaerobic Digestion of Solid Wastes*, Barcelona, June 1999, 192-195
- [45] Ahring, B. K., "Perspectives for Anaerobic Digestion", *Advances in Biochemicals Engineering/Biotechnology*, Vol. 81 Series editor : T. Saeper, Springer Verlag Berlin, Heidelberg, 2003.
- [46] Hendroko, R., A. Wahyudi, Satriyo K. W., Praptiningsih G. A., Salafudin, and T. Liwang, "Bio-refinery Study in Crude *Jatropha* Oil Process : Co-Digestion Sludge of Crude *Jatropha* Oil and Capsule Husk *Jatropha curcas* Linn as Biogas Feedstocks", Unpublished
- [47] Sa'adah, R., "Laporan Penelitian Biogas", 2010, Down load from [http://eprints.undip.ac.id/11591/2/laporan\\_penlit\\_Puji\\_Rahmi.pdf](http://eprints.undip.ac.id/11591/2/laporan_penlit_Puji_Rahmi.pdf)
- [48] Velmurugan, B. and R. A. Ramanujam, "Anaerobic Digestion of Vegetable Wastes for Biogas Production in a Fed-Batch Reactor", *Int. J. Emerg. Sci.*, 1(3), September 2011, 478-486.
- [49] Budiyo and T. D. Kusworo, "Biogas Production from Cassava Starch Effluent Using Microalgae as Biostabilisator", *Internat. J. of Sci. and Eng.* Vol. 2(1):4-8, July, 2011.
- [50] Gerardi, M. H., "The Microbiology of Anaerobic Digesters", A. John Wiley & Sons, Inc., Publication, USA, 2003.
- [51] Böhnke, B., Bischofsberger, W., Seyfried, C. F., "Anaerob Technik", Springer Verlag, 1993.
- [52] Wulf, S., "Anaerobic Digestion and Biogas Production", A Presentation at First Bonner Summer School on Sustainable Agriculture, August 2005.
- [53] Marchaim, U., "Biogas Processes for Sustainable Development", MIGAL Galilee Technological Centre Kiryat Shmona, Israel, FAO, 1992.
- [54] Satyanarayan, S., Wate, S. R., Deshpande, C. V., Srinivasan, M. V., "Effect of Nitrogen Supplementation as Urea on Biogas Production from Cattle Dung", *Asian Environment*, 1989;12(2):3–9.
- [55] Dennis, A. and Burke, P. E., "Dairy Waste Anaerobic Digestion Handbook", Environmental Energy Company, 2001.
- [56] Kanokwan Boe, "Online Monitoring and Control of The Biogas Process Institute of Environment and Resources", Dissertation, Technical University of Denmark, May 2006
- [57] Björnsson, L., Murto, M. and Mattiasson, B., "Evaluation of Parameters for Monitoring an Anaerobic Co-Digestion Process", *Applied Microbiology and Biotechnology*, 2000, 54, 844-849
- [58] Angelidaki, I. and Ahring, B. K., "Effects of Free Long-Chain Fatty Acids on Thermophilic Anaerobic Digestion", *Appl. Microbiol. Biotechnol.*, 1994, 37: 803-812

# Evaluation of Concentration and Initial pH of Synthetic Nutrient Solution in N<sub>2</sub>O Biofiltration by *Nitrobacter winogradskyi* Inoculated on Lampung Natural Zeolite and Activated Carbon

Nindya Sani Widhyastuti, Tania Surya Utami<sup>a</sup>, Nurhafizah Putri, Laili Purnamasari, Qurrota A'yunin

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : nana@che.ui.ac.id

## ABSTRACT

Nitrous oxide (N<sub>2</sub>O) gives highest contribution in global warming and also categorized as a dangerous gas. Removal of N<sub>2</sub>O could be achieved by biofilter technology. Activated Lampung Natural Zeolite was utilized as filter media because of its high porosity. As comparison, activated carbon was also utilized due to its great surface area. *Nitrobacter winogradskyi* was used to reduce N<sub>2</sub>O into harmless gas N<sub>2</sub>. This research aims to study the effect of bacteria culture addition in biofiltration and to determine the optimum operation condition by adjusting concentration of synthetic nutrient solution to 0.37%, 0.31%, 0.27%, 0.23%, 0.21% weight wt/wt and initial pH of media to pH 4, 5, 6, 7, 8. Concentration of synthetic nutrient solution studied because aerobic microorganisms need nutrients for growth as energy source and oxygen or growth substrate. Initial pH of media studied because optimum pH affects bacteria growth speed hence affects pollutant removal efficiency. In this experiment, biofilter was operated for 24 hours with gas concentration was 15000 ppm N<sub>2</sub>O in air and gas flow rate was maintained at 88 cc/minute. Removal efficiency optimum achieved by 0.31% (wt/wt) and initial pH 7 for both filter media. From BET and TPC, activated carbon has better capability for biofiltration media than natural zeolite.

## Keywords

Biofilter, Natural Zeolite, Activated Carbon, Nitrous oxide, *Nitrobacter winogradskyi*

## 1. INTRODUCTION

N<sub>2</sub>O has a significant role in causing global warming, where biggest contribution given by agricultural by-product, also biomass burning and land use. Although emission from N<sub>2</sub>O gas is lower than CO<sub>2</sub>, however N<sub>2</sub>O gas could absorb heat 320 times stronger than CO<sub>2</sub> in atmosphere [1]. Beside that, N<sub>2</sub>O gas could stay longer in atmosphere and more stable than CO<sub>2</sub> or CH<sub>4</sub> gas [2].

Biofilter is reactor in which pollutant air stream is passed through a porous packed bed on which a mixed culture of pollutant-degrading organism grow in a biofilm on the surface of a media [3]. The benefit of biofilter compared to other methods are low investment cost, stable if operated in relative long time, and has high degradation ability of pollutant gas, and could convert a mixed of organic and inorganic into harmless oxidation product [4].

In this research natural zeolite was chosen as filter media because its stable structure and high porosity [5]. Activated Carbon was utilized as filter media due to wide surface area and high adsorption [6]. Beside that, *Nitrobacter winogradskyi* was used to oxidize N<sub>2</sub>O into harmless N<sub>2</sub> [7].

This research studied biofiltration ability of nitrous oxide pollutant by *Nitrobacter winogradskyi* bacteria on natural zeolite and activated carbon as inoculated filter media with adjusting operation condition which was synthetic nutrient solution and initial pH of media. This research also studied the effect of *Nitrobacter winogradskyi* inoculation to pollutant degradation ability, and growth of *Nitrobacter winogradskyi* along preparation and biofiltration. The main goal of this research is to determine better biofiltration media between natural zeolite and activated carbon on N<sub>2</sub>O removal, from its function as filter media and microbes growth media.

## 2. METHODOLOGY

### 2.1 Inoculum Preparation

Preparation of bacteria culture consist of culture of bacteria on agar, broth, and synthetic media, include inoculation of bacteria into natural zeolite. Synthetic nutrition is useful as source of carbon and inorganic nutrition for bacteria along biofiltration and as source of moisture content for filter media [8]. Synthetic media composition for *Nitrobacter winogradskyi* [9] are NaNO<sub>2</sub> (1

gram), NaCl (0.3 gram),  $K_2HPO_4$  (0.5 gram),  $MgSO_4 \cdot 7H_2O$  (0.5 gram),  $MnCl_2$  (0.02 gram),  $FeSO_4$  (0.005 gram) in aquadest (1 liter). Inoculation of biofilter media with adapted microbial aggregates greatly reduces adaptation time of biofilter [10].

## 2.2 Lampung Natural Zeolite Activation

Natural zeolite used in this research was clinoptilolite from CV Mina Tama, Bandar Lampung, Indonesia which trade name is ZKK (Zeo Kap Kan) and particle size is P-4 range 5-7.5 mm. Zeolite activated by water vapour removal and dealumination using HF. Dealumination could increase porosity and adsorption capacity, also extend adsorber life [11].

## 2.3 Activated Carbon Reactivation

Activated carbon used in this research was from CV Sari Hikmah Nusantara, Depok, Jawa Barat, Indonesia which particle size is  $\pm 4$  mm. Activated carbon reactivated by water vapour removal.

## 2.4 Biofiltration Experiment

Biofilter system used in this experiment had been used by Utami et al. [2009] with addition of *mass-flow regulator* and *thermo-hygro meter* installation on biofilter column as shown in Figure 1.

Biofilter equipment used was laboratory scale equipment with height 120 cm, outer radius 4 cm, and column thickness 0.325 cm. *Down-flow mode* stream used to increase control of moisture content [13]. Concentration of  $N_2O$  gas was 15000 ppm in the air and flow rate was 88 cc/minute. Biofiltration was run with *batch* system for 24 hours. Gas was flowed through filter media which had been inoculated by bacteria.  $N_2O$  gas then will be adsorbed by biofilm and filter media will be oxidized by bacteria which live inside that biofilm. Mass of filter media used was 4 kg for height of filter media inside column achieved 100 cm.

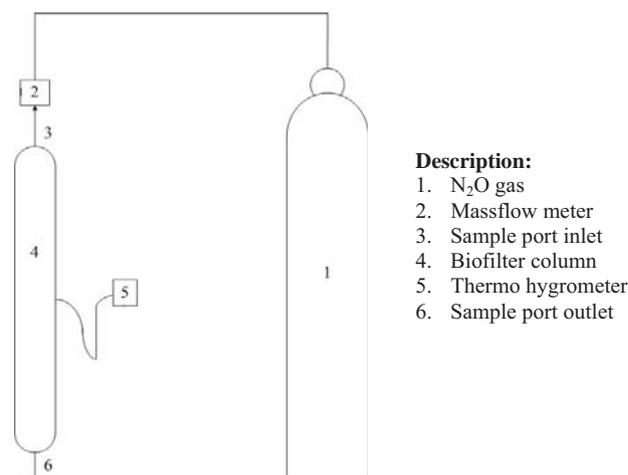


Figure 1: Schematic diagram of biofilter

## 2.5 Analytical Method

Concentration of inlet and outlet gas from biofilter column analyzed using Gas Chromatography (GC). Temperature and moisture content of filter media monitored using *thermo-hygro meter*. Amount of bacteria counted using Total Plate Count (TPC) method. Morphology of filter media analyzed using Scanning Electron Microscopy (SEM) and Field Emission Scanning Electron Microscopy (FESEM).

## 3. RESULT AND DISCUSSION

### 3.1 Biofilter Performance Test in Reducing $N_2O$

In this research, one of the factors that influence biofiltration is amount of nutrient. Aerobic microorganism needs nutrient for growth in addition to oxygen and an energy source or growth substrate. The inlet gas contaminant, referred to as the substrate, is usually both the microbe's energy and carbon source for building cellular material [14].

In the other hand, initial pH of media was also studied because optimum pH affects bacteria growth speed hence affects pollutant removal efficiency [15]. Beside that, ideal pH of filter media depends on reduced pollutant and characteristic of bacteria ecosystem [16].

Variation of concentration of synthetic nutrient solution used is 0,37%, 0,31%, 0,27%, 0,23%, 0,21% (w/w). Variation of initial pH of media used is 4, 5, 6, 7, 8. The effect of concentration of synthetic nutrient solution and initial pH of media variation can be obtained at removal efficiency.

For concentration of synthetic nutrient solution variation, highest average of removal efficiency for 24 hours achieved by 0.31% (wt/wt) concentration of nutrient solution for both media. Therefore, 0.31% (wt/wt) was optimum concentration of nutrient solution for biofilter system in this experiment.

In the other hand, for initial pH of media, highest average of removal efficiency for 24 hours achieved by initial pH 7 for both media. Therefore, initial pH 7 was optimum initial pH for biofilter system in this experiment. This was appropriate with optimum pH for biological activity is around 7 [17], where a near neutral pH provides widest spectrum of bacterial activity [18].

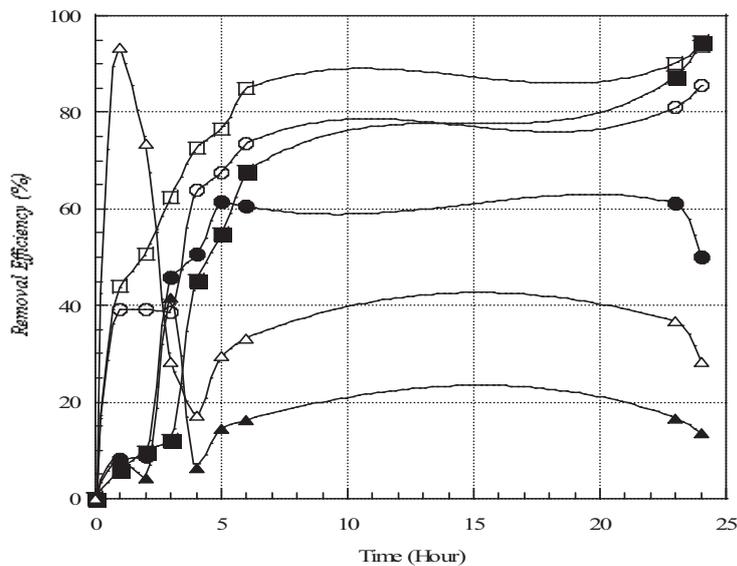


Figure 2. N<sub>2</sub>O Removal Efficiency (RE) at 0,31% (wt/wt) concentration of synthetic nutrient solution using natural zeolite (●) and activated carbon (○); and at initial pH media 7 using natural zeolite (■) and activated carbon (□); and without microbes inoculation using (▲) natural zeolite and (△) activated carbon

Curve in Figure 2 shows that pollutant removal efficiency in the earlier hours were low because microbes exposed to new environment may require adaptation time before they start vigorous biodegradation [19]. Figure 2 also show effect of microbes inoculation to pollutant degradation ability. Adsorption process on filter media without microbes inoculation in the earlier hours were still unstable due to start-up phase [20]. Inoculation of bacteria succeeded increasing average of removal efficiency in all variations. Hence, inoculation of bacteria is one of important parameter in determining biofiltration performance. This was because in the biofiltration system, the pollutant are removed due to biological degradation rather than physical straining. Once the pollutant are adsorbed on the biofilm or dissolved in the water layer surrounding the biofilm, the contaminants are adsorbed and biodegraded by microbes in the biofilm, pollutant may also be adsorbed at the surface of the packing [3].

Table 1: Average and Optimum Removal Efficiency of N<sub>2</sub>O by Biofiltration Media Inoculated by *Nitrobacter winogradskyi* with Optimum Operation Condition of Synthetic Media

Removal Efficiency (%)	Concentration of Synthetic Nutrient Solution 0,31% (wt/wt)		Initial pH 7	
	Lampung Natural Zeolite	Activated Carbon	Lampung Natural Zeolite	Activated Carbon
Average	61.1	43.6	47.29	71.89
Optimum	61.5	85.7	94.73	93.8

Table 1 shows that the optimum removal efficiency in biofiltration using Lampung Natural Zeolite media reached 61.5% with 0.31% (wt/wt) concentration of nutrient solution, whereas the optimum removal efficiency in biofiltration using Activated

Carbon reach 85.7% in the same concentration. Both of the media reached the optimum removal efficiency at the same solution concentration. This indicates that 0.31% (wt/wt) concentration of synthetic nutrient solution is the sufficient concentrations that needed by bacteria to reduce N<sub>2</sub>O to get the optimum performance of the biofiltration process. In addition, the concentration of 0.31% (wt/wt) is the suitable conditions for bacteria to reproduce and obtain nutrients.

Moreover, Table 1 also shows the optimum initial pH of media for Lampung Natural Zeolite and Activated Carbon is same which is initial pH 7. This happened because both experiments use the same *Nitrobacter winogradskyi* as degrading microbes. Optimum removal efficiency of N<sub>2</sub>O gas difference is not significant, both have a high value. However, the average value for Activated Carbon is higher than Lampung Natural Zeolite. This is because adsorption at the beginning of biofiltration using activated carbon is better than natural zeolite due to larger surface area as mentioned in Table 2 from BET analysis. Based on Zilli et al. (2003) and Kim et al. (2002), the high pollutant removal in the early stage was mainly due to adsorption onto filter media and mass transfer into aqueous phase, but not due to biodegradation activity of microbes [21, 22].

Table 2: Biofiltration Media Characterization

Parameter	Lampung Natural Zeolite	Activated Carbon
Surface Area (m <sup>2</sup> /g)	1.207 × 10 <sup>2</sup>	2.578 × 10 <sup>2</sup>
Pore Volume (cc/g)	1.810 × 10 <sup>-1</sup>	1.580 × 10 <sup>-1</sup>
Pore Size (Å)	2.999 × 10 <sup>1</sup>	1.226 × 10 <sup>1</sup>

### 3.2 Bacteria Growth Test Result

TPC analyzed by Health and Environmental Engineering Laboratorium, Civil Engineering Department, Engineering Faculty of Universitas Indonesia. TPC analysis in Tabel 3 shows that there were quite significant decreasing of bacteria population in both media media after biofiltration due to lack of synthetic nutrition supply that needed by bacteria to keep growing and oxidizing pollutant. Based on Fu et al. (2011), It is needed to design biofilter system with spray nozzle installation at the top of biofilter column which useful to provide nutrition for bacteria hence microbes population could be kept along biofiltration [23].

Table 3: Amount of Bacteria (CFU/mL) in Biofiltration Media during Preparation and Running

Sampling Time	Concentration of Synthetic Nutrient Solution 0,31% (wt/wt)		Initial pH 7	
	Lampung Natural Zeolite	Activated Carbon	Lampung Natural Zeolite	Activated Carbon
At 0 hour incubation at synthetic media	2.5 × 10 <sup>7</sup>	12 × 10 <sup>8</sup>	3 × 10 <sup>13</sup>	26 × 10 <sup>9</sup>
After 48 hour incubation at synthetic media	1.64 × 10 <sup>9</sup>	5 × 10 <sup>11</sup>	2.2 × 10 <sup>12</sup>	49 × 10 <sup>10</sup>
Before biofiltration	1.85 × 10 <sup>12</sup>	121 × 10 <sup>12</sup>	2.5 × 10 <sup>14</sup>	22 × 10 <sup>12</sup>
After biofiltration	5.25 × 10 <sup>10</sup>	24 × 10 <sup>11</sup>	20 × 10 <sup>11</sup>	45.5 × 10 <sup>10</sup>

Table 4: Amount of Bacteria (CFU/mL) in Biofiltration Media during Incubation in Synthetic Media

Incubation Time (Hour)	Lampung Natural Zeolite	Activated Carbon
t = 0	3 × 10 <sup>4</sup>	1.1 × 10 <sup>6</sup>
t = 24	3.3 × 10 <sup>5</sup>	3.3 × 10 <sup>6</sup>
t = 48	3.8 × 10 <sup>6</sup>	4.2 × 10 <sup>7</sup>
t = 72	4 × 10 <sup>7</sup>	8 × 10 <sup>8</sup>

TPC (Total Plate Count) also done to determine colony of microbes which attached on surface of natural zeolite and activated carbon when being incubated in synthetic media during 0, 24, 48, and 72 hours. Based on TPC result shown on Table 4, activated carbon has 10<sup>1</sup> CFU/mL greater amount of bacteria than natural zeolite. This means activated carbon is more favorable as growth media for *Nitrobacter winogradskyi* than natural zeolite. It is predicted due to its large surface area, hence activated carbon could adsorb more water, then increase its moisture level. Park (2009) stated that microbes grow excellent on wet surface [24].

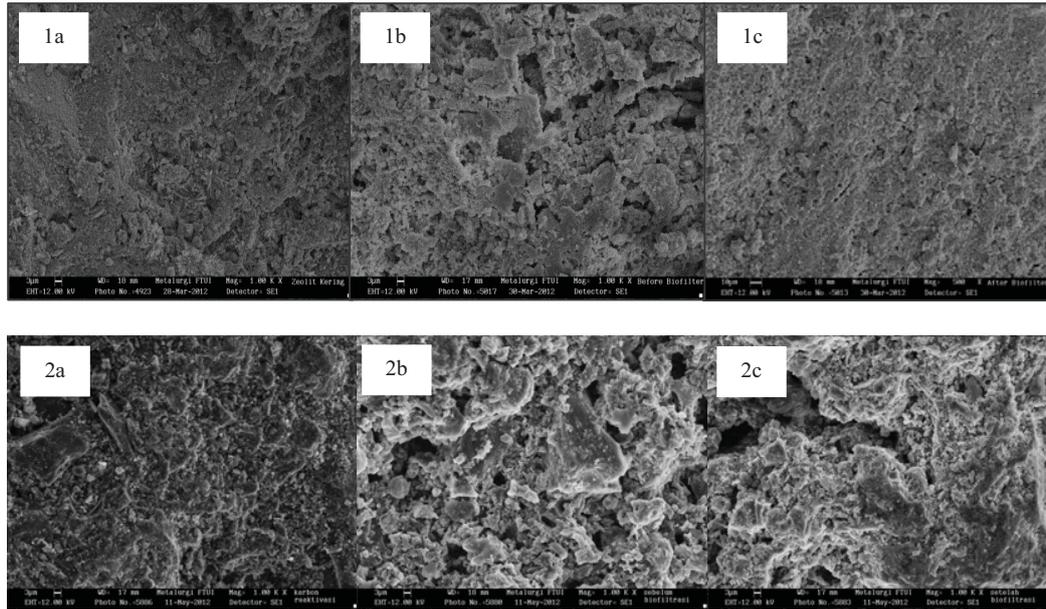


Figure 5. Morphology of biofiltration media on (1) Lampung Natural Zeolite and (2) Activated Carbon surface using SEM: (a) zeolite without bacteria inoculation, (b) before biofiltration, and (c) after biofiltration

Scanning Electron Microscope (SEM) test did to support TPC data that function to see the morphological change on filter media due to bacteria growth. SEM analyzed with 1000 times of magnification by Test Laboratorium, Metallurgical and Material Engineering, Engineering Faculty of Universitas Indonesia. SEM result in Figure 5 shows that biofilms grow thicker along biofiltration. Nevertheless, biofilm thickness was not equal with increasing amount of microbes population. This was due to biofilm accumulation is affected by presence of substrate concentration and product metabolism, also by biomass [25, 26]. Beside that, there was inactive biofilm because of decreasing of microbes population along biofiltration. However based on GC result, increasing of pollutant removal efficiency happened along biofiltration for 24 hours operation. It was predicted that plenty of active fraction and specific surface on biofilm were available.

Figure 6 shows morphology of biofiltration media that analyzed by Field Emission Scanning Electron Microscope (FESEM). FESEM could produce clearer image and has high resolution until 1.5 nm which is 3 until 6 times better than conventional SEM. From FESEM image, it is shown that microbes were attached on both biofiltration media which marked by red circle.

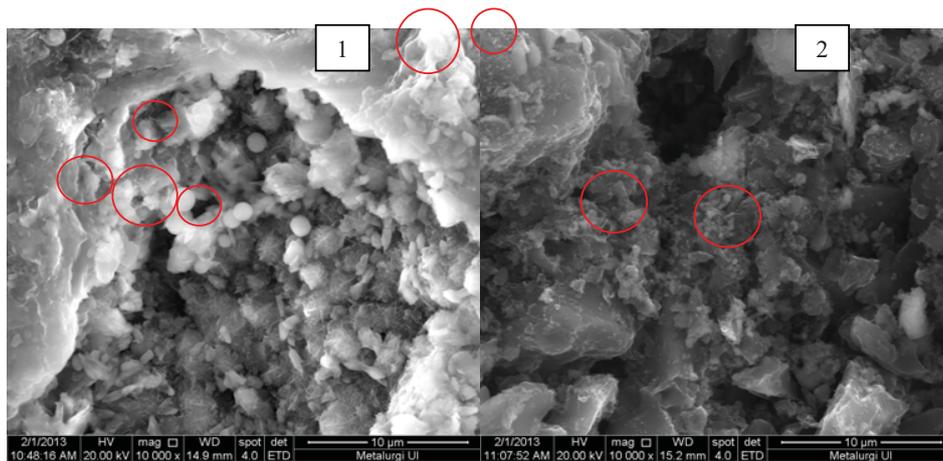


Figure 6. Morphology of biofiltration media on (1) Lampung Natural Zeolite and (2) Activated Carbon using FESEM after incubated for 72 hours in synthetic media

#### 4. CONCLUSION

Optimum concentration of synthetic nutrient solution was 31% (wt/wt) and optimum initial pH of media was 7 for both Lampung Natural Zeolite and Activated Carbon. Optimum *Removal Efficiency* at 31% (wt/wt) concentration of synthetic nutrient solution for Lampung Natural Zeolite was 61.5% with average was 61.1% for 24 hours operation; for Activated Carbon was 85.7% with average was 43.6% of 24 hours operation. Optimum *Removal Efficiency* at initial pH 7 for Lampung Natural Zeolite was 94.73% with average was 47.29% for 24 hours operation; for Activated Carbon was 93.8% with average was 71.89% of 24 hours operation. Bacteria inoculation increased *Removal Efficiency*. BET shows that activated carbon has 2.14 larger surface area than natural zeolite. TPC shows that activated carbon has  $10^1$  CFU/mL greater amount of bacteria than natural zeolite. Hence, activated carbon has better capability as biofiltration media than natural zeolite in reducing  $N_2O$  and inoculated by *Nitrobacter winogradskyi*.

#### REFERENCES

- [1] Algas, "Asian Least Cost Greenhouse Gas Abatement Strategy: Mengurangi Emisi Gas Rumah Kaca", 1997, Available: <http://www.pelangi.or.id/publikasi/megrk-bab1.htm> [Accessed 8 Desember 2008].
- [2] A. Wihardjaka, "Loka Penelitian Pencemaran Lingkungan Pertanian: Mewaspadai Emisi Gas Nitro-Oksida dari Lahan Persawahan", 2004.
- [3] T. P. Kumar, Rahul, M. A. Kumar, and B. Chandrajit, "Biofiltration of Volatile Organic Compounds (VOCs) – An Overview", *Research Journal of Chemical Sciences*, vol. 1, pp. 83–92, 2011.
- [4] B. A. Sheridan, T. P. Curran, and V. A. Dodd, "Assessment of the influence of media particle size on the biofiltration of odorous exhaust ventilation air from a piggery facility", *Bioresource Technology*, vol. 84, pp. 129–143, 2002.
- [5] E. Maulidyasti, "Peningkatan Proses Degradasi Hidrogen Sulfida dalam Biofilter Menggunakan Zeolit Alam Lampung yang Diinokulasi oleh *Thiobacillus thioparus*", Sarjana, Universitas Indonesia, 2008.
- [6] M. Sembiring And T. Sinaga, "Arang Aktif", Jurusan Teknik Industri Fakultas Teknik Universitas Sumatera Utara, 2003.
- [7] J. Hudepohl, Y. Nate, C. A. D. Davidova, Plessis, and D. P. Y. Chang, "Biofilter Technology for NOx Control: Final Report for Air Resources", 1999.
- [8] T. S. Utami, L. Adriaty, H. Hermansyah, and M. Nasikin, "Reducing Nitrous Oxide Emission Using Goat Manure-Compost Based Biofilter", *World Applied Sciences Journal*, vol. 13, pp. 226–232, 2011.
- [9] IFO, "List of Cultures Microorganisms", 11th ed Osaka: IFO, 2000.
- [10] M. Arnold, A. Reittu, A. V. Wright, P. J. Martikainen, and M. L. Suihko, "Bacterial Degradation of Styrene in Waste Gases Using a Peat Filter", *Applied Microbiology Biotechnology*, vol. 48, pp. 738–744, 1997.
- [11] M. W. Ackley, S. U. Rege, and H. Saxena, "Application of Natural Zeolites in The Purification and Separation of Gases", *Microporous and Mesoporous Materials*, vol. 61, pp. 25–42, 2003.
- [12] T. S. Utami, H. Hermansyah, and M. Nasikin, "Pengaruh Parameter Operasi dalam Proses Biofiltrasi  $N_2O$  dengan Medium Filter Berbasis Kompos", Seminar Tjipto Utomo Kampus ITENAS Bandung, 2009.
- [13] E. L. Pagans, X. Font, and A. S'Anchez, "Biofiltration for Ammonia Removal from Composting Exhaust Gases", *Chemical Engineering Journal*, vol. 113, pp. 105–110, 2005.
- [14] Janni, Kevin A, W. J. Maier, E. Tarn, T. H. Kuehn, C. H. Yang, B. B. Bridges, and D. Vesley, "Evaluation of Biofiltration of Air An Inovetiove Air Pollution Control Technology : Final Report", University of Minnesota, 1998.
- [15] S. P. P. Ottengraf, "Exhaust Gas Purification", *Biotechnology (H. J. Rehm, G. Reed, eds), VCH, Weinheim, Germany*, vol. 8, pp. 427–452, 1986.
- [16] J. S. Devinsky, M. A. Deshusses, and T. S. Webster, "Biofiltration for Air Pollution Control", Boca Raton, FL: Lewis, 1999.
- [17] L. D. Vedova, "Biofiltration of Industrial Waste Gases in Trickle-Bed Bioreactors, Case study: Trichloroethylene Removal", *Universit`a degli Studi di Padova*, 2008.
- [18] G. Leson, and A. M. Winer, "Biofiltration: An innovative air pollution control technology for VOC emissions", *Journal of the Air and Waste Management Association*, vol. 41, pp. 1045-1054, 1991.
- [19] S. B. He, G. Xue, and H. N. Kong, "The Performance of BAF Using Natural Zeolite as Filter Media Under Conditions of Low Temperature and Ammonium Shock Load", *Hazardous Material*, vol. 143, pp. 291–295, 2007
- [20] H. Duan, L. C. C. Koe, and R. Yan, "Treatment of  $H_2S$  using a horizontal biotrickling filter based on biological activated carbon: reactor setup and performance evaluation", *Environmental Biotechnology Applied Microbiology Biotechnology*, vol. 67, pp. 143-149, 2004.
- [21] M. Zilli, E. Palazzi, L. Sene, A. Converti, and M. D. Borghi, *Process Biochemistry*, vol. 37, 2003.
- [22] H. S. Kim, Y. J. Kim, J. S. Chung, and Q. Xie, *Journal of Air Waste Management Association*, 52, 2002.
- [23] Y. Fu, L. Shao, L. Tong, and H. Liu, "Ethylene Removal Efficiency and Bacterial Community Diversity of A Natural Zeolite Biofilter", *Bioresource Technology*, vol. 102, pp. 576-584, 2011.
- [24] B. G. Park, W. S. Shin, and J. S. Chung, "Simultaneous Biofiltration of  $H_2S$ ,  $NH_3$  and Toluene Using Cork as a Packing Material", *Korean Journal of Chemical Engineering*, vol. 26, pp. 79-85, 2009.
- [25] P. S. Stewart, and M. J. Franklin, "Physiological Heterogeneity in Biofilms", *Natural Rev Microbiology*, vol. 6, pp. 199-210, 2008.
- [26] R. M. M. Diks, S. P. P. Ottengraf, and S. V. B. Bioeng, "Existence of a Biological Equilibrium in a Trickling Filter for Waste Gas Purification", vol. 44, pp. 1279-87, 1994.

## Preliminary Study of Biodiesel Synthesis from Microalgae Lipid of *Chlorella vulgaris* Based Walne Medium through Esterification- Transesterification and Transesterification Reaction

Dianursanti<sup>a</sup>, Prima Anggraini<sup>b</sup>, Destya Nilawati<sup>c</sup>, Anondho Wijanarko<sup>d</sup>

<sup>a</sup>Department of Chemical Engineering, Faculty of Engineering  
University of Indonesia, Depok 16424  
E-mail : danti@che.ui.ac.id

<sup>b</sup>Department of Chemical Engineering, Faculty of Engineering  
University of Indonesia, Depok 16424  
E-mail : prima.llymha@gmail.com

<sup>c</sup>Department of Chemical Engineering, Faculty of Engineering  
University of Indonesia, Depok 16424  
E-mail : destya.nilawati@gmail.com

<sup>d</sup>Department of Chemical Engineering, Faculty of Engineering  
University of Indonesia, Depok 16424  
E-mail : anondho@che.ui.edu

### ABSTRACT

*Chlorella vulgaris* is one species of microalgae which has a lipid content of 10.2% so it becomes one of raw material in biodiesel production. In biodiesel production, there are many kind of reactions that can be used. The first reaction is esterification reaction and the second reaction is transesterification reaction. Sometimes, people use esterification then followed by transesterification. Each of reactions give different yield and the oxidative stability of biodiesel. Therefore, we need to find which reaction can give the highest yield of biodiesel and the best oxidative stability. In this study, lipid microalgae were synthesized by two methods which are esterification-transesterification reaction method and transesterification reaction method. Esterification-transesterification reaction method produces biodiesel about 76.43% and contains 63.25% saturated methyl esters. The transesterification reaction method can produce about 85.5% with saturated methyl esters composition is 60.25%. Saturated methyl esters composition indicates the oxidative stability of biodiesel. So, transesterification reaction method can produces higher biodiesel but has lower oxidative stability compared to esterification-transesterification reaction method.

### Keywords

*Chlorella vulgaris* , biodiesel, esterification-transesterification reaction, transesterification reaction.

### 1. INTRODUCTION

Nowadays, fossil fuel still becomes main energy source for people in the world. It makes many new problems such as the issue that fossil fuel can't fulfill the need of energy in the next time, the price is increasing time by time, and fossil fuel can release CO<sub>2</sub> to atmosphere which causes global warming. Based on those problems, the new energy sources must be developed soon. One kind of new energy source is biodiesel. Biodiesel is fuel that made from vegetable oil or animal lipid which has character like diesel oil. Biodiesel can be made by transesterification or esterification reaction with acid or base catalyst. Biodiesel is renewable energy and it can be made from many sources like corn, soybean, sunflower seed, microalgae, etc.

Microalgae is used as raw material for biodiesel for some reasons. The first reason is microalgae has high lipid content. The second reason is microalgae is not an edible plant so it won't make new problem like famine. The third reason is microalgae easy to be grown in Indonesia. Microalgae *Chlorella vulgaris* has attracted attention of many researchers as a potential raw material for biodiesel due to the high content of lipid. *Chlorella vulgaris* has an average lipid content of 10.2% [1] with lipid productivity is 11.2 to 40.0 mg/L/day [2]. Biodiesel from microalgae is the third generation from biofuel [3].

Many research has done to find the best condition to make biodiesel from microalgae because there are many factors may effect it [4,5,6,7,8]. One of them is the reaction used in biodiesel production. In biodiesel production, there are many kind of reactions that can be used. The first reaction is esterification reaction and the second reaction is transesterification reaction. Sometimes, people use esterification then followed by transesterification. Each of reactions give different yield and the

oxidative stability of biodiesel. Therefore, we need to find which reaction can give the highest yield of biodiesel and the best oxidative stability.

## 2. MATERIAL AND METHODS

This research has been done in Bioprocess Laboratory, Department of Chemical Engineering University of Indonesia. The type of microalgae that is used was domestic microalga, *Chlorella vulgaris*, which cultivated in Walne medium. After cultivated for 204 hours, *Chlorella vulgaris* is separated from its medium using centrifugation method. After that the cake is taken and dried in oven at 60°C. Dried microalgae then extracted by Soxhlet method using n-Hexane at 80°C for 6 to 8 hours. After that, the lipid extracted is dried in oven at 100°C. The Soxhlet's apparatus can be seen in Figure 1 below.

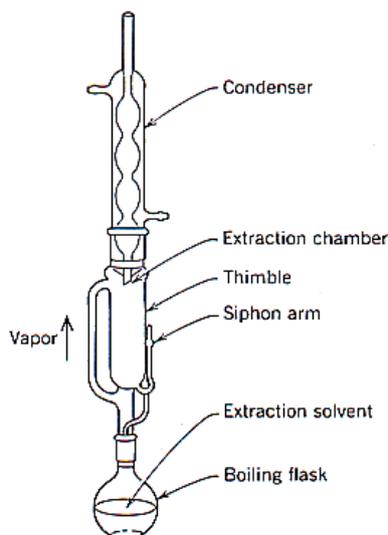


Figure 1: The Soxhlet's apparatus

In this study, the lipid of microalgae were synthesized by two methods. The first one is esterification with methanol and acid catalyst ( $\text{H}_2\text{SO}_4$ ) at 55°C for 1 hour then followed by transesterification with methanol and alkaline catalyst (KOH) at 55°C for 1 hour. The second method directly performed transesterification with methanol and acid catalyst at a temperature of 90°C for 40 minutes. In esterification-transesterification reaction method, molar ratio for lipid to methanol is 1:600 with the amount of  $\text{H}_2\text{SO}_4$  is 1 ml and KOH is 0.01 grams. For transesterification reaction method, the number of methanol is 3.7 ml and  $\text{H}_2\text{SO}_4$  is 0.3 ml. The apparatus for the reaction can be seen in Figure 2 below.

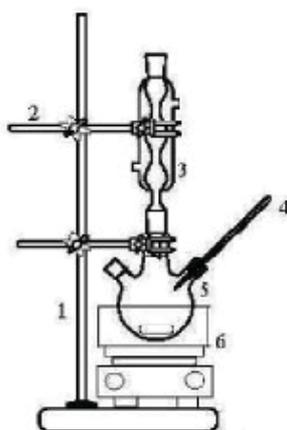


Figure 2: The apparatus for biodiesel reaction

The content of Fatty Acid Methyl Esters (FAME) produced in this study is measured using Gas Chromatography-Mass Spectroscopy (GC-MS). Beside that, the yield of biodiesel produced is measured also.

### 3. RESULTS AND DISCUSSION

The first result that will be discussed in this study is the yield of biodiesel produced from esterification-transesterification reaction method compared to transesterification reaction method. The result is shown in Figure 3 below.

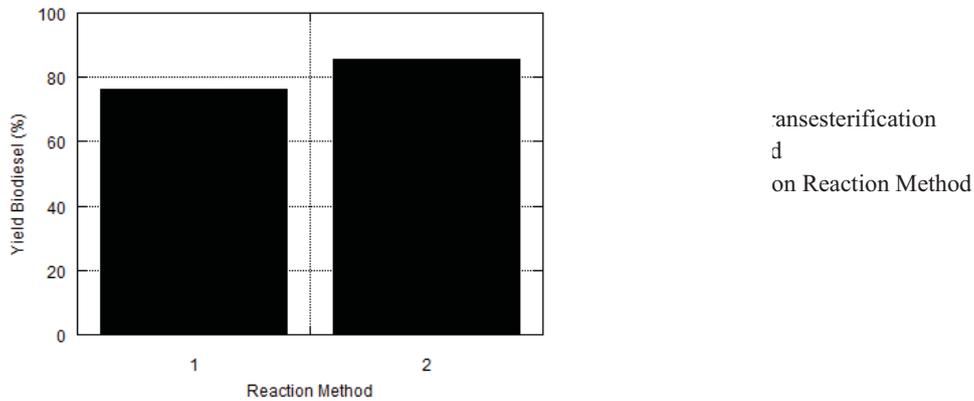


Figure 3: Yield biodiesel between esterification-transesterification reaction and transesterification reaction

Figure 3 show the comparison between two kind of reaction used in biodiesel production. The first bar is esterification-transesterification reaction method and the second bar is transesterification reaction method. Esterification-transesterification reaction method produce the yield of biodiesel about 76.43% compared to the lipid content before reaction. The second reaction method (transesterification) can produce biodiesel about 85.5% of biodiesel produced. From that result, we can conclude that transesterification reaction method may give higher biodiesel yield than esterification-transesterification reaction method. Beside that, transesterification reaction method provide shorter biodiesel production time.

The second result from this study is composition of fatty acid methyl ester. The composition of methyl esters from biodiesel are different depend on the method used. The composition of methyl esters from that two methods is shown in Table 1 and Table 2 below. Table 1 is composition of methyl esters from esterification-transesterification reaction method and Table 2 is composition of methyl esters from transesterification reaction method.

Table 1: Composition of methyl esters from esterification-transesterification reaction method

Composition	Amount (%)
Myristic acid methyl ester	1.55
Palmitic acid methyl ester	57.75
Stearic acid methyl ester	4.22
Oleic acid methyl ester	33.26
Linoleic acid methyl ester	3.22

Table 2: Composition of methyl esters from esterification-transesterification reaction method

Composition	Amount (%)
Methyl 12-methyltetradecanoate	0.76
Palmitic acid methyl ester	56.34
Palmitoleic acid methyl ester	1.55
9,12-hexadecadienoic acid methyl ester	2.95
4,7,10-hexadecatrienoic acid methyl ester	1.22
Heptadecanoic acid methyl ester	0.7
7-hexadecenoic acid methyl ester	1.90
Stearic acid methyl ester	3.21
Linoleic acid methyl ester	25.79
9,12,15-octadecatrienoic acid methyl ester	1.88
11-octadecenoic acid methyl ester	3.72

The comparison of methyl ester composition from esterification-transesterification reaction method and transesterification method can be seen in Table 3 below.

Table 3: Comparison of fatty acid composition from two transesterification methods

Composition	Amount (%)	
	First Method	Second Method
Myristic acid methyl ester	1.55	-
Methyl 12-methyltetradecanoate	-	0.76
Palmitic acid methyl ester	<b>57.75</b>	<b>56.34</b>
Palmitoleic acid methyl ester	-	1.55
9,12-hexadecadienoic acid methyl ester	-	2.95
4,7,10-hexadecatrienoic acid methyl ester	-	1.22
Heptadecanoic acid methyl ester	-	0.7
7-hexadecenoic acid methyl ester	-	1.90
Stearic acid methyl ester	4.22	3.21
Oleic acid methyl ester	33.26	-
Linoleic acid methyl ester	3.22	25.79
Linolenic acid methyl ester	-	1.88
11-octadecenoic acid methyl ester	-	3.72

From Table 4 we can see that palmitic acid methyl ester is the biggest amount of fatty acid methyl ester from biodiesel produced in two different methods. Palmitic acid is main fatty acid in *Chlorophyceae* microalgae [9]. From those fatty acid methyl esters composition, only myristic acid methyl ester, palmitic acid methyl ester, heptadecanoic acid methyl ester, and stearic acid methyl ester included into saturated methyl ester. So, it can be calculated that the esterification-transesterification reaction method contain 63.52% saturated methyl ester and the transesterification reaction method contain 60.25% saturated methyl ester. Shortly, the comparison of saturated fatty acid methyl ester composition in biodiesel produced from those two methods can be seen in Figure 4 below.

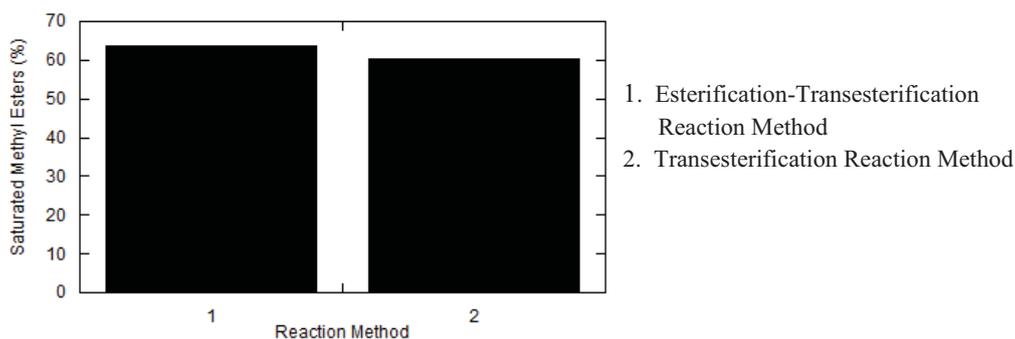


Figure 4: Saturated methyl esters composition between esterification-transesterification reaction and transesterification reaction

Figure 4 is the comparison between two kind of reaction used in biodiesel production. The first bar is esterification-transesterification reaction method and the second bar is transesterification reaction method. Esterification-transesterification reaction method produce the saturated methyl esters about 63.52%. The second reaction method contain saturated methyl esters about 60.25%. The higher saturated methyl esters composition indicates higher oxidative stability. So, we can conclude that esterification-transesterification method provides higher oxidative stability [9].

#### 4. CONCLUSION

From this study, we can conclude that esterification-transesterification reaction method needs more time compared to transesterification reaction method. Esterification-transesterification reaction method produces lower yield of biodiesel but has higher oxidative stability compared to the other reaction method. Higher oxidative stability comes from higher number of saturated methyl ester content in biodiesel.

## 5. REFERENCE

- [1] Maruyama, I., Nakao, T., Shigeno, I., Ando, T., Hirayama, K. (1997). *Application of Unicellular Algae Chlorella vulgaris for the Mass-Culture of Marine Rotifer Brachionus*. *Hydrobiologia*. 358:133-138.
- [2] Mata, T.M., Martins, A., Caetano, N.S. (2010) *Microalgae for Biodiesel Production and Other Applications: A Review*. *Renewable and Sustainable Energy Review* Vol 14 pp: 217-232.
- [3] Dragone, G. (2010). *Third Generation Biofuels from Microalgae*. *Technology and Education Topics in Applied Microbiology and Microbial Biotechnology*. Institute for Biotechnology and Bioengineering, Centre of Biological Engineering, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.
- [4] Miao, X. & Wu, Q., (2006). *Biodiesel production from heterotrophic microalgal oil*. *Bioresource Tecnology*, 97, pp.841- 846. [5] Veillette, M. et al., (2011). *Microalgae-based Oil for Biodiesel Production*. *Energy*, pp.787-790.
- [6] Johnson, M.B., & Wen, Z. (2009). *Production of Biodiesel Fuel from the Microalga Schizochytrium limacinum by Direct Transesterification of Algal Biomass*. *Energy Fuels*. 23. pp. 5179-5183.
- [7] Xu, R & Mi, Y. (2011). *Simplifying the Process of Microalgal Biodiesel Production Through In Situ Transesterification Technology*. *J Am Oil Chem Soc*. 88. pp. 91-99.
- [8] Ehimen, E.A., Sun, Z.F., Carrington, C.G. (2010). *Variables Affecting the In Situ Transesterification of Microalgal Lipids*. *Fuels*. pp. 677-683.
- [9] Kumar, P., Suseela, M.R. & Toppo, K., 2011. *Physico-Chemical Characterization of Algal oil : a Potential Biofuel*. *Applied Sciences*, 2(3), pp.493-497.

## Simulation of Natural Gas Pipeline for Leak Detection

Mochammad Haryo Pramantyo<sup>a</sup>, Asep Handaya Saputra<sup>b</sup>

<sup>a</sup>Department of Chemical Engineering - Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel : (021) 7270011 ext 51. Fax : (021) 7270077  
E-mail : haryo.pramantyo@gmail.com

<sup>b</sup>Department of Chemical Engineering - Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel : (021) 7270011 ext 51. Fax : (021) 7270077  
E-mail : asephandaya@gmail.com

### ABSTRACT

*Minimizing the natural gas leak along the pipeline is the primary key for pipeline network reliability. There are various methods for the detection of leaks. These methods have been established, but its use is very dependent on the system of each pipeline network. The method used in this study is based on the material balance in some segments of pipeline. The calculation will be performed by pipeline software to identify the amount of gas leaks. In order to confirm the gas leaks, the leak detection method were conducted with some variation in size and location of the leak. The best method considering the response time and low false alarm will be evaluated and selected.*

### Keywords:

*Gas leak, leak detection, pipeline*

### 1. INTRODUCTION

The use of natural gas in Indonesia each year is increasing. Based on data from the year of 2010, the energy consumption for natural gas in industry ranked second or 28.86% from total industrial energy consumption (Syahrial, 2011). Natural gas reserves in Indonesia based on data from the Department of Energy and Mineral Resources in 2010 amounted to 152.89 TCF (Department ESDM, 2010). With the high oil prices, then it is the time for the industry to be able to fully utilize the use of natural gas for fulfilling the energy demand.

Utilization of natural gas is not without obstacles. The unequal distribution of development in Indonesia with the majority of the natural gas reserves away from the center of industry (Figure 1), is a challenge that must be faced. In order to cope with these conditions, the development of infrastructure to support the distribution of natural gas should be increased. One tangible manifestation of infrastructure development, there is now a transmission pipeline linking South Sumatra West.

This transmission pipelines are now in operation with a total capacity of about  $\pm 600$  MMSCFD, given the importance of these networks will require reliable protection system. One thing that is avoided in the operation of the pipeline is a leak. The impact of natural gas leaks other than the economic impact can also cause loss of life and environmental damage. Although natural gas is released into the atmosphere does not burn, the impact caused by methane emissions 21 times greater than CO<sub>2</sub> (Speight, 2007).

In Canada cause of gas leak (Alberta EUB Report, 2006) such as construction damage, earth movement, corrosion, joint failure, overpressure, and damage by others/<sup>3rd</sup> party. Total natural gas leak that occurred was 1.326 cases with a total length of 235.592 km pipeline. In Europe during the year 1970-2007 have been cases of leakage of 1.172 cases with the leakage frequency of 0.11 per 1000 km (EGIG, 2008).

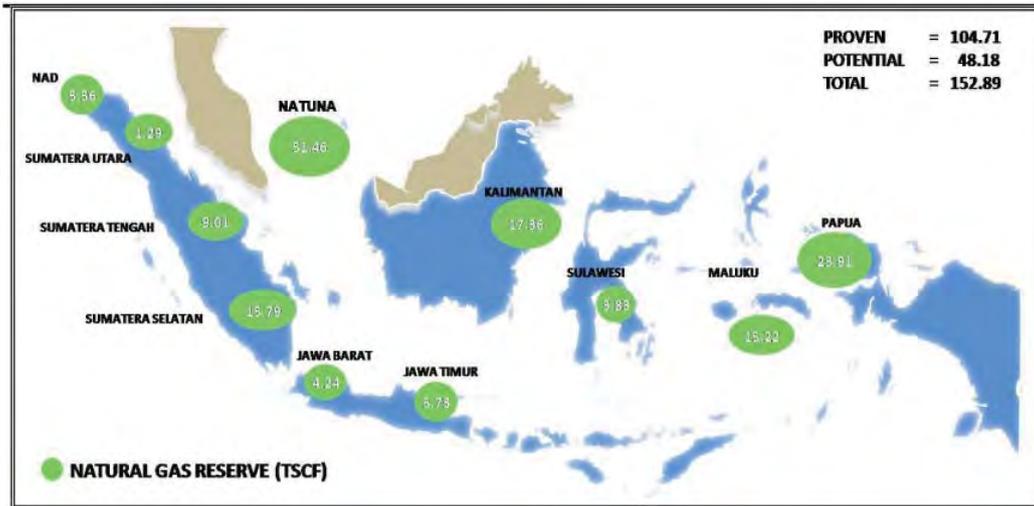


Figure 1: Natural Gas Resources in Indonesia

In order to detect the gas leak, there must be a system that can identify the event of a pipeline leak. Several kinds of methods have been invented and implemented throughout the piping network in the world. The available methods can be categorized as a hardware-based methods, software-based method, and non-technical method (Pal-Stevan Murfay, 2012). In this paper focused on software-based method by mass balance and pressure monitoring. The two methods were chosen because of low cost and can be applied to existing transmission pipelines.

## 2. MATERIALS AND METHOD

In this study, simulated leak in the pipe is done by using the PIPELINE STUDIO. PIPELINE STUDIO will calculate operating conditions that occur per time step with a leak at the pipe wall that has a different size and location. The results of the simulation PIPELINE STUDIO will then be analyzed by the Mass Balance Method and Pressure Monitoring.

### 2.1 Mass Balance Methods

In the steady state condition, the mass entry ( $M_{in}$ ) of pipes that do not leak will be balanced by the mass exit of the pipe ( $M_{out}$ ). In general, the mass difference in and out should be balanced by changes in inventory in the ( $M_{pipe}$ ), so:

$$M_{in} - M_{out} = \frac{dM_{pipe}}{dt} \quad (1)$$

If there is no leak, theoretically mass in the pipe depends on the result of multiplying the volume density of the product pipeline. Which are both a function of temperature and pressure, and density is also a function of the composition of the product. If there is an imbalance in the mass balance is calculated, the amount of mass that is leaking can be described as:

$$\Delta M_{leak} = \Delta M_{in} - \Delta M_{out} - \Delta M_{pipe} \quad (2)$$

### 2.2 Pressure Monitoring

If a leak occurs, the pressure in the pipeline will fall by an amount  $\Delta P$  (Geiger, 2006). With the use of pressure transmitter that has been installed, using statistical analysis of the presence of a leak is declared when the mean value of the pressure measurements decreased.

### 2.3 Pipeline System

The pipeline that used for this paper is real life 196 km long pipeline and has a circular uniform outside diameter of 36 inch and inside diameter of 34.75 inch. The pipeline only have pressure transmitters and flow meters at the upstream and downstream of the pipe. For the simulation, there are three different locations for the leak which is at 49 km, 98 km, and 147 km from the upstream. The size of the leak that simulated are 1 inch and 5 inch at each of the location. The composition of the natural gas is given in Tables 1. The flow through this pipeline is 400 MMSCFD.

Table 1: Natural Gas Composition

Component	Mole Percentage
Methane	91.514
Ethane	2.8313
Propane	0.7511
i-Butane	0.2098
n-Butane	0.1966
i-Pentane	0.0933
n-Pentane	0.0545
n-Hexane	0.1074
Nitrogen	0.2293
Carbon Dioxide	4.0084
Water	0.0039
Sulfur	0.0003

### 3. RESULT AND DISCUSSION

The pipeline model is first run in steady state condition, where the simulated result are compared to the real data from the instrumentation. After the model in PIPELINE STUDIO give result exactly the same as the real data, then the simulations are divided into six categories:

- The leak had a diameter of 1 inch and at 49 km from the upstream.
- The leak had a diameter of 5 inch and at 49 km from the upstream.
- The leak had a diameter of 1 inch and at 98 km from the upstream.
- The leak had a diameter of 5 inch and at 98 km from the upstream.
- The leak had a diameter of 1 inch and at 147 km from the upstream.
- The leak had a diameter of 5 inch and at 147 km from the upstream.

From the result of the simulation, pressure and the flow then to be counted using equation (2) for mass balance and a linear statistic approach for the pressure monitoring. The simulation time step is minutely with interval until 1440 minutes. The leak are assumed to be happened at time step 675 until 1440.

Figures 2 to 4 show the pressure profile for diameter of leak 1 inch at different location. From the graphic we can see that the leak happen at the vertical line and in an hour it change the pressure 3 psia. This simulation are based on that there is no change in flow at the inlet and outlet which is hold constant at 400 MMSCFD. With the same flow, Figures 5 to 7 show the pressure profile for diameter of leak 5 inch. There is significance change in pressure drop, for an hour it is already drop from 943 psia to 878 psia or the pressure drop is 65 psia/hour. From Figures 2 to 7 we also can see that the pressure drop happen at the closes pressure transmitter first.

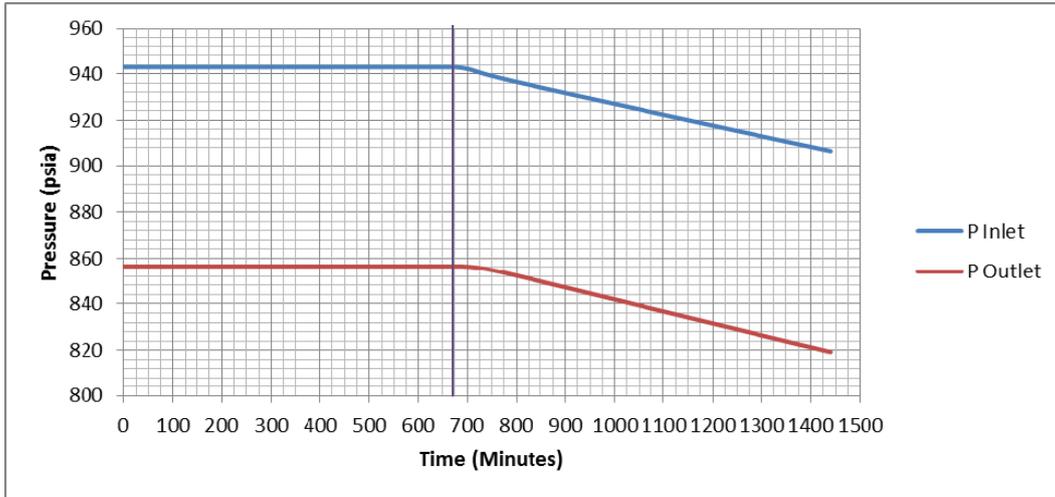


Figure 2: Pressure Profile for 1 inch leak at 49 km

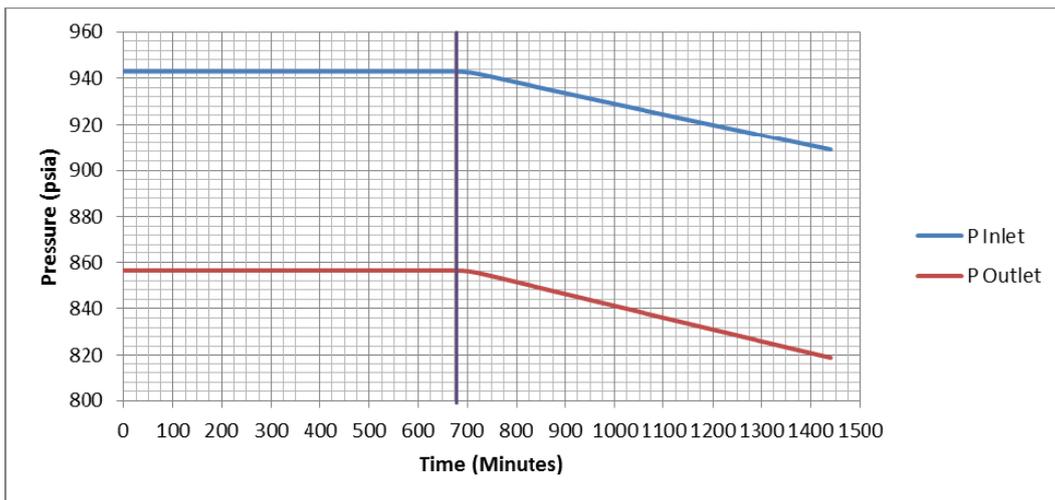


Figure 3: Pressure Profile for 1 inch leak at 98 km

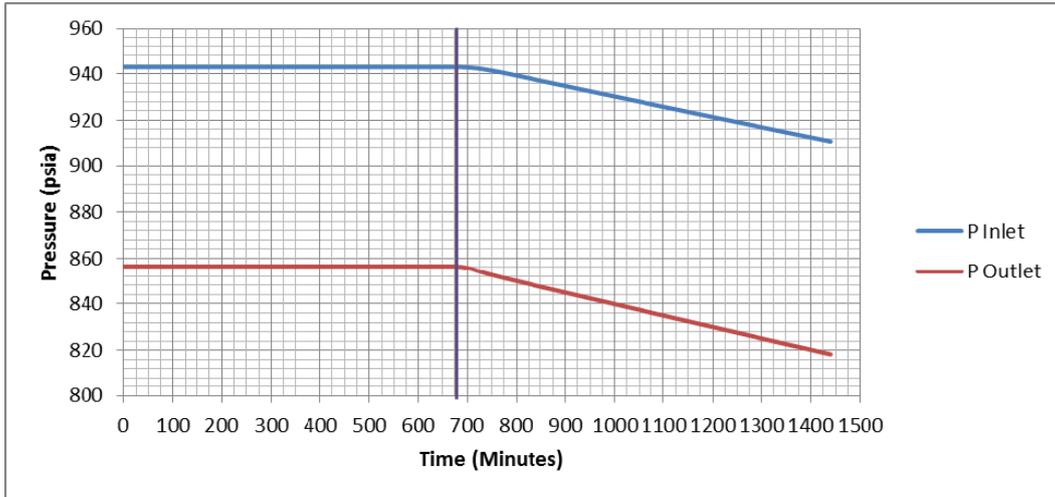


Figure 4: Pressure Profile for 1 inch leak at 147 km

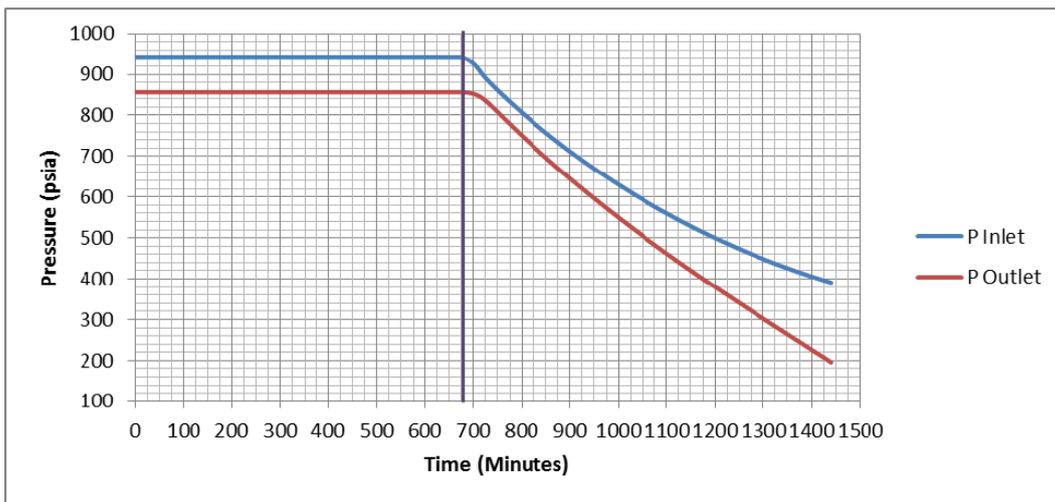


Figure 5: Pressure Profile for 5 inch leak at 49 km

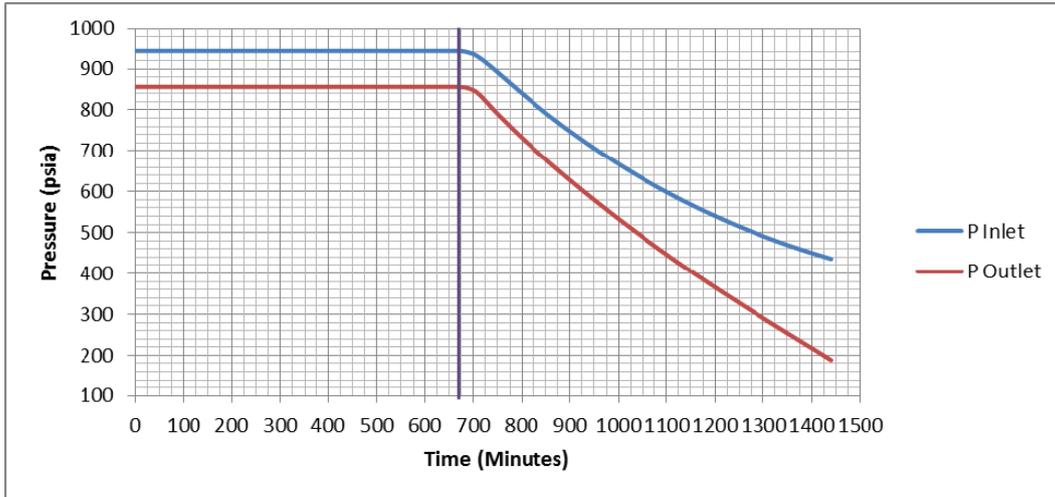


Figure 6: Pressure Profile for 5 inch leak at 98 km

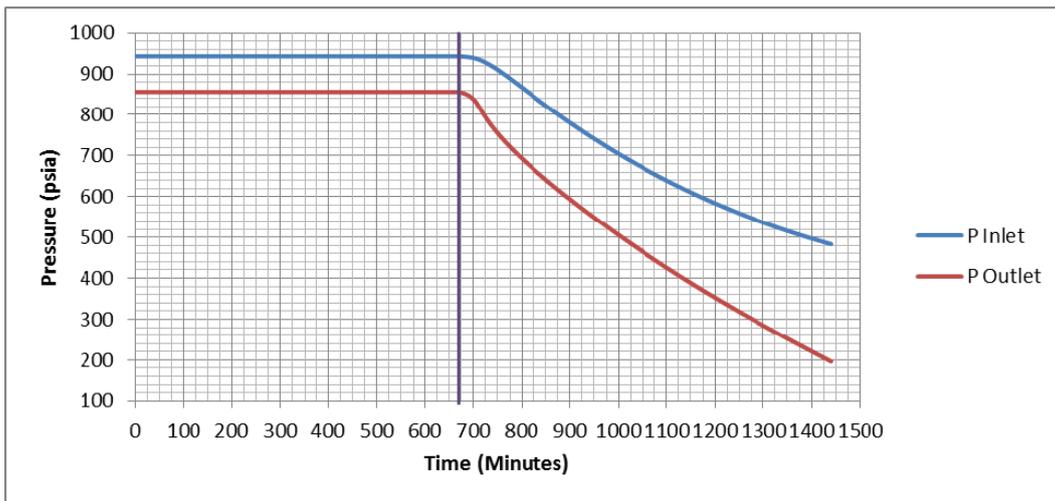


Figure 7: Pressure Profile for 5 inch leak at 147 km

Table 2: Mass Balance Estimated Leak

Leak Location (kilometer)	Leak Size (inch)	Magnitude of leak simulated (MMSCFH)	Estimated Leak Magnitude (MMSCFH)	% Error	Delay in Leak detection time (Minutes)
49	1	1.06	0.87	-17.82	30
49	5	22.33	19.51	-12.62	15
98	1	1.04	0.86	-17.32	30
98	5	21.84	19.22	-12.00	15
147	1	1.01	0.84	-17.12	30
147	5	20.50	18.29	-10.77	15

Using equation (2) the estimated leak magnitude are counted and compared to the simulated leak at each location and size. We can see that with the mass balance methods the average error for the leak magnitude is -14.61%. From the simulation the

change in the pipeline inventory are the only indication for the leak, it is happen because there is no change in flow at the inlet and outlet of the pipeline systems.

#### 4. CONCLUSION

In this study, it was found that the pressure point analysis is not recommended for the leakage smaller than 1 inch. The change of the pressure is small ( 3 psia/hour) which is under normal operation the change of the pressure barely noticed because at transient state it is normal to have such a change. But to be more discussed is the effect of location of the pressure transmitter. This study is based on the real condition of the pipeline systems were the pressure transmitter only attached at the inlet and outlet of the pipe (196 km in distance). With this method the location of the leak can be estimated from the pressure transmitter that change first, then the group of pipeline patrol can be sent from the closes location. Although not given the exact location of the leak but it is good enough for the pipeline patrol to reduce its search range..

The mass balance methods were quite accurate in terms of giving the estimated leak size and leak detection time. But with this method the location of the leak can't be determined. Further study is needed to combine this two methods and given the better leak detection methods.

#### REFERENCES

- [1] ADEC. "Technical Review of Leak Detection Technologies". Alaska Department of Enviromental Conservation,1999.
- [2] Geiger, Gerhard. "State-of-the-Art in Leak Detection and Localisation". Germany : University of Applied Sciences Gelsenkirchen, 2006
- [3] Murvay, Pal-Stefan., and Ioan Silea. "A Survey on Gas Leak Detection and Localization Techniques". Journal of Loss Prevention in the Process Industries, 2012.
- [4] Speight, James G. *Natural Gas : A Basic Handbook*. Houston : Gulf Publishing Company, 2007.
- [5] Syahrial,Ego. "Handbook of Energy & Economic Statistics of Indonesia". Jakarta, 2011
- [6] Department ESDM, "Statistik Gas Bumi". Jakarta, 2011.

# Distillation Column Control using Multiple Model Predictive Control Based on Representative Model Predictive Control Method

A. Wahid<sup>a</sup>, A. Ahmad<sup>b</sup> and V. Cynthia<sup>c</sup>

a. Department of Chemical Engineering, University of Indonesia, Depok.  
Email author: wahid@che.ui.edu

b. Department of Chemical Engineering, Universiti Teknologi Malaysia, Johor  
Email author: arshad@fkkksa.utm.my

c. Department of Chemical Engineering, University of Indonesia, Depok.  
Email author: vaniacynthia@gmail.com

## ABSTRACT

A Multiple Model Predictive Control (MMPC) is now widely used for controlling nonlinear multivariable process. The MMPC consists of some linear MPCs or called local MPCs. Representative Model Predictive Control (RMPC) can be used for determining some models which are able to represent whole operating point. In this paper, the application of RMPC on proposing some models for MMPC is described. The result shows improvement of controller's performance than the single MPC. For the change of bottom composition set point from 0.01 to 0.05 the use of MPC2.3.5 is recommended, and for the 0.01 to 0.1 change, the MPC4.5.8 is recommended.

## Keywords

*Representative Model Predictive Control (RMPC), Multi Model Predictive Control (MMPC), distillation column control, Column A*

## 1. INTRODUCTION

Distillation column is the most common unit operation in the chemical industry. It is an important unit for separation process in chemical industries [1]. A distillation column especially used to get products with highest purity, beside to separate multicomponent mixtures such as crude oil. To separate crude oil used an atmospheric distillation column, firstly. Furthermore, distillate products (up products of the atmospheric distillation column) separated again using a hydrocarbon distillation column such as a depropanizer or a debutanizer to get an LPG product. Whereas, the bottom products (residue) separated by a vacuum distillation column. Distillation systems also used to separate a mixture from non-mixture substances and for materials that sensitive with temperature, such as aromatic substances in atsiri oil.

For many years, dynamics and control of distillation processes have become one of the important issues among process system engineers and researchers. The distillation process itself is a nonlinear multiple-input multiple-output system with strong inherent interactions, and significantly sensitive to exogenous disturbances.<sup>[2]</sup>

Nonlinear MPC (NMPC) has been developed to overcome distillation column control problems. However, the scope of NMPC application is typically much smaller than that of linear MPC applications. This is likely due to the computational and modeling complexity of NMPC algorithms<sup>[3, 4]</sup>. Multiple MPC is the alternative solution to solve this problem. MMPC consists of some linear models that represent the whole operating point of CV (controlled variable). This structure is based on the identification of different models in order to optimize the prediction on each step involved in the computation of the cost function<sup>[5]</sup>. The utilization of MMPC algorithm needs the identification of local linear models which represent the whole operating point of CV<sup>[6]</sup>.

Those local linear models are called local MPCs or Representative MPC (RMPC). The research about RMPC algorithm application has been done by using ten models (local MPCs). The best three local MPCs are proposed to be used in MMPC. A caution of choosing the local MPCs is needed because of the distinctness of each local MPC's response<sup>[7]</sup>. In this paper, the application of RMPC on proposing some models for MMPC is described.

## 2. DISTILLATION COLUMN MODEL

Distillation column model to be used is based on fundamental model names Column A which is developed by Skogestad. Column A has 40 theoretical stages and separates binary mixture with relative volatility 1.5 to products with 99% purity. The dynamic model of distillation column uses the following assumptions: binary mixture; constant pressure; constant relative volatility; equilibrium on all stages; total condenser; constant molar flows; no vapor holdup; linearized liquid dynamics, but effect of vapor flow ("K2"-effect) is included. These assumptions may seem restrictive, but they capture the main effects important for dynamics and control (except for the assumption about constant pressure)<sup>[1]</sup>.

Manipulated variables are reflux flow and boil up flow (LV-configuration). Controlled variables are overhead product mole fraction ( $y_D$ ) and bottom product mole fraction ( $x_B$ ). In the whole experiment the top concentration will be measured and used in state estimation but the controller will not attempt to regulate it directly. It will vary as needed to regulate the bottom concentration. A typical two product distillation column is shown in Figure 1.

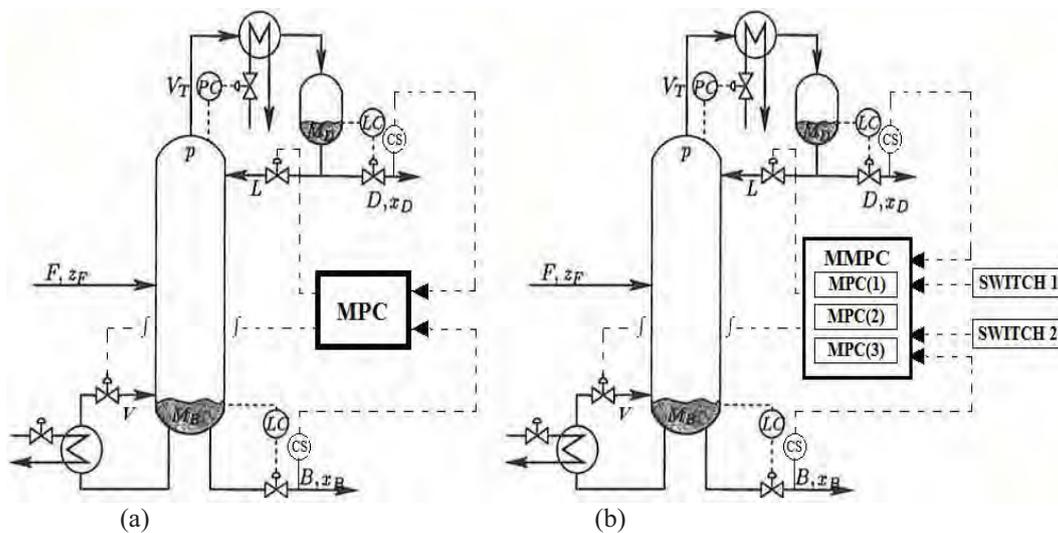


Figure 1. Typical simple distillation column controlled with LV-configuration using: (a) MPC and (b) MMPC

## 3. SYSTEM IDENTIFICATION

System identification is done by pulsing each controller output at each level of operation. This affects both measured process variables. System identification is done by increasing reflux flow  $L$  with constant boil up flow  $V$  and increasing  $V$  with constant  $L$ . Each controller output to measured process variable pair is a sub-process. In this experiment there are four sub-processes:  $L$  to  $y_D$ ,  $L$  to  $x_B$ ,  $V$  to  $y_D$ , and  $V$  to  $x_B$ .

This experiment yields FOPDT model parameters ( $K_p, \tau_p$ , and  $\theta_p$ ) as shown in Table 1. The FOPDT model parameters are then used in the non-adaptive DMC tuning equations<sup>[8]</sup> for obtaining MPC tuning parameters as shown in Table 2.

Table 1. FOPDT Model Parameters

	L to y1	L to y2	V to y1	V to y2
Process variable values	20 %	20 %	20 %	20 %
FOPDT model fit parameters				
$K_p$	0.0183	0.9419	-0.8606	-0.0155
$\tau_p$	4.2691	7.1635	4.8275	1.8804
$\theta_p$	1.2265	10.5241	9.7691	1.0350
Process variable values	30 %	30 %	30 %	30 %
FOPDT model fit parameters				
$K_p$	0.0123	0.7499	-0.6736	-0.0104
$\tau_p$	2.9506	5.2838	3.3369	1.1593
$\theta_p$	1.2118	8.4448	7.3528	1.1055

	L to y1	L to y2	V to y1	V to y2
Process variable values	50 %	50 %	50 %	50 %
FOPDT model fit parameters				
$K_p$	0.0074	0.5322	-0.4692	-0.0062
$\tau_p$	1.9001	3.6507	2.1219	0.6803
$\theta_p$	1.1546	6.5375	5.1468	1.1361
Process variable values	70 %	70 %	70 %	70 %
FOPDT model fit parameters				
$K_p$	0.0053	0.4124	-0.3599	-0.0045
$\tau_p$	1.5225	2.9019	1.6706	0.5913
$\theta_p$	1.1111	5.6263	3.9917	1.1183

Table 2: MPC Tuning Parameters

Tuning Parameter	Process variable values			
	20 %	30 %	50 %	70 %
Ts	0.72	0.53	0.36	0.29
P	66	50	36	29
M	26	20	15	13

#### 4. SINGLE MPC FOR NONLINEAR PROCESS

To obtain the local MPCs to be used in MMPC, firstly Column A is controlled by single MPC. It uses one local model for the whole operating points. There are two schemes of bottom concentration set point changes. First is moderate set point changes i.e. 0.01 to 0.05. In this scheme, PI controller can be used although gives unstable response when the controlled variable reaches 0.05. This scheme will be called scenario 1 for the rest of the paper. Local MPCs are chosen based on their Integral Absolute Error (IAE) values which are less than PI controller's IAE value, 0.4437. The response of  $x_B$  given by PI controller is shown in Figure 2.

The second set point changes is from 0.01 to 0.1 where PI controller can not be used anymore. This scheme will be called scenario 2 for the rest of the paper. Because PI controller can not be used as comparison basis, the five best local MPCs, with the least IAE, will be chosen.

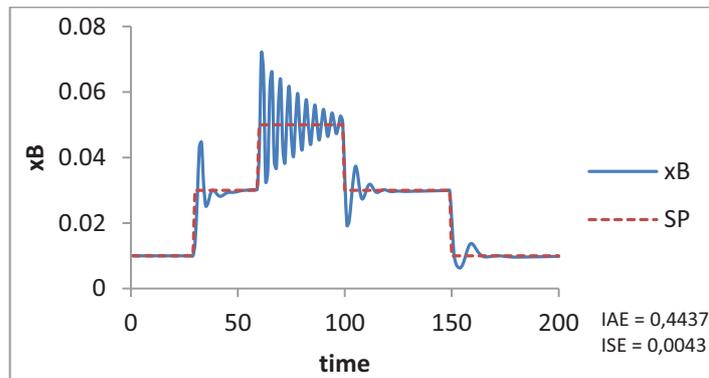


Figure 2: PI Controller Performance on Scenario 1

Ten local models are tested, they are in the operating point of 0.01 (called as MPC1) to 0.1 (called as MPC10). Column A controlled by single MPC uses MPC tuning parameters as shown in Table 2 with an addition of one set of parameters which actually yields less IAE values in response than IAE given by parameters of non-adaptive DMC tuning. The parameter set is  $T_s=0.1$ ;  $P=12$ ;  $M=2$ . By using this set of parameters, 9 out of 10 models give less IAE values than others, except for MPC1.

Table 3 and Table 4 show IAE values for each single MPC in each parameter for scenario 1 and scenario 2 respectively. For scenario 1, local MPCs chosen for MMPC are MPC2, MPC3, MPC4, MPC5, and MPC6. For scenario 2, MPC4, MPC5, MPC6, MPC7, and MPC8 are chosen. The differences of the best model between the two scenarios show that single MPC represents its operation range.

Table .: Integral Absolute Error of Single MPC at Scenario 1

Controller	Ts = 0.72 P = 66 M = 26	Ts = 0.53 P = 50 M = 20	Ts = 0.36 P = 36 M = 15	Ts = 0.29 P = 29 M = 13	Ts = 0.1 P = 12 M = 2
PI	0.4437				
MPC1	0.9587	0.8361	0.7920	0.7029	1.2259
MPC2	0.4415	0.3822	0.3578	0.3522	0.3228
MPC3	0.4209	0.3709	0.3441	0.3440	0.2947
MPC4	0.4428	0.3974	0.3700	0.3659	0.3193
MPC5	0.4878	0.4434	0.4085	0.4013	0.3595
MPC6	0.5434	0.5014	0.4629	0.4523	0.4151
MPC7	0.5974	0.5544	0.5167	0.5026	0.4644
MPC8	0.6461	0.6010	0.5648	0.5473	0.5073
MPC9	0.6887	0.6408	0.6067	0.5849	0.5438
MPC10	0.7265	0.6747	0.6436	0.6182	0.5761

Table .: Integral Absolute Error of Single MPC at Scenario 2

Controller	Ts = 0.72 P = 66 M = 26	Ts = 0.53 P = 50 M = 20	Ts = 0.36 P = 36 M = 15	Ts = 0.29 P = 29 M = 13	Ts = 0.1 P = 12 M = 2
PI	Not converged				
MPC1	3.3701	3.3116	2.8399	2.7446	4.9612
MPC2	1.4079	1.2873	1.1723	1.1419	1.0667
MPC3	1.0049	0.9085	0.8492	0.8487	0.7456
MPC4	0.8859	0.8366	0.7760	0.7675	0.6536
MPC5	0.8692	0.8178	0.7511	0.7441	0.6176
MPC6	0.8700	0.8132	0.7425	0.7362	0.6114
MPC7	0.8857	0.8309	0.7487	0.7394	0.6250
MPC8	0.9267	0.8658	0.7729	0.7578	0.6565
MPC9	0.9931	0.9134	0.8251	0.7987	0.7026
MPC10	1.0637	0.9609	0.8847	0.8481	0.7536

## 5. MULTIPLE MPC FOR NONLINEAR PROCESS

The models used in MMPC are the local MPCs proposed in the section above. The two scenarios of set point changes will be tested in this experiment. There are 5 local MPCs for each scenario. They will be combined each other to obtain MMPC consists of only two and three models. The more models we use in MMPC do not guarantee the better response. That is because each model has an error. The utilization of many models yields greater error. Besides, MMPC with too many models is not practical because of the difficulty in handling those models.

We also have to consider the operating range where each model will perform. How we switch one model to another will affect the response. It shows that setting the right models in the right operating range is important.

Combination of MPC2, MPC3, and MPC5 (MPC2.3.5) gives the best response for scenario 1 with IAE 0.2296 and ISE 0.0015. This response is obtained at switch specification 0.02 and 0.04. It means when measured CV values < 0.02, system is controlled by MPC2, when  $0.02 \leq CV < 0.04$ , system is controlled by MPC3, and when  $CV \geq 0.04$ , system is controlled by MPC5.

Figure 3 shows that MPC2.3.5 has a combined characteristic of single MPCs which performs in their regions. At the low region, MMPC has MPC2 characteristic which is better than MPC3 and MPC5. At the middle region, MMPC gives response like MPC3 and at the high region it is like MPC5.

For the scenario 2, MPC4.5.8 gives the best response with IAE 0.5528 and ISE 0.0076 which is obtained at switch specification 0.02 and 0.09. Same as those on scenario 1, here are the switches from one model to another based on the changes of measured CV. Comparison between single MPC and MMPC for scenario 2 is shown in Figure 4.

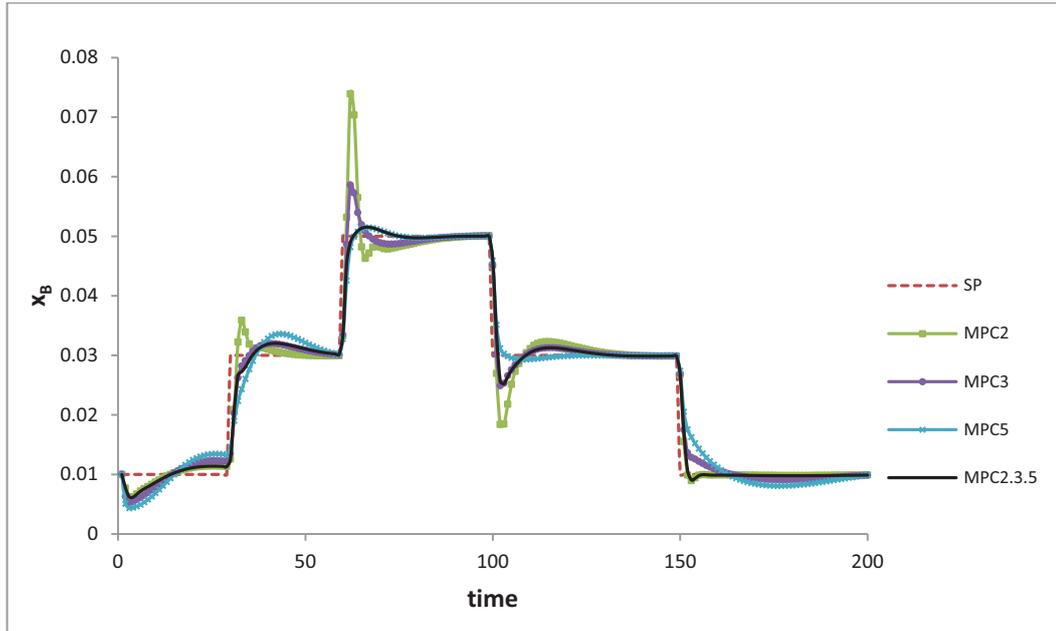


Figure 3: Comparison of MPC2, MPC3, MPC5, and MPC2.3.5

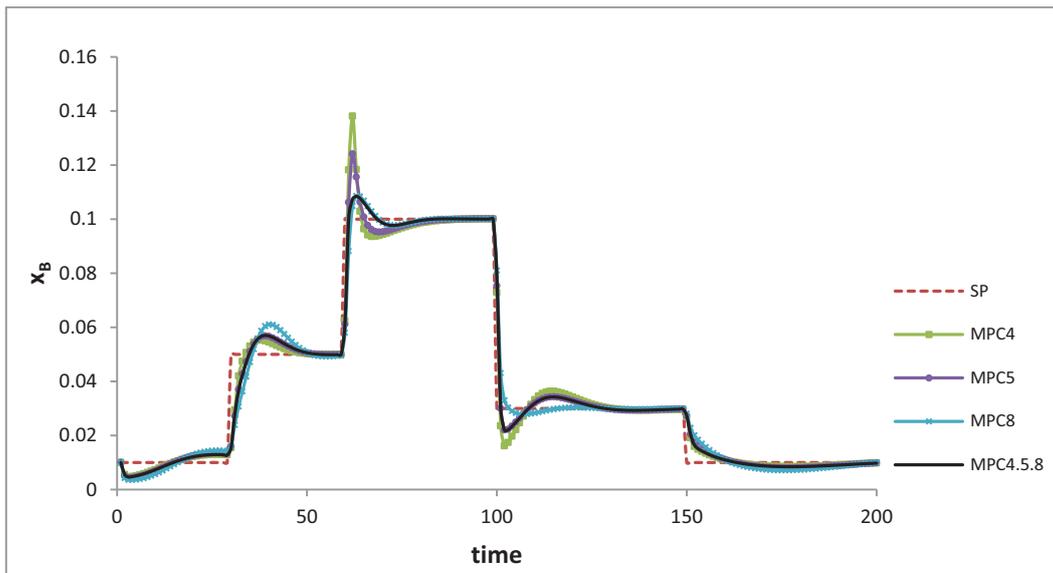


Figure 4: Comparison of MPC4, MPC5, MPC8, and MPC4.5.8

What we have to consider is the combination of local MPCs must be able to cover the overall set point changes. To obtain the best MMPC, it must consist of local MPCs operating at the lowest, middle, and highest region of the overall set point changes. And then, determining the right switch specification is by observing each local MPC's response then deciding the operating region where it performs best.

Eventhough determining the best MMPC, models combination and switch specifications, needs a careful experiment, in average MMPCs give better response than single MPC. Table 5 shows comparison of PI controller's, MPC's, and MMPC's IAE and ISEfor scenario 1 and scenario 2.

One of the implementation of MMPC in industry is propane/butane splitter<sup>[6]</sup>. The controlled outputs are the temperature at the first stage of the top section of the distillation column and the percentage of propane in the bottom stream. The manipulated inputs are the flow rate of hot oil to the reboiler and the reflux flow rate to the top of the column. The feed flow rate and the temperature of the hot oil stream are measured disturbances to the controller. A conventional MPC controller based on a single

linear model for the output prediction had been in operation for several years showing a poor performance. Output  $y_1$  was maintained satisfactorily inside its range, but the width of the reference range corresponding to this output had to be kept larger than desired. For output  $y_2$ ; the closed-loop response was not satisfactory since this output remained outside its reference range for most of the time in which the system was observed. The MMPC presented a performance significantly better than the conventional single MPC controller. Output  $y_1$  only needs narrower reference range and output  $y_2$  remained inside its reference range. Step change in each CV's set point yields good responses too. The use of MMPC has been operating successfully for more than a year in the refinery of Cubatão, Brazil.

Table 5: Comparison of PI controller's, MPC's, and MMPC's IAE and ISE

Scenario 1			Scenario 2		
Controller	IAE	ISE	Controller	IAE	ISE
PI	0.4437		PI	not converged	
MPC3	0.2947	0.0018	MPC6	0.6114	0.0083
MPC2.3.4	0.2309	0.0015	MPC4.5.6	0.5687	0.0078
MPC2.3.5	0.2296	0.0015	MPC4.5.7	0.557	0.0076
MPC2.3.6	0.2349	0.0015	MPC4.5.8	0.5528	0.0076
MPC2.4.5	0.2383	0.0016	MPC4.6.7	0.5608	0.008
MPC2.4.6	0.2402	0.0016	MPC4.6.8	0.5581	0.0081
MPC2.5.6	0.2457	0.0017	MPC4.7.8	0.5678	0.0078
MPC3.4.5	0.2759	0.0016	MPC5.6.7	0.5797	0.0078
MPC3.4.6	0.2774	0.0016	MPC5.6.8	0.5776	0.0078
MPC3.5.6	0.2792	0.0016	MPC5.7.8	0.5798	0.0079
MPC4.5.6	0.3166	0.0019	MPC6.7.8	0.5997	0.0084

## 6. CONCLUSION

The use of MMPC based on RMPC gives better response than single MPC. What you have to consider are the models' ability to cover the whole set point changes, the combination of the models used, and the switch specification of MMPC.

## REFERENCES

- [1] Skogestad, S., *Dynamics and Control of Distillation Columns: A Tutorial Introduction*. Trans IChemE, 1997. **75**.
- [2] Khaisongkram, W., Banjerdpongchai, D *Linear controller design and performance limits of binary distillation column subject to disturbances with bounds on magnitudes and rates of change*. Journal of Process Control, 2006. **16**: p. 845-854.
- [3] Camacho, E.F., Bordons, C., *Nonlinear Model Predictive Control: An Introductory Review*. 2007, University of Seville, Spain.
- [4] Qin, S.J., Badgwell, T.A., *A survey of industrial model predictive control technology*. Control Engineering Practice, 2002. **11**: p. 733-764.
- [5] Palma, F.D., Magni, L., *A multi-model structure for model predictive control*. Annual Reviews in Control, 2004. **28**: p. 47-52.
- [6] Porfirio, C.R., Neto, E. Almeida., Odloak, D., *Multi-model predictive control of an industrial C3/C4 splitter*. Control Engineering Practice, 2003. **11**: p. 765-779.
- [7] Wahid, A., Ahmad, A. *Representative Model Predictive Control*. in *Proceeding of the 11th International Conference on QIR (Quality in Research)*. 2009. Faculty of Engineering, University of Indonesia, Depok, Indonesia.
- [8] Dougherty, D., Cooper, D, *A practical multiple model adaptive strategy for multivariable model predictive control*. Control Engineering Practice, 2003. **11**: p. 649-664.

# Monitoring Consumption of Premium and Diesel Subsidized Fuel for Transportation Sector on Island of Bintan Using Control Card and Barcode Sticker

Dewi Tristantini\*, Muhammad Geri Yaniardi, Humala Paulus Halim

*\*Faculty of Engineering, University of Indonesia, Depok 16424*

*\*E-mail : detris@che.ui.ac.id*

## ABSTRACT

Government has spent much budget for fuel subsidy when it is compared with other component of state budget. Monitoring, tracking and control systems are required to record fuel purchases for each type of motor vehicle in distribution location per area. It will ultimately create a system of verification and validation the distribution of certain type of fuel based on Integrated Information Technology related to quota of subsidized fuel in each region. Distribution of fuel subsidy can be supervised properly by these systems. The concept of supervision and control of distribution are carried through method of recording daily transaction and tracking retail outlets through front end devices. It will be installed in each dispenser equipment of filling stations gasoline and diesel fuel with a computer data acquisition card reader and electronic data capture. By this way, it has result in total saving for gasoline 1 393 030 kL and for diesel fuel 32 557 616 kL with a total amount 33 950 646 kL in 2011. If state budget subsidy is assumed to be Rp2000,- per liter, total saving can reach Rp 67 901 000 000,-. When total saving by supervision and control of subsidized fuel is compared with amount of budget monitoring and control of Rp 23 467 000 000,- the system can save state budget amounting of Rp 44 434 000 000,-.

## Keyword

*Monitoring, Gas Stations, Control Card, Barcode Stickers, Bintan Island*

## 1. INTRODUCTION

Current demand of fuel subsidy in Indonesia is increasing which can be seen from budget of fuel subsidy every year. Government spends fund on fuel subsidy in accordance with amount of fuel subsidized consumed. This value is quite high compared with other components of expenditure especially for post-crisis of finance and economic in 1997-1998. Along with increase of fuel consumption and motor vehicle, they cause allocation of fuel subsidy increasing. The government has made various efforts in the form of limiting subsidy and saving fuel consumption. They are expected to be able to limit subsidy to certain groups. Hence, number of fuel subsidy in budget can reflect actual needs of subsidized object. Although arrangement of user of subsidized fuel is clear, but its application is not easy. There are still parties which do not have right to consume subsidized fuel such as large industries and rich people. In addition, subsidized fuel is smuggled out of country since fuel price in overseas is more expensive than fuel price in the country.

## 2. RESEARCH METHODOLOGY

### 2.1 Preliminary Data Collection and Implementation Preparation

Initial data processing and identification of problems are directed to mapping of main issues which have become cause of each problem that exists in distribution of subsidized fuel especially gasoline and diesel fuel in the following ways.

1. Initial data processing with statistical method related to realization of distribution of subsidized fuel typed gasoline and diesel fuel in entire territory of Indonesia. This data was taken from Regulatory Body of Oil and Gas Downstream (BPH Migas) to calculate distribution of allocation of subsidized fuel typed gasoline and diesel fuel in entire territory of Indonesia.
2. Indepth Interview with Provincial Government (Dipenda) at 33 provinces.
3. Indepth Interview with Central institution and relevant stakeholders such as Pertamina (Persero), DPP Hiswana Gas which represent network of filling stations, and Ministry of Finance related to verification of realization of distribution of subsidized fuel which is paid to Business Entity.
4. Preliminary data which is processed to conduct statistical analysis of use of gasoline and diesel fuel is recapitulation of number of motor vehicle in 2008 from National Police Headquarter and allocation of quota distribution of subsidized fuel typed gasoline and diesel fuel 2007-2008 from BPH Migas.

## 2.2 Data Processing of Motor Vehicles on Implementation Area

Initial data processing of motor vehicle in Province of Riau Region was conducted by Coordination Meeting between BPH Migas and Riau Islands Police related to data integration of motor vehicle. It was processed and synchronized into database of motor vehicle in system data center.

## 2.3 Arrangement of Strategic Plan of Development and Implementation System

In arranging strategic plan of development, a utilization of information systems of setting management and monitoring national consumed fuel will be implemented via some strategies.

1. Coordination meeting with 33 Provincial Government to seek input on social impact that will be resulted from implementing system in each province.
2. In depth interview related to mapping of the Management Information System (MIS) infrastructure especially MIS and its association with administration system and tax registration of motor vehicle (DIPENDA).
3. In depth interview was also conducted to map MIS infrastructure of online banking services and network infrastructure between bank and merchant.

## 2.4 Development of Technical Cooperation Inter-Institution and Socialization

Development of technical cooperation inter-institution is needed to integrate authority of relevant institution and synchronization of inter-system information through Limited Coordination Meeting and Overall Coordination Meeting to socialize Management Information System Regulation and Supervision of National Fuel Volume Usage.

1. BPH Migas – Ministry of Home Affair: Obtaining support of implementation of activities from Ministry of Home Affair to be forwarded to Provincial Government of Riau and ranks below it.
2. BPH Migas – National Police Headquarter: Acquisition support of implementation of activities from National Police Headquarter to be forwarded to Police Area and institutions under it.
3. BPH Migas - Provincial Government and DIPENDA of Riau: Acquisition of technical cooperation to integrate system and data.
4. BPH Migas-Bintan, Tanjungpinang, and Pemko Government: Technical Cooperation inter-institution to implement activities by survey, socialization and implementation of system.

## 2.5 Design of System Monitoring and Control of Subsidized Fuel for Transportation

Strategy to control the volume of subsidized fuel typed Gasoline and Diesel Fuel is conducted through five approaches.

1. Policy Approach Tool & Support: Data Center for Regulatory and Supervisory against National Fuel Usage.
2. Supervision Authority approach inherent in BPH Migas Authority against subsidized fuel distribution.  
 Tool & Support:  
 Monitoring System of Fuel Distribution at filling station, Integration System of Local Government - BPH Migas.
3. Approach To Data - Know Your Customer.  
 Tool & Support:  
 Integration System, Consumer Identification with Control Card Program.
4. Territorial Approach and System Integration - Local Government Development.  
 Tool & Support:  
 Arrangement of system utilization and development per territorial based Provision of Commercial Business Area and Distribution of Specific Types of fuel.
5. TAPPER (Tapping, Processing, and Reporting) System Tests.  
 Tool & Support:  
 Technical cooperation among sectors, community support, the readiness of information system infrastructure.

Table 1: Tapper Methodology (Tapping, Processing and Reporting)

SYSTEM	DEVICE	OUTPUT
<b>Customer identification</b>	Motor Vehicle Database Identification of Control Card on vehicle (Barcode sticker)	Database users of premium subsidized fuel and diesel oil..
<b>Tapping</b> Record transaction activity at point of handover . Namely distribution of fuel transaction at filling station and recording transaction of subsidized fuel in each dispenser.	Front end device: Card reader GPRS	recording logbook data through computer of filling stations to network access center  Transaction volume data recording the purchase of subsidized fuel for each vehicle Processing
<b>Processing</b> Processing the data sent / taken from front end devices at each filling	Network access center	transaction data processing

SYSTEM	DEVICE	OUTPUT
station		
<b>Reporting</b> Report of recording transaction at each filling station and volume of subsidized fuel usage per vehicle type	data center of volume regulation and supervision of national fuel	Report of distribution of fuel realization per filling stations

### 2.6 Projection of Total Vehicle Fuel Typed Gasoline and Diesel Fuel Users in Riau Province.

Based on data obtained from Riau Islands Police Units in 2008 about data population and number of vehicles in Riau, projected number of vehicles is drawn up until 2015. The number of vehicles through 2015 is projected using population data in 2008. Projection calculation is done because the population has a correlation or strong relationship with number of vehicles.

#### Projected Number of Vehicles Typed Gasoline Fuel

Statistically, number of vehicles using gasoline has population correlation of 0.99 with P-value 0.00 ( $\alpha \leq 5\%$ ). Population has strong and direct relationship with number of vehicles.

Data of number of vehicles and population is used to calculate proportion of number of vehicles per population in 2008 [1,2]. The calculation of number of vehicles in 2009-2015 is multiplying proportion of those with population from 2009-2015. Total population in 2009 - 2015 is projected until 2015. Projected population in 2009 up to 2015 was calculated using population growth data 2000-2008 [3].

$$\text{Total population (n)} = \text{Number of residents (n-1)} + (\text{growth rate (n-1)} \times \text{Number of residents (n)}) \quad (1)$$

Assumptions: population growth rate is same every year.

$$\text{Number of vehicles (n)} = (\text{number of vehicles (n-1)} / \text{population (n-1)}) \times \text{population (n)} \quad (2)$$

$$\text{Number of vehicles (n)} = \text{proportion of number of vehicles per year} \times \text{number of population (n)} \quad (3)$$

With n = 2009, ..., 2015

Assumption: proportion of number of vehicles and number of people per year used is same.

#### Projected Number of Vehicles Typed Diesel Fuel

It is almost the same projection with number of vehicles typed gasoline fuel. Statistically, number of vehicles using diesel fuel and population has value of 0.93 with correlation value P-value 0.00 ( $\alpha \leq 5\%$ ). The population has strong and direct relationship with number of vehicles.

Data of number of vehicles and population is used to calculate proportion of number of vehicles per population in 2008 [1,2]. So calculation of number of vehicles in 2009-2015 is multiplying proportion of those with populations from 2009 until 2015. Total population in 2009-2015 is projected until 2015. Projected population in 2009 up to 2015 was calculated using population growth data 2000-2008 [3].

$$\text{Total population (n)} = \text{Number of residents (n-1)} + (\text{growth rate (n-1)} \times \text{Number of residents (n-1)}) \quad (4)$$

Assumptions: population growth rate is same every year.

$$\text{Number of vehicles (n)} = (\text{number of vehicles (n-1)} / \text{population (n-1)}) \times \text{population (n)} \quad (5)$$

$$\text{Number of vehicles (n)} = \text{proportion of number of vehicles per year} \times \text{number of population (n)} \quad (6)$$

With n = 2009, ..., 2015 ;

Assumption: proportion of number of vehicles and number of people per year used is same.

### 2.8 Calculation of Quota Allocation of Gasoline and Diesel Fuel in Riau Province

Specified quota allocation of gasoline and diesel fuel in Riau Province in 2006 through 2008 based on data from BPH Migas is shown below.

Table 2: Allocation of Premium 2006 to 2008 in the Riau Islands Province [4]

City	Allocation per Year (kL)					
	2006		2007		2008	
	Premium	Diesel	Premium	Diesel	Premium	Diesel
Batam	124,712	88,060	114,369	75,450	124,539	88,060

City	Allocation per Year (kL)					
	2006		2007		2008	
	Premium	Diesel	Premium	Diesel	Premium	Diesel
Karimun	9,953	6,995	6,975	6,928	9,939	6,995
Bintan	19,233	35,981	17,148	30,226	19,206	35,981
Natuna	5,337	7,661	3,547	5,129	5,329	7,661
Lingga	3,871	8,189	299	1,747	3,866	8,189
Tanjung Pinang	29,014	27,640	20,963	20,487	28,974	27,640
Total	192,120	174,526	163,301	139,967	191,853	174,526

### Projection of Quota Allocation of Gasoline in Riau Province

Projection need of gasoline volume quotas for the next 7 years is conducted by using data quota volume of gasoline in 2008 and data on number of vehicles in 2008 in particular types of private cars and motorcycles.

$$\text{Proportion (n)} = \text{Volume of the needs of gasoline (n)} / \text{number of vehicles gasoline users (n)} \quad (7)$$

$$\text{Projection (n)} = \text{proportion of quota gasoline per vehicle} \times \text{estimated number of vehicles (n)} \quad (8)$$

With n = 2009, ..., 2015

Assumption: the proportion of the quota volume needs premium per vehicle is the same every year

### Projection of Quota Allocation of Diesel Fuel in Riau Province

Projected need for quota volume of diesel fuel for seven years into the future is done using data quota volume of diesel fuel in 2008 and data of number of vehicles in 2008 in particular types of trucks, buses and large cars.

$$\text{Proportion (n)} = \text{Volume of diesel fuel demand (n)} / \text{number of vehicle Diesel Fuel users (n)} \quad (9)$$

$$\text{Projection (n)} = \text{proportion quota diesel demand per vehicle} \times \text{estimated number of vehicles (n)} \quad (10)$$

With n = 2009, ..., 2015

Assumption: proportion of quota volume of diesel fuel demand per vehicle is same every year

## 3. RESULTS AND DISCUSSION

Based on results of the calculation of projected proportion of number of vehicles per population in 2008, projected number of users of gasoline vehicles in 2009 to 2015 is obtained.

Table 3: Projected Number of Vehicles Table Gasoline up to 2015 Users

City	Year (Unit)						
	2009	2010	2011	2012	2013	2014	2015
Batam	1,519,076	1,716,556	1,939,708	2,191,870	2,476,813	2,798,798	3,162,642
Karimun	42,800	48,364	54,651	61,755	69,784	78,856	89,107
City	Year (Unit)						
	2009	2010	2011	2012	2013	2014	2015
Bintan	30,140	34,058	38,485	43,489	49,142	55,531	62,749
Natuna	3,499	3,954	4,468	5,049	5,705	6,447	7,285
Lingga	9,031	10,205	11,531	13,030	14,724	16,638	18,801
Tanjung Pinang	17,966	20,302	22,916	25,924	29,294	33,102	37,405
Total	1,622,512	1,833,439	2,071,759	2,341,117	2,645,462	2,989,372	3,377,989

Based on results of projected proportion of number of vehicles per population in 2008, projected number of users of diesel fuel in vehicles from 2009 to 2015 is obtained.

Table 4: Projected Number of Users Diesel Vehicles up to 2015

City	Year (Unit)						
	2009	2010	2011	2012	2013	2014	2015
Batam	17,683	19,981	22,579	25,514	28,831	32,579	36,814
Karimun	1,052	1,189	1,343	1,518	1,715	1,938	2,190
Bintan	836	945	1,067	1,206	1,363	1,540	1,740
Natuna	33	37	42	48	54	61	69
Lingga	99	112	127	143	162	183	206
Tanjung Pinang	7,793	8,806	9,950	11,244	12,706	14,358	16,224
Total	27,496	31,070	35,108	39,673	44,831	50,659	57,243

From data above, calculation data on number of vehicles that consumes fuel typed gasoline and diesel fuel in 2011 is obtained.

Table 5: Total Control Card and Barcode Stickers Used

No	City	Amount of Vehicle for Control Card and Barcode Stickers	
		Gasoline	Diesel
1	Bintan	38,485	1,067
2	Tanjung Pinang	22,916	9,950
Total		61,401	11,017
Grand Total		72,418	

Number of vehicles reflects number of control cards and barcode stickers that will be distributed to all vehicle owners and users of gasoline and diesel fuel on Bintan Island in 2011. To facilitate process of calculating cost of control cards and barcode stickers and prepare control cards and barcode sticker backup, number of control cards and barcode sticker is rounded up to 75,000 units. Cost for research can be calculated by calculation of Rp.23,467,710,200.

Based on Equation 7 and Equation 8, projected quota of gasoline fuel need for 2009 until 2015 is obtained.

Table 6: Projected Allocation of Gasoline in Riau Province

City	Year (kL)						
	2009	2010	2011	2012	2013	2014	2015
Batam	131,433.840	148,520.240	167,827.880	189,645.500	214,299.420	242,158.340	273,638.920
Karimun	10,351.770	11,697.500	13,218.180	14,936.540	16,878.290	19,072.470	21,551.890
City	Year (kL)						
	2009	2010	2011	2012	2013	2014	2015
Bintan	21,227.520	23,727.100	26,551.630	29,743.340	33,349.970	37,425.470	42,530.780
Natuna	5,031.670	5,685.790	6,424.950	7,260.190	8,204.010	9,270.530	10,475.700
Lingga	3,949.390	4,462.810	5,042.970	5,698.560	6,439.370	7,276.490	8,222.430
Tanjung Pinang	31,881.610	36,026.210	40,709.620	46,001.870	51,982.120	58,739.790	66,375.970
Total	203,875.800	230,119.650	259,775.230	293,286.000	331,153.180	373,943.090	422,795.690

Based on Equation 9 and Equation 10, projected quota of diesel fuel need for 2009 until 2015 is obtained.

Table 7: Projected Allocation of Diesel in Riau Province

City	Year (kL)						
	2009	2010	2011	2012	2013	2014	2015
Batam	92,935.260	105,016.840	118,669.030	134,096.010	151,528.490	171,227.190	193,486.730
Karimun	7,285.510	8,232.620	9,302.860	10,512.230	11,878.820	13,423.070	15,168.070
Bintan	36,021.330	40,704.100	45,995.630	51,975.060	58,731.820	66,366.960	74,994.660
Natuna	7,233.560	8,173.930	9,236.540	10,437.290	11,794.130	13,327.370	15,059.930
Lingga	8,365.630	9,453.160	10,682.070	12,070.740	13,639.940	15,413.130	17,416.830
Tanjung Pinang	30,413.740	34,367.520	38,835.300	43,883.890	49,588.790	56,035.340	63,319.930
Total	182,255.030	205,948.170	232,721.430	262,975.220	297,161.990	335,793.060	379,446.150

Results of these projections will be used to determine amount of quota as a reference in order to determining effectiveness of monitoring subsidized gasoline and diesel fuel of transportation sector on Bintan Island using control cards and barcode stickers. Based on data projected number of vehicles up to 2015, it can be calculated value of monitoring results and diesel fuel in district of Tanjung Pinang in 2011 which data is obtained from projected number of vehicles in 2011 multiplied by percentage of vehicles based on data from Tanjung Pinang City Police. Next assumption is that average volume of fuel use per day and number multiplied by number of vehicles. Total volume of fuel usage for all vehicles in district of Tanjung Pinang can be obtained. Total volume of fuel usage for all types of vehicles in district of Tanjung Pinang is multiplied by 365 days. Volume of use of all vehicles in district of Tanjung Pinang for 1 year, volume of fuel usage for one year compared with projected Quota Volume Fuel Year 2011 for Tanjung Pinang can be obtained to get difference in volume of subsidized fuel that can be saved. Difference in volume of subsidized fuel can be saved multiplied by assumed amount of government subsidy per liter in 2011. It is assumed that amount of subsidy amounting to Rp.2,000 per liter. Value of monitoring result and diesel fuel compared to projected data volume quota need of gasoline and diesel fuel in Riau Province until 2015 shows comparison between projected results with results of monitoring in 2011 at Tanjung Pinang.

Table 8: Saved Subsidy Fuel Typed Gasoline of Tanjung Pinang

Vehicle Type	Percentage (%)	Amount of Vehicle	Assumption of Gasoline Usage Average per Day (L)	Total Assumption of Gasoline Usage per Day (L)	Total Assumption of Gasoline Usage per Year (kL)	Quota in 2011 (kL)	Deviation (kL)	Assumption of Subsidy (Rp/L)	Saved Subsidy (Rp)
Motorcycle	87	19,928	3	59,783	21,820.890	40,709.620	687.926	2,000	1,375,851,936
Specific Vehicle	0	9	15	137	50.186				
Freight Car	4	917	25	22,916	8,364.340				
Passenger Car	9	2,062	13	26,812	9,786.278				
Total	100	22,916	56	109,648	40,022	40,709.620	687.926	2,000	1,375,851,936

Results show saving gasoline fuel in 2011 in district of Tanjung Pinang 687.926 kL with value of Rp.1,375,851,936.

Table 9: Saved Subsidy Fuel Typed Diesel of Tanjung Pinang

Vehicle Type	Percentage (%)	Amount of Vehicle	Assumption of Gasoline Usage Average per Day (L)	Total Assumption of Gasoline Usage per Day (L)	Total Assumption of Gasoline Usage per Year (kL)	Quota in 2011 (kL)	Deviation (kL)	Assumption of Subsidy (Rp/L)	Saved Subsidy (Rp)
Freight Car	8	79,600	14	1,114,400	406,756.000	38,835.300	3,759,975.200	2,000	7,519,950,400,000

Passenger Car	85	845,750	10	8,457,500	3,086,987.500				
Specific Vehicle	7	69,650	12	835,800	305,067.000				
Total	100	995,000	36	10,407,700	3,798,811	38,835	3,759,975	2,000	7,519,950,400,000

For diesel fuel, economy of Tanjung Pinang in 2011 for 847 kL is Rp.1,694,390,000. Value of monitoring results in district of Bintan for gasoline and diesel fuel compared to projected data volume quota need of gasoline and diesel fuel in Riau Province until 2015 shows comparison between projected results with results of monitoring in 2011 in district of Bintan.

Table 10: Saved Subsidy Fuel Typed Gasolines in district of Bintan

Vehicle Type	Percentage (%)	Amount of Vehicle	Assumption of Gasoline Usage Average per Day (L)	Total Assumption of Gasoline Usage per Day (L)	Total Assumption of Gasoline Usage per Year (kL)	Quota in 2011 (kL)	Deviation (kL)	Assumption of Subsidy (Rp/L)	Saved Subsidy (Rp)
Motorcycle	85	3,271,225	1	3,271,225	1,193,997.125	26,551.630	2,558,100.970	2,000	5,116,201,940,000
Bus	1	38,485	5	192,425	70,235.125				
Freight Car	2	76,970	5	384,850	140,470.250				
Passenger Car	12	461,820	7	3,232,740	1,179,950.100				
Total	100	3,848,500	18	7,081,240	2,584,653	26,552	2,558,101	2,000	5,116,201,940,000

Results show saving gasoline fuel in 2011 in district of Bintan 705 kL with value of Rp.1,410,208,000.

Table 11: Saved Subsidy Fuel Typed Diesel in district of Bintan

Vehicle Type	Percentage (%)	Amount of Vehicle	Assumption of Gasoline Usage Average per Day (L)	Total Assumption of Gasoline Usage per Day (L)	Total Assumption of Gasoline Usage per Year (kL)	Quota in 2011 (kL)	Deviation (kL)	Assumption of Subsidy (Rp/L)	Saved Subsidy (Rp)
Freight Car	42	448	60	26,888	9,814.266	45,995.630	31,710.421	2,000	63,420,841,200
Passenger Car	52	555	20	11,097	4,050.332				
Specific Car	6	64	18	1,152	420.611				
Total	100	1,067	98	39,138	14,285	45,996	31,710	2,000	63,420,841,200

Saving diesel fuel of Bintan in 2011 for 31,710 kL is Rp.63,420,841,000. Total result in saving gasoline and diesel fuel in 2011 on Bintan Island is 33,950,646 kL with value of Rp.67,901,291,146.

Table 12: Total Saving of Monitoring and Control Systems on Bintan Island

No	City	Volume Saving (kL)		Budget Saving (Rp)	
		Premium	Diesel	Premium	Diesel
1	Bintan	687.926	3,759,975.200	5,116,201,940,000	63,420,841,200
2	Tanjung Pinang	2,558,100.970	31,710.421	1,375,851,936	7,519,950,400,000
	Total	2,558,788.896	3,791,685.621	5,117,577,791,936	7,583,371,241,200
	Grand Total	6,350,474.517		12,700,949,033,136	

#### 4. CONCLUSIONS

The use of subsidized gasoline and diesel fuel of transportation sector in Bintan Island using control card and barcode sticker results data difference between number of vehicle users of gasoline and diesel fuel with use of volume fuel data. This indicates a distribution of subsidized fuel that is not on target especially for diesel fuel. Thus, the surveillance system needs to be applied immediately and control the use of subsidized gasoline and diesel fuel for transportation sector on Bintan Island with Full Card and Barcode to reduce the number of these differences. In turn, the fuel subsidy fraud can be minimized.

Yield of saving by monitoring and controlling the use of subsidized fuel for transportation sector on Bintan Island with Control Card and Barcode in 2011 is 1,393.030 kL for gasoline and diesel of 32,557.616 kL. Total yield of saving is 33,950.646 kL. If the state budget subsidy is assumed to be Rp.2000 per liter, the total saving that can be reached is Rp. 67,901,291,146,

If the result of saving of the supervision and control of the use of subsidized fuel is compared with the amount of budget monitoring and control of Rp.23,467,710,200, the system can save the state budget amounting to Rp.44,433,580,936. In that case, the system of supervision and control of fuel subsidies should be immediately applied with strong legal basis.

With the implementation of monitoring system of subsidized gasoline and diesel fuel for transportation sector using control cards and barcode, monitoring distribution of subsidized fuel at filling station can be supervised and unsupervised distribution level of dealer to users which are entitled in accordance with applicable regulations.

#### REFERENCES

- [1] POLDA KEPRI BINTAN, "Data Kendaraan tahun 2008", 2010.
- [2] POLRES BINTAN, "Data Kendaraan tahun 2008", 2010.
- [3] Asosiasi Industri Sepeda Motor Indonesia. "Perkembangan Tingkat Penjualan Kendaraan Bermotor Roda-2 Tahun 1990 s.d 2008", 2009.
- [4] BPH Migas, "Kuota Premium Bersubsidi Provinsi Kepulauan Riau 2006-2008", 2010.
- [5] BPH Migas. "Realisasi Penjualan BBM PSO tahun 2005-2009", 2010a.
- [6] BPH Migas. "Skema Penyediaan dan Pendistribusian Jenis BBM Tertentu", 2010b.
- [7] Fathoni, A. Z., Pusdiklat Migas Cepu, *BBM (Bahan Bakar Minyak)*, 2008.
- [8] Gabungan Industri Kendaraan Bermotor Indonesia. "Indonesia Automotive Market & Forecast 1997 – 2015", 2010.
- [9] Keputusan Presiden nomor 86 Tahun 2002, "Pembentukan Badan Pengatur Penyediaan Dan Pendistribusian Bahan Bakar Minyak Dan Kegiatan Usaha Pengangkutan Gas Bumi Melalui Pipa", 2002.
- [10] MABES POLRI, "data kendaran bermotor nasional", 2010
- [11] Peraturan Badan Pengatur Hilir Minyak Dan Gas Bumi Nomor 07/P/BPH Migas/IX/2005 Tanggal 30 September 2005, "Pengaturan Dan Pengawasan Penyediaan Dan Pendistribusian Jenis Bahan Bakar Minyak", 2005
- [12] Peraturan Badan Pengatur Hilir Minyak dan Gas Bumi Nomor 09/P/BPH Migas/IX/2005, "Penugasan Badan Usaha Untuk Penyediaan Dan Pendistribusian Bahan Bakar Minyak Tertentu yang telah diubah dengan Peraturan Badan Pengatur Hilir Minyak dan Gas Bumi Nomor : 18/P/BPH Migas/V/2009", 2009.
- [13] Peraturan Pemerintah No. 36 Tahun 2004, "Kegiatan Usaha Hilir Minyak dan Gas Bumi sebagaimana telah diubah dengan Peraturan Pemerintah No. 30 Tahun 2009", 2009.
- [14] Peraturan Pemerintah No. 67 Tahun 2002, "Badan Pengatur Penyediaan dan Pendistribusian Bahan Bakar Minyak dan Kegiatan Usaha Pengangkutan Gas Bumi melalui Pipa", 2002.
- [15] Peraturan Presiden Nomor 71 Tahun 2005, "Penyediaan dan Pendistribusian Jenis Bahan Bakar Minyak Tertentu sebagaimana telah diubah dengan Peraturan Presiden No. 45 Tahun 2009", 2009.
- [16] POLRESTA Tanjung Pinang, "Data Kendaraan tahun 2008", 2010.
- [17] Surat Keputusan Kepala BPH Migas, "Penugasan Badan Usaha Untuk melaksanakan Penyediaan dan Pendistribusian jenis BBM Tertentu Tahun 2010", 2010.
- [18] Undang-undang Nomor 22 Tahun 2001, "Minyak dan Gas Bumi", 2001.

## Activated Carbon Produced from Bamboo Using Activating Agent $H_3PO_4$ And KOH

Mahmud Sudibandriyo<sup>a</sup>, Siti Tias Miranti<sup>a</sup>, Maria S. Melania<sup>a</sup>

<sup>a</sup>Chemical Engineering Department, Faculty of Engineering  
Universitas Indonesia, Depok 16424  
Tel : (021) 7863516. Fax : (021) 7863515  
E-mail : msudib@che.ui.ac.idu

### ABSTRACT

Adsorption is one of the techniques that can be used in many applications in industrial processes, such as for separations, water treatments, and gas storages. The key success in the application of adsorption method is the selection of the adsorbent. Depending on the specific application, total surface area and the pore size of the adsorbent are the most important parameters in the selection of the adsorbent. Activated carbon has been a long pronounced as an excellent candidate adsorbent for separation purposes as well as gas storage (adsorptive storage). This research aims are to produce activated carbon from bamboo as the raw materials. Bamboo plants was selected as a raw material because it contains a fair amount of carbon (47.6%) and also available in almost many places in Indonesia. Moreover, unlike coals as main sources of activated carbon, bamboo can be considered as renewable natural resources. In this research, activation method is controlled by variation of activating agent,  $H_3PO_4$  and KOH with mass ratio of activating agent/carbon mass: 1/1, 2/1, and 3/1. The temperature of activation are varied at 600°C, 700°C, and 800°C for 30 and 60 minutes. The results shows that the highest surface area of 781  $m^2/g$  is obtained by activation using  $H_3PO_4$  with a mass ratio of activating agent/carbon mass 3/1 at temperature of activation of 700°C, for 60 minutes. Meanwhile, activation using KOH results in 824,83  $m^2/g$  obtained by activation at 800°C for 30 minutes. For comparison, the study produces activated carbon by physical activation method conducted at 700°C for 60 minutes and the surface area of activated carbon obtained is 291  $m^2/g$ .

### Keywords

*Activated Carbon, Bamboo, Chemical Activation,  $H_3PO_4$ , KOH.*

## High Quality Biodiesel Production from Acid Oils Using Ion-exchange Resin as Catalysts and Adsorbent

Naomi Shibasaki-Kitakawa and Toshikuni Yonemoto

*Department of Chemical Engineering, Tohoku University,  
Aoba-yama 6-6-07, Aoba-ku, Sendai 980-8579, JAPAN  
Tel : +81-22-795-7255. Fax : +81-22-795-7258  
E-mail : toshiy@rpel.che.tohoku.ac.jp*

### INTRODUCTION

Even today, the refined edible oils are mainly used as feedstocks for biodiesel and this causes an increase in the price of edible oils. The side-stream products, such as soapstocks, acid oils and deodorized distillates, obtained during edible oil refining have been suggested for use as alternative feedstocks for biodiesel. Especially, the crude oils of palm and rice bran have a high content of free fatty acid and, hence the amount of acid oils generated is large, about 10-15 wt% of refined oil output. There are a little industrial uses for acid oils such as ink, but most acid oils are burned out as waste. However, there exists no commercially realizable process for biodiesel production from acid oils.

The purpose of this research is to construct a simple and economical production process of high quality biodiesel from waste acid oils using the ion-exchange resins as catalysts and adsorbent.

### MATERIALS AND METHODS

The acid oil, donated by the rice bran oil company, consisted of about 95 wt% of free fatty acids and 5 wt% of acylglycerols. Figure 1 shows a schematic diagram and photograph of our production process. Two water-jacketed columns were individually packed with the cation-exchange resin, Diaion PK208LH, and the anion-exchange resin, Diaion PA306S, respectively, and connected in series. The temperature of each column was kept constant at 50 °C. The mixed solution at the stoichiometric molar ratio of methanol to the total fatty acid residue in the oil was supplied to the bottom of the first column at the constant flow rate. The effluent from the process was analyzed to check the quality of biodiesel.

### RESULTS AND DISCUSSION

Table 1 shows the analytical result of standard tests for biodiesel quality of product without purification except for removing residual methanol by evaporation. The contents of FAME and residual reactants were fully satisfied with the standard values. This indicated that free fatty acids and mono-, di-, and tri-glycerides were converted to biodiesel by esterification and transesterification with cation- and anion-exchange resin catalysts, respectively. The contents of byproducts also met the standard low values without downstream purification processes to remove them. This was because the by-products, water and glycerol were adsorbed on the anion-exchange resin and the effluent was free from them. Other properties for contaminants and fuel properties were found to be satisfied with the standards.

Figure 2 shows the photographs of the feed oil and the effluents from the first and second columns at room temperature. The feed oil was liquefied by the esterification through the first column. The dark brown pigment was removed by the adsorption through the second column.

### CONCLUSION

The simple process permitted the economical production of high quality biodiesel from the waste acid oils without complicated downstream purification process.

**Keywords**

Acid oil, biodiesel production, esterification, ion-exchange resin, transesterification

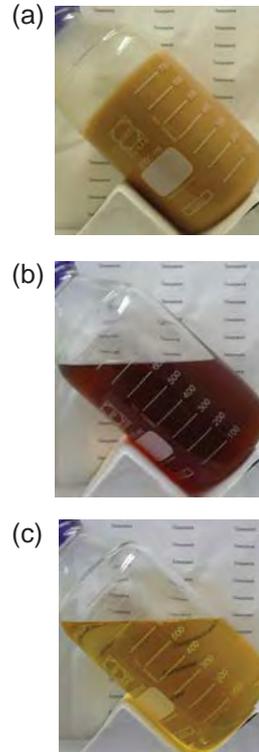
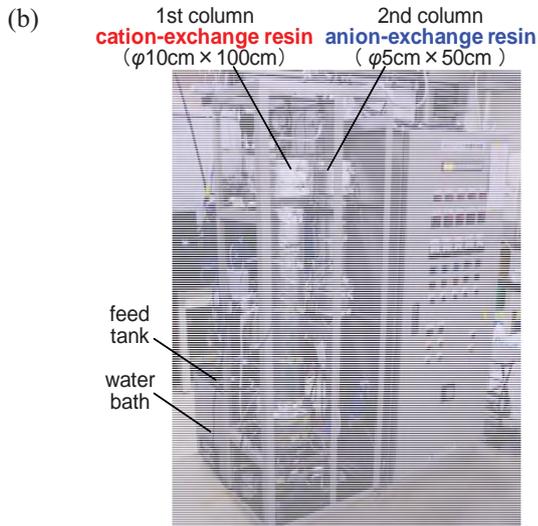
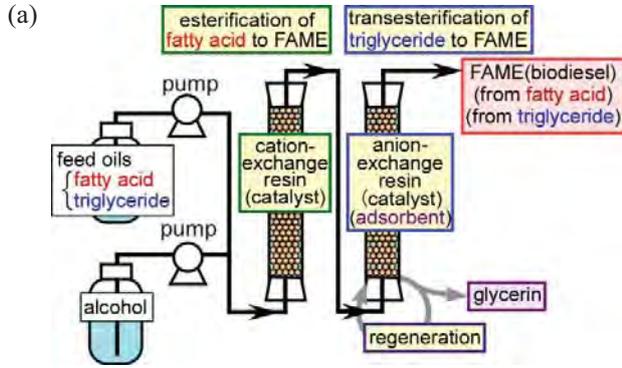


Figure 2: Photographs of feed oil (a) and effluents from the first (b) and second (c) columns at room temperature

Figure 1: Schematic diagram and photograph of production process

Table 1: Analytical result of standard tests for biodiesel quality of product

properties	units	standards	product without	
		EN14214	purification	
product	FAME	[wt%]	≥96.5	97.1
reactants	acid value (FFA)	[mg-KOH/g]	≤0.5	0.04
	monoglyceridel	[wt%]	≤0.8	0.48
	diglyceride	[wt%]	≤0.2	0.02
	triglyceride	[wt%]	≤0.2	0.03
byproducts	water	[mg/kg]	≤500	291
	free glycerol	[wt%]	≤0.02	0.00
	total glycerol	[wt%]	≤0.25	0.13
contaminants	sulfur	[mg/kg]	≤10	<5
	sulfated ash	[wt%]	≤0.02	<0.005
	phosphorous	[mg/kg]	≤4	<1
	carbon residue (at 10% distillation residue)	[wt%]	≤0.3	0.11
	total contamination	[mg/kg]	≤24	2
fuel properties	density at 15°C	[kg/m <sup>3</sup> ]	≥860, ≤900	880.4
	kinematic viscosity at 40°C	[mm <sup>2</sup> /s]	≥3.5, ≤5.0	4.353
	flash point	[°C]	≥101	128.0
	cetane number	[-]	≥51	53.1
	iodin value	[-]	≤120	94.9
	methyl linolenate	[wt%]	≤12	1.2

# The Effect of Biofilm and Biomass in Electricity Generation by Microbial Fuel Cell System

Rita Arbianti<sup>a\*</sup>, Tania Surya Utami<sup>a</sup>, Heri Hermansyah<sup>a</sup>, Desy Qoiriyani<sup>a</sup>, Ester Kristin<sup>a</sup>, Ira Trisnawati<sup>a</sup>

<sup>a</sup>Department of Chemical Engineering  
Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel : (021) 7270011 ext 51. Fax : (021) 7270077  
\*E-mail : arbianti@che.ui.ac.id

## ABSTRACT

Electricity consumption of the world had come up because of the rapid development of technology that uses electrical energy such as cellular phones or computers. Hence, research to complement the shortage of electricity continues to be done. Microbial Fuel Cell (MFC) provides new opportunities for sustainable energy production from fuel that is biodegradable, and can reduce the compound substrate, even from wastewater. Single chamber MFC reactor without ion exchange membrane with tempeh industry wastewater as substrate used in this experiment. We used graphite electrode as an electron mediator and grow biofilm in the anode for 3 weeks (precolonization anode) then compared it with clean anode system. Soy bean husk is added as biomass in substrate for second variation. Optimum electricity production obtained from clean anode without addition of soy bean skin system. Power density obtained was 1009,34 mW/m<sup>2</sup> when using wastewater model and 44,62 x 10<sup>-2</sup> mW/m<sup>2</sup> when using industry tempeh wastewater.

## Keywords

*Microbial Fuel Cell (MFC), single-chamber reactor, biofilm, biomass, wastewater of tempeh industry.*

## 1. INTRODUCTION

World consumption of the electrical energy is increasing every year because of the rapid development of technology and consumerism. The high electricity demand is not matched by availability of primary fuel, ie fossil fuels. This limitation requires creativity of researchers to be able to find alternative fuels that can producing electrical energy. Interesting alternative comes from the fuel cell. Contrary to the reaction of electrolysis, fuel cells reacting hydrogen and oxygen to produce water and electricity. In fact the use of hydrogen as an alternative fuel less than optimal in terms of cost.

Research to reduce the limitations of fuel cells continues. The abundance of bacteria is the original idea of the invention MFC (Microbial Fuel Cell) which is the development of fuel cell technology. MFC is a device that uses bacteria to generate electricity from organic and non-organic compounds [1]. MFC provides new opportunities for sustainable energy production with fuel that is biodegradable and can reduce the compound substrate [2]. MFC is comprised of anode, cathode and electrolyte. The main principle is the microbial activity in the liquid medium in the anode compartment. Microbial activity can produce organic component containing hydrogen elements such as ethanol, methanol, or methane gas that can be used to produce electrons and electrical current. This research will use a single-chamber reactor design MFC as the single-chamber reactor produces a higher power density than two-chamber [3]. Ion-exchange membranes are not used in the reactor design. Ion exchange membrane serves to prevent the diffusion of oxygen from the cathode into the anode and allow proton transfer occurs from the anode compartment into the cathode compartment [3]. According to Liu *et al.* (n.d), ion-exchange membrane will make the rate of removal of COD in waste slower and will reduce power density generated by the system [3]. Industry tempeh wastewater is used as the substrate in this system. Liquid waste of industry tempeh contains nutrients of nitrogen, phosphorus, and organic materials such as carbohydrates, vitamins, and proteins that act as nutrients for bacteria [4]. The use of waste as a substrate without the addition of bacteria can provide two benefits at once, which saves the cost of purchasing expensive bacteria and reduce the cost of wastewater treatment industry tempeh.

## 2. METHOD

Industry tempeh wastewater was taken from tempe manufacture located in the Lio village, Depok. Materials and tools used in the experiment originated from the Bioprocess Laboratory and Basic Chemistry Laboratory Department of Chemical

Engineering UI. Voltage is measured using digital multimeter (Sanwa Electric Instrument co., Ltd cd 771) and current is measured using analog microampere (Yokogawa Electric Works. Ltd, tipe 2011b9000em class 1.0, Singapore).

### 2.1. Electrolysis Tools Preparation

Electrodes used in this study are graphite electrodes that are relatively inexpensive, simple, and has a specific surface area [5]. Graphite electrode immersed in a solution of 1 M HCl for 1 day and then rinsed using distilled water. After that, the electrodes immersed again in 1 M NaOH solution for 1 day and then rinsed again using distilled water. Electrode preparation aims to regenerate the electrode and removes metal contamination and organic materials [5].

### 2.2. Substrate and Electrolyte Preparation

Industry tempeh wastewater is used as the substrate in this system, but to get an ideal system, we made a model of liquid waste. To make a model of liquid waste, boiling 200 grams of soy beans (*Glycine max*) by as much as 500mL of water (ratio 1:2.5;w/v) for 15 minutes. This is done through the process of boiling soy in tempeh industry, with the ratio of 3:5 (w/v) [6]. Then the temperature of boiling water left in place until normal ( $\pm 28^{\circ}\text{C}$ ), followed by filtering the cooking water, so it will get the effluent model and then peeled soy beans to be used as biomass.

### 2.3. MFC Configurations

For starting the experiment, we have to preparation the tools. First, set an electrode in the reactor then connected it to the cable and resistor. This is for anode part. Then we set another electrode to the hole side reactor and connected it to cable and resistor. This is for cathode part. Then we connected the two cables and then we will connect it to multimeter.

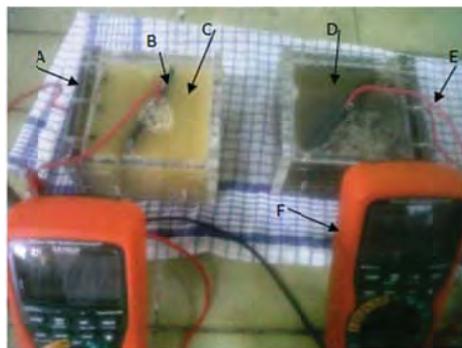


Figure 1: The scheme of MFC reactor.

(A) cathode, (B) anode, (C) industry tempeh wastewater, (D) liquid waste model, (E) cable or external circuit (F) multimeter.

### 2.4. MFC Experiments

MFC experiments performed with 2 variations which are variations pretreatment anode and the addition of biomass variations. Variations pretreatment anode is done by comparing the MFC system with clean anode and pre-colonized anode. Pre-colonized anode is the anode that permit biofilms or bacterial colonies growth in their surface. Pre-colonized done by immersing the anode in the anaerobic system for 3 weeks by refreshing the new waste every week. Biofilms that grow on the anode surface is expected to be a catalyst towards the transfer of electrons from bacteria to the anode. Researchers Yang, Jia and Liu [7] have explained that the presence of biofilm on the anode can reduce the diffusion of oxygen into the compartment so that it will reduce the potential for oxidation-reduction reactions that can raise coulombic efficiency and power generated by the system. Biofilm in the pre-colonized anode also can speed up the lag phase of bacteria compared to clean anode [8].

The experiment was continued by adding biomass to the MFC system with clean anodes and pre-colonized anode and compare them with systems that are not given additional biomass. Biomass in the form of soybean husk is used as an additional substrate. Soybean husk is expected to be a nutrient for bacterial metabolism to increase electricity production. MFC system with additional substrate can produce electricity up to twice compared to using only waste [6].

### 2.5. Analysis and Calculations

Of the MFC experiments, the data obtained in the form of currents and voltages. Power density ( $\text{mW}/\text{m}^2$ ) is the power generated per unit area of the electrode and is calculated using the equation:

$$\text{Power density (mW/m}^2\text{)} = \frac{I \times V}{A} \quad (1)$$

I (mA) is the electrical current, V (V) is voltage and A (m<sup>2</sup>) is the electrode surface area.

### 3. RESULT AND DISCUSSION

#### 3.1. Effect of Pre-colonized Anode

MFC performance in the variation of anode pretreatment can be seen from Figure 2, the system of pre-colonized anode had a shorter lag phase than the system with clean anode, respectively 37 hours and 41 hours. Microbial lag phase are influenced by the size of the inoculum, the time required for physical or stress recovery when inoculation, the time required for the synthesis of important coenzymes, and the time required to synthesize new enzymes for metabolism of substrates present in the growth media [10]. Both systems, clean anode and pre-colonized anode, have the same size of inoculums and medium with the possibility of same bacterial colonies and nutrients, so that we can conclude the differences are because of microbial adaptation speed for synthesizing new enzymes and their ability for recovery from stress.

At the peak of each electricity production pre-colonized anode is smaller than the clean anode. Power density was 3.20 mW/m<sup>2</sup> for pre-colonized anode and 1009.34 mW/m<sup>2</sup> for clean anode. The thickness of the biofilm on the pre-colonized anode reduced after the system starts up (microbial analysis), it showed the process of bacteria release from the anode surface into the liquid medium (desorption), so we can conclude that the electricity production of pre-colonized anode system was measured during the desorption process and clean anode occurs when bacteria start forming biofilms. Research conducted by Reimers and *et al* [8] showed similar results to electricity production in this system. A total of 6 pieces of anode and cathode electrodes were inoculated using sea water for 25 days before the system starts and the other electrode pair left clean. Results of research conducted indicate clean electrode has a strong current compared to the other electrode. System with clean electrodes can produce current up to 9 mA, while the maximum current of pre-colonized anode was 5 mA.

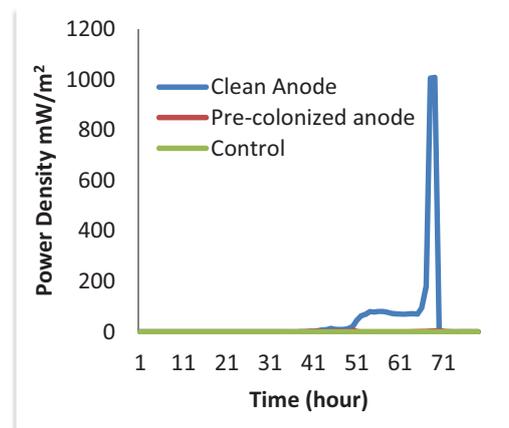


Figure 2: Electricity Production in Variation of Pretreatment Anode

#### 3.2. The Use of Biomass as a Substrate Addition

Biomass in the form of soybean husk researched by the systems of clean anode and pre-colonized anode. The result is a system with the added of biomass in the clean anode system generating electricity smaller than the system without the addition of biomass, respectively 3.32 mW/m<sup>2</sup> and 1009.34 mW/m<sup>2</sup> (Figure 3), while the pre-colonized anode system produces more electricity than when biomass added to the system, respectively 45.75 mW/m<sup>2</sup> and 3.20 mW/m<sup>2</sup> (Figure 4). Electron transfer from the bacteria into the anode to produce an electric current needed space for bacteria to make the shift easily, but the presence of soybean husk that satisfies both MFC systems can complicate the process of electron transfer, especially for planktonic bacteria in the clean anode system. Reduction of electron transfer due to the soybean husk will make the electrons are captured by the anode to produce electricity is not maximal. Pre-colonized anode system has had a bacterial system that stick to the anode surface (biofilm) that electron transfer is not reduced by the presence of soybean husk in the reactor. Pre-colonized anode system given positive results for the electricity generated in the addition of biomass. It is proved that the soybean husk can be an additional substrate in the MFC system to increase the production of electricity, but its use must be adapted to the system created to maximize their function.

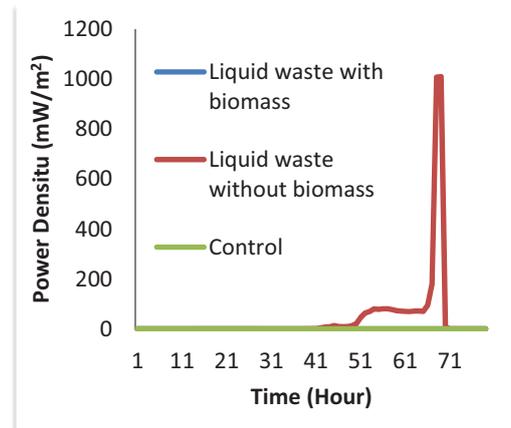


Figure 3: Electricity Production in Variation of Adding Biomass in the Clean Anode System

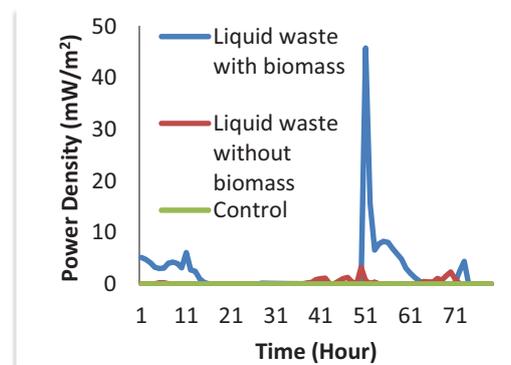


Figure 4: Electricity Production in Variation of Adding Biomass in the Pre-colonized Anode System

### 3.3. The Use of Industry Tempeh Wastewater as a Substrate

The results of the maximum power of the two variations then operated using industry tempeh wastewater substrate. Electricity generated at the industry tempeh wastewater is  $44.62 \times 10^{-2} \text{ mW/m}^2$  (Figure 5). Electricity production is lower due to several things, such as industry tempeh wastewater viscosity, contamination, and nitrate content in industry tempeh wastewater. Viscosity of industry tempeh wastewater will reduce power production due to the reduction of oxygen diffusion from the cathode towards the MFC system [6] and the magnitude of the resistance in the MFC system [3]. Contamination that occurred in the excess of the boiling process and from other area of the factory can bring new colonies. The presence of other bacteria colonies in industry tempeh wastewater can work synergistically or antagonist. Antagonist properties of a colony of bacteria that live in the same medium can lead to competition, especially if the bacteria are fighting over the same source of nutrients for survival [9]. This competition will lead to a limitation in the growth of these bacteria, thus affecting the metabolism of the bacteria will also be affect electricity production [11]. Large nitrate content in industrial soybean wastewater also affects electricity production in MFC system. Nitrate will act as an electron acceptor, so the electricity generation not only captured by oxygen but also by nitrate which will make the electricity generation is not maximal [6].

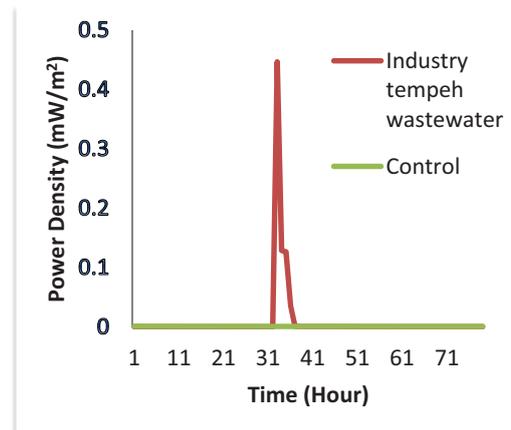


Figure 5: Electricity Production Industry Tempeh Wastewater

### 3.4. Microbial Analysis

The growth of bacterial cells in the model wastewater was observed by looking at the increase of cell based on Optical Density (OD) techniques in the incubation time [12]. OD method is done by measuring the absorbance using a spectrophotometer at a wavelength of 600 nm. Based on experiments conducted, it was found the growth curve as shown in Figure 6.

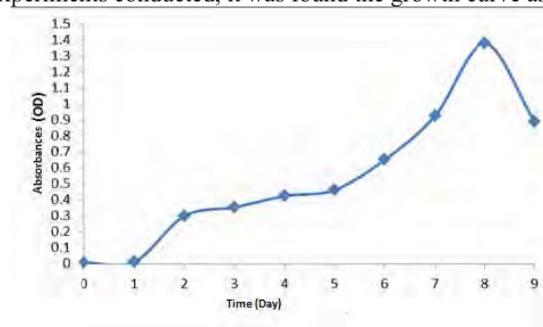


Figure 6: Bacterial Growth Curve in the Liquid Waste Model

Bacteria that grow on the medium of liquid waste is then allowed to grow to form a biofilm on the anode surface before the system starts (pre-colonized), so the analysis was also performed on the biofilm morphology. Attachment of bacteria to solid surfaces is the beginning of biofilm formation that occurs naturally in order to survive in adverse conditions, such as nutrient limitation or because of competition to get the same nutrients [9]. Bacteria that form biofilms has better resistance to chemicals, drought, and nutrient limitation compared with its planktonic cells [9].

Attachment occurs when organic material adsorbed on the wet anode surface. Pile of organic material on the surface of the anode will attract bacteria come in and stick to the surface to get nutrients. Bacteria that grow on the anode surface produce Extracellular Polymeric Substances (EPS) which content matrix that forming biofilm. Matrix formed from extracellular protein complex, sugars and bacterial cells, as well as conductive nanowires that can facilitate the conduction electrons [12]. When abundance bacteria come, they will form microcolony [13]. The last process is the development and spread of biofilms in all parts of the surface [13]. Bacteria that have been adsorbed can still move toward the liquid phase when the availability of nutrients in the liquid phase more than those on solid surfaces [13].

Based on the analysis of biofilm morphology (Figure 7), communities of bacteria that grow on the surface of the anode in wastewater tempeh model were spherical or coccus-shaped bacteria. Transfer of electrons from bacteria to the surface of the anode has 3 ways, there are through pili, through the outer membrane of the bacterial cell (cytochrome), through a redox mediator [3]. Redox mediator can be obtained from the addition of chemicals and the results of bacterial excretion [3]. This study does not add electron mediator MFC system, the community of bacteria attached to the surface of the anode also lacked pili (Figure 7), and the electricity generated by the experiment will go down when the bacteria undergo desorption phase. So, we can be concluded that the mechanism of electron transfer is likely to occur towards the anode bacteria through the outer cell membrane protein (cytochrome). The mechanism of transfer through the cytochrome can only happen if the microbes in

contact with the anode, so if more microbes are contacted with the anode, the electron transfer will be higher. In other words, the transfer of electrons increases with increasing surface area covering the biofilm anode.

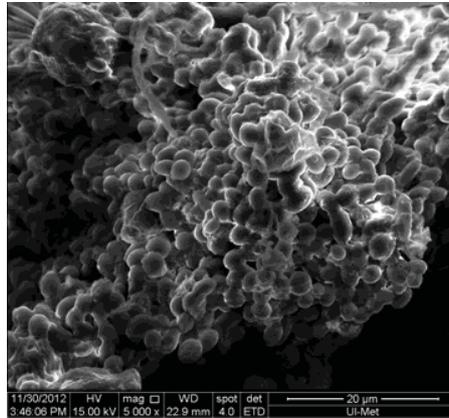


Figure 7: Biofilm Morphology in The Anode

The thickness of the bacteria was also obtained from the SEM test. The results obtained showed that biofilms grown on electrodes without the addition of biomass has a thickness smaller than biofilms grown in the system are added biomass (Figure 8). Biofilms were grown using natural substrate of liquid waste only has a thickness of between 127.8 µm - 176 µm, while the biofilm prepared by the addition of soybean husk as an additional substrate thickness ranged from 473 µm - 684 µm. Greater thickness in the MFC system with the addition of biomass showed positive results of soy husk as an additional substrate for bacteria. Soybean husk is proven to increase the metabolism of the bacteria to form colonies more on the anode surface.

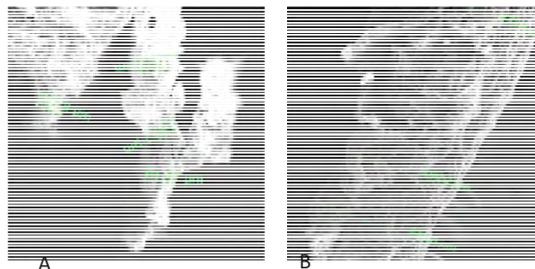


Figure 8: Differences of Thickness Before Incubation in the Substrate Variation with 100 Magnified.  
 (A) Biofilm without adding biomass (B) biofilm with adding biomass.

After the incubation is complete biofilm retested using SEM to determine the changes that occur. Based on the test results obtained from SEM the thickness after the system starts getting reduced (Figure 9). Originally biofilm on a system that was not given additional biomass has a thickness in the range of 127.8 µm - 176 µm and turned into a range of 19.55 µm - 44.8 µm after incubation process is completed and the biofilm biomass system provided additional thickness is reduced from the range of 473 µm - 684 µm to 163.4 µm range - 245.5 µm.

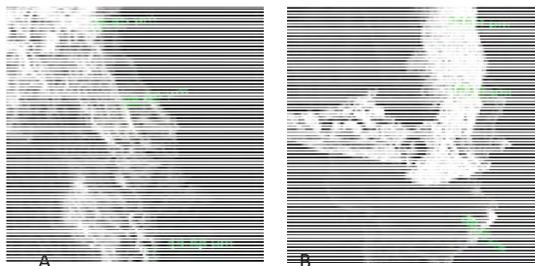


Figure 9: Differences of Thickness After Incubation in the Substrate Variation with 100xMagnified.  
 (A) Biofilm without adding biomass (B) biofilm with adding biomass.

Replacement of liquid waste at the pre-colonized anode system before electrical measurements will cause nutrients in the liquid phase into more than at the anode surface. An abundance of nutrients in the liquid phase resulting in bacterial defense system does not require any form of forming biofilm on the anode surface, so that the bacteria will make the release from the biofilm system into a liquid phase (desorption). This is what causes the thickness of the biofilm on the electrode decreased after incubation. In addition, bacteria in the biofilm system can fulfill their own nutritional needed. They will eat the dead cell in the system to still alive, so that the thickness of biofilm will decrease as the number of death bacteria on the system [9].

#### 4. CONCLUSION

Single-chamber MFC with clean anode systems without the addition of biomass produces the maximum power among other systems, which is 1009.34 mW/m<sup>2</sup>. Soybean husk has a pretty good ability to increase the production of electricity. Biomass is added to the pre-colonized anode system generating power density of 45.75 mW/m<sup>2</sup>, while the pre-colonized anode system without biomass has power density as 3.20 mW/m<sup>2</sup>. The use of industry tempeh wastewater produced power density as 44.62x10<sup>-2</sup> mW/m<sup>2</sup>.

#### 5. REFERENCES

- [1] Kurnianingsih, Nia. Bakteri Microbial Fuel Cell. <http://www.alpensteel.com/article/65-109-energi-fuel-cell-sel-bahan-bakar/1740--bakteri-mikrobal-fuel-cell.htmL> (diakses Februari 2011).2009.
- [2] Rabaey, Korneal dan Verstraete, Willy. TRENDS in Biotechnology. *Microbial Fuel Cells: Novel Biotechnology for Energy Generation*. Belgium: Elsevier.2005, vol. 23, no. 26.
- [3] Drapcho, Caye M., Nuan, Ngiem Phu., dan Walker, Terry H. *Biofuels Engineering Process Techmology*. McGraw-Hill Companies: Amerika.2008.
- [4] Said, Nusa Idaman. n.d. *Teknologi Pengolahan Limbah tahu-Tempe Dengan Proses Biofilter Anaerob dan Aerob*. <http://www.kelair.bppt.go.id/Sitpa/Artikel/Limbahtt/limbahtt.html> (diakses 17 Maret 2012).
- [5] Novitasari, Deni. *Optimasi Kinerja Microbial Fuel Cell (MFC) untuk Produksi Energi Listrik Menggunakan Bakteri Lactobacillus bulgaricus*. Fakultas Teknik Universitas Indonesia.2011.
- [6] Kristin, Ester. *Produksi Energi Listrik Melalui Microbial Fuel Cell Menggunakan Limbah Industri Tempe*. Fakultas Teknik Universitas Indonesia. 2012.
- [7] Yang, Shoqiang., Jia, Boyang., Liu, Hong. *Effects of the Pt Loading Side and Cathode-Biofilm on The Performance of A Membrane-Less and Single-Chamber Microbial Fuel Cell*. Cina: Elsevier.2009, vol. 100, pp1197-1202.
- [8] Reimers *et al.* *Substrate Degradation Kinetics, Microbial Diversity, and Current Efficiency of Microbial Fuel Cells Supplied with Marine Plankton*. Amerika: American Society for Microbiology.2007,vol. 73, no. 21.
- [9] Kusumawardani, Diah. *Kompetisi Bakteri Asam Laktat dan Staphylococcus aureus dalam Penempelan dan Pembentukan Biofilm pada Permukaan Stainless Steel*. Fakultas Teknologi Pertanian: Institut Pertanian Bogor.2002.
- [10] A. Patol, Sunil., Hagerhall, Cecilia., Gorton, Lo. *Electron Transfer Mechanism between Microorganisms and Electrodes in Bioelectrochemical Systems*. Verlag Wien: Springer.2012, Vol: 4, pp. 159-192.
- [11] Zahara, Nova Chisilia. *Pemanfaatan Saccharomyces dalam Sistem Microbial Fuel Cell untuk Produksi Energi Listrik*. Fakultas Teknik Universitas Indonesia.2011.
- [12] Sciencecodex. *Fuel Cell uses Bacteria in Sewage to Make Electricity*.[http://www.sciencecodex.com/life\\_at\\_the\\_jolt\\_fuel\\_cell\\_uses\\_bacteria\\_in\\_sewage\\_to\\_make\\_electricity](http://www.sciencecodex.com/life_at_the_jolt_fuel_cell_uses_bacteria_in_sewage_to_make_electricity) (diakses 19 Juni 2012 pukul 14.00).2008.
- [13] Kumar, Ganesh C., Anand, S.K. *Significance of microbial biofilms in food industry*(International Journal Food and Microbiology. 1998, vol. 42, pp. 9-27.

## Simulation of Bagasse Saccharification and Fermentation to Bioethanol

Misri Gozan<sup>1</sup>, Ius Pratama<sup>1</sup>, Muhamad Samsuri<sup>2</sup>

- 1) Chemical Engineering Departement, Faculty of Engineering, Universitas Indonesia, Kampus UI, Depok 16424, Indonesia, mgozan@che.ui.ac.id, ph: +62 21 7863516, fax: +62 21 7863515
- 2) Ministry of Research and Technology (RISTEK), Jakarta-Indonesia, +62-21-3169183 (ph), +62-21--3101728 (fax) msyamsuri@ristek.go.id.

### ABSTRACT

One of future research on National Research Agenda for renewable energy development is bioethanol development from lignocellulosic material. The problem in increase of ethanol production from lignocellulosic material includes bagasse is how to convert integrat polysaccharide to monosaccharide using specific enzymes. Integrated conversion including how to convert cellulose, hemicellulose and cellubiose, which is caused by partial hydrolysis of cellulose to glucose. The other phenomena, the existence of lignin in bagasse makes difficult to access enzyme in converting polysaccharide to monosaccharide. It causes ethanol production is not optimal.

This upstream bioethanol process simulation aim to optimize process production cost and the simulation can be modified to any variation of method in the process in bioethanol production to compare the effectivity of each variation. Acid hydrolization is applied in this process design, the acid will crack the polimer of cellulose and fermented by yeast which contain *S.cereviseae*. The source data in the simulation are obtained from the previous researches that have relation with the process.

Bagasse-based bio-ethanol yield in this process of 23:27%. With a capacity of 1.081 tons / yr bagasse prices and \$ 20 / ton, the importance of the sale price of \$ 2.4/kg. The production cost per year \$ 1.24/kg, IRR = 14:14%. From the sensitivity analysis, the variable selling price of bioethanol is the most sensitive variable.

## Waste Processing Equipment for Small Industries Based on Ozone and Ultraviolet-C

Styani, E.<sup>a</sup>, Nurhasanah<sup>b</sup>, Djavar, N.<sup>c</sup>

<sup>a</sup> Academy of Chemical Analysis Bogor  
Centre for Education and Training Industry  
Ministry of Industry Republic of Indonesia  
Tel : (0251)8650351 . Fax : (0251) 8650352  
E-mail : ernasekarboedhi17@gmail.com

<sup>b</sup> Academy of Chemical Analysis Bogor  
Centre for Education and Training Industry  
Ministry of Industry Republic of Indonesia  
Tel : (0251)8650351 . Fax : (0251) 8650352  
E-mail : ana@aka.ac.id

<sup>c</sup> Academy of Chemical Analysis Bogor  
Centre for Education and Training Industry  
Ministry of Industry Republic of Indonesia  
Tel : (0251)8650351 . Fax : (0251) 8650352  
E-mail : noviardjavar@yahoo.co.id

### ABSTRACT

Conventional Waste Water Processing equipment for small industrial technology is expensive and difficult to operate. This study was made to find a low-cost waste water treatment system that can be made small in size and easy to operate. Research using ozone and ultraviolet light showed excellent possibilities to build a waste processing unit suitable for small industries. Preliminary research has shown that the ability of Ozone and Ultraviolet-C (UV-C) to oxidize poly-azo sulfonated pigment (black ink inkjet printer) tens of thousands of times more powerful than the ability of the oxygen gas. Applied research is to treat waste laboratory provides the ability to reduce the value of Biological Oxygen Demand (BOD) and the value of Chemical Oxygen Demand (COD) is excellent. Furthermore, the results of the study made a laboratory waste processing equipment. The result is a waste processing equipment that looks simple, compact, can be developed and operated at a low cost, and very likely apply to small industrial and household waste that has high value on BOD and COD.

### Keywords

*Waste Water, Waste Water Processing equipment, Ozone, ultraviolet-C (UV-C), small industries.*

### 1. INTRODUCTION

A major problem in the treatment of industrial waste household and small industrial waste processing unit is priced relatively high and the way the operation that requires certain skills. The problems should be solved or small industrial activities and cottage industries in Indonesia will not process the waste generated from their activities. One possible waste treatment system that's cheap and easy to operate is based on ozone treatment system combined with ultraviolet-C light. Unfortunately, this waste processing unit, not yet available in small sizes. The smallest treatment unit using ozon-ultraviolet process can be found in 'five star' hotel activities.

On the other hand, technology-based provider of drinking water reverse osmosis process, also provides ultraviolet light and ozone generator for sterilization system. That is, the availability of spare parts to set up a waste processing unit for household and small industries . As the reactor, can be used poly vinyl chloride (PVC) pipe. It is recommended to use a high-quality PVC. At this experiment, the spare parts used are UV-C lamps 6 Watts, ozone generator 15 Watt with capacity of 0.45 grams per hour, and Wavin brand PVC with diameter 4 inches.

Having been studied the oxidation power of UV-Ozon to oxidize sulfonated poliaz black pigment. This study conducted aeration experiment on black ink solution of ink jet printer based on sulfonated poliaz pigment. The aeration proses was conducted by three treatments. The first aeration treatment was done with air. The aeration process on the second treatment

was done with air which was flowed through ozon generator. Then, the third treatment of the aeration process was conducted with air which was flowed through ozon generator and shone by UV-C light. The aeration process used air without ozon could not fade the colour ink, so it indicated that sulfonazied pigment poliazo could not be oxidized with air. On the other hand, the aeration process used with the mixture of air and ozon could increase the oxidation power up to multiple ten times. If it used UV-C light, the air's oxidation power mixed with the oxon would increase much higher. The ability of Ozone and Ultraviolet-C (UV-C) to oxidize poliazo sulfonated pigment (black ink inkjet printer) tens of thousands of times more powerful than the ability of the oxygen gas. In subsequent experiments, ozone and ultraviolet-C rays are combined to form a small reactor to treat wastewater from a laboratory study at the Academy of Chemical Analysis Bogor. The reactor showed excellent performance in the lower values of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The results of this research into the basic planning of waste treatment equipment that is simple and inexpensive for small industries or home industries.

At the end of the study is to create an industrial waste treatment reactor design small and cottage industries. This design should be equipped with waste water pH control unit for inlet and sediment filter unit for outlet. Initial experiments have given satisfactory results. The problem that remains is to adjust the size of the equipment with the load of the wastewater .

## 2. THE EXPERIMENT

### 2.1. Preliminary Experiment

The first experiment using three measuring glass as a reactor with a capacity of 2000 mL. Prepared three measuring glass. The three pieces measuring glass filled with 1800 ml of black ink solvent ink-jet-based poly-azo sulfonated with concentrations of 0.1%. Also prepared three ozone reactor. The first ozone generators, only the air pump activated , while the ozone generating unit is deactivated by cut off the electrical wire. The first measuring glass supplied air without ozone. The second measuring glass supplied air from ozone generators but not shone by ultraviolet-C light. Only a third measuring cup presented to the ultraviolet-C light . The first experimental equipment can be seen in Figure 1

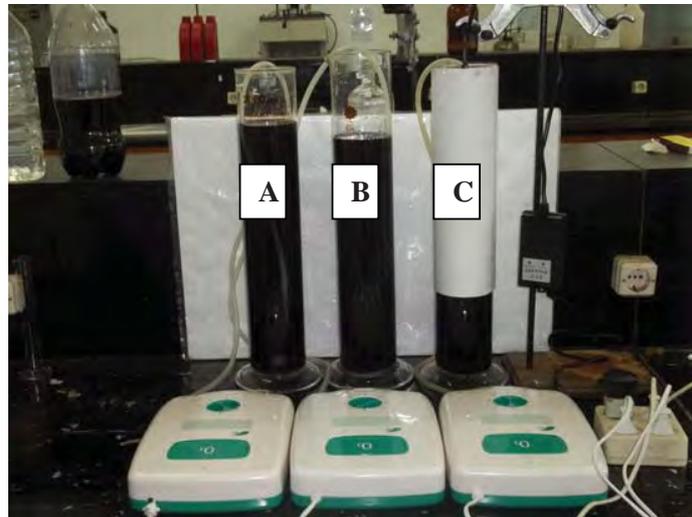


Figure 1: The first experimental equipment

The ultraviolet-C is a very dangerous light, so the third measuring glass (on the right), covered by aluminum foil and carton. The ultraviolet-C lamp used in this experiment is the small one use in ordinary reverse osmosis for home appliance. The power consumption is 6 watt with two peak of radiation at 253.7 nm (90%) and 185.0 nm (10%). The ozone generator also from ordinary reverse osmosis for home appliance with 13 watt power consumption equal to 0.4 g ozone per hour.[1] Physical appearance of these two main components can be seen in Figure 2A and 2B.

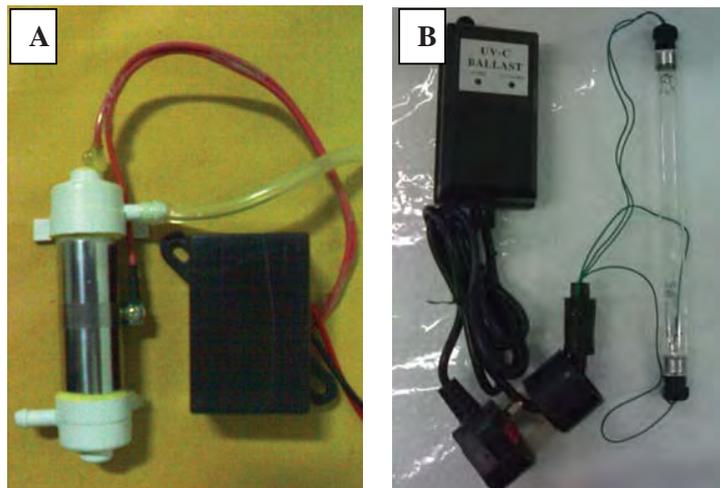


Figure 2 A: Ozone Generator and 2B. Ultraviolet Lamp

## 2.2. Second Experiment

In the second experiment, the process is run in a reactor made from Poli-vinyl Chloride Pipe. The inlet and the outlet use 0,125 inch connector. Air diffuser is made from a ceramic filter. Experiment processes perform by flowing 50 liter educational laboratory waste water through the reactor. The speed of flow relatively low i.e. about 0.5 liter per minute. The set of ultraviolet lamp and the ceramic air diffuser can be seen on Figure 3.

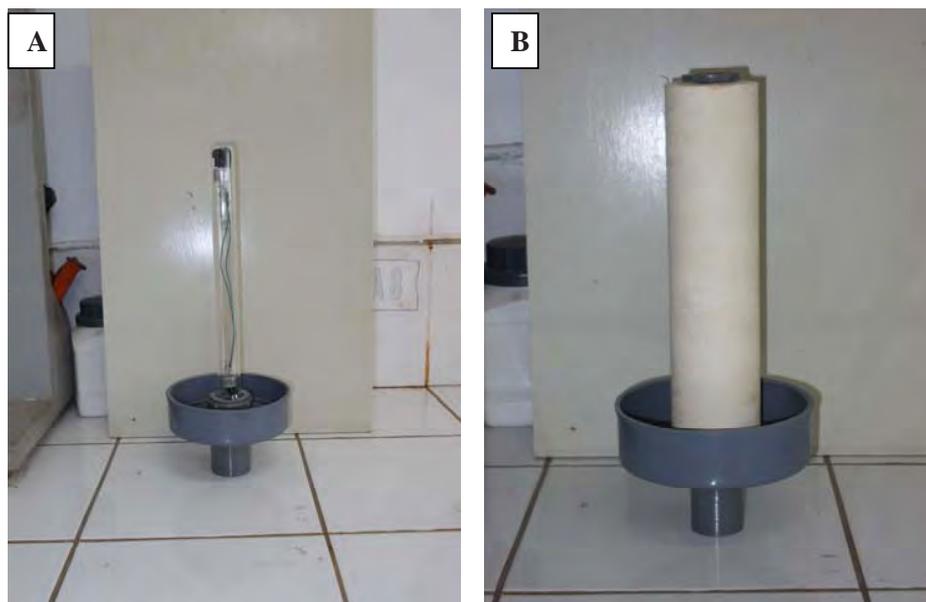


Figure 3: A Ultraviolet Lamp. B. Air Diffuser

In the reactor configuration, air diffuser placed in the bottom and the ultraviolet lamp on the top of the reactor. The reactor placed upright. Inlet placed in the bottom and outlet placed in the top. Inlet connected to reservoir of waste water with 19 liter (5 gallons) capacity. Outlet connected to a sediment filter. Treated water collected to a second 19 liter bottle. All of the experiments configuration (minus bottle) can be seen on Figure 4.



Figure 4: Complete Experimental Configuration.

### 3. RESULT AND DISCUSSION

#### 3.1. Preliminary Experiment

##### 3.1.1. Results

The first step of the experiment showed an extremely fast oxidation process on measuring glass, air flow and exposed to ozone and ultraviolet light. Comparison of black ink color density poly-azo sulfonated pigment measuring glass in the third, after a process lasting for 3 (three) hours, can be seen in Figure 5. While the color density measurement results, using color comparison method Nessler provide data as listed in Table 1.

**T : 0 minute**



**T : 60 minutes**



**T: 120 minutes**



**T: 180 minutes**



Figure 5: Photograph of the three measuring flask after 3 hours processes  
 A.: by air. B: by air and ozone. C. by air, ozone, and ultraviolet-C light.

Table 1: Measurement results Remaining Poly-azo sulfonated pigment

No	Treatment trial	Color concentration (%)		
		replication 1	replication 2	average
1.	Irradiation UV-C	96*	99*	97,5*
2.	Air Aeration	97*	98*	97.5*
3.	Air Aeration + Ozon	3,0	2,6	2,8
4.	Air Aeration + Ozon + UV-C	0,39	0,37	0,38
5.	Air Aeration + Ozon + UV-C using UV reactor	88,0	93,0	90,5

\*highly inaccurate readings due to differences color can not be seen clearly

### 3.1.2. Discussion

Ozone, O<sub>3</sub>, also called tri-oxygen, is tri-atomic molecule consisting of three oxygen atoms. This material is allotropi oxygen is extremely unstable when compared with in-atomic allotropi (O<sub>2</sub>). In the lower atmosphere, ozone is a pollutant air with damaging effects the respiratory system of animals and will burn sensitive plants. In the upper layers of the atmosphere, where ozone even at low concentrations is very useful to avoid damaging ultraviolet rays, preventing it from reaching the earth's surface [1]

Ozone can be made using ozone generators, the most popular being used in almost every industry that uses ozone is the charge corona-discharge method, using the discharge tube. This method changes the oxygen in the air to produce ozone and nitrogen oxides as a by-product. As a result, if used moderately moist air, will also be produced nitric acid. Two ozone generators are widely used vacuum ultraviolet ozone generator (V-UV, vacuum ultra-violet). This method uses a light source that produces narrow-spectrum ultraviolet light and short berlamdha, as produced by the sun. Vacuum ultraviolet rays from the sun is what keep the ozone layer in the atmosphere in order to stay there. This method produces ozone at concentrations of about 0.5% or lower and it takes a relatively longer exposure. Another method is the technique of cold plasma. In this method, pure oxygen is exposed to a plasma generated by dielectric barrier discharge of. Diatomic oxygen will break down into single atoms that then recombine to form ozone triplet. This method requires pure oxygen gas as a feedstock and produces a maximum concentration of about 5% ozone. In the process of making these ozone, oxygen allotropi also produced a short-lived, but more reactive than ozone as O<sub>4</sub>, O<sub>5</sub>, O<sub>6</sub>, O<sub>7</sub>, and so on. [2]. These experiments using vacuum ultraviolet ozone generators techniques. That is, the use of ultraviolet-C reactor, will strengthen the formation of ozone produced by the generator. This condition causes an increase in the use of ozone reactivity.

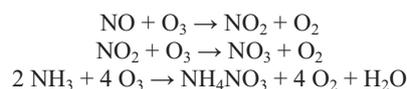
## 3.2. Second Experiment

### 3.2.1. Results

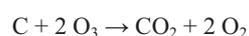
Experiments using ozone and ultraviolet-C reactor to treat laboratory waste of academy of chemical analysis Bogor, obtained as the following results ∴ COD value dropped from about 750 ppm to about 10 ppm. In this experiment it was observed that the production of waste water is not constant while the processing is constant. To adjust with fluctuations in the wastewater stream, need to complete the waste treatment unit with the container receptacle.

### 3.2.2. Discussion

Ozone is able to destroy and oxidize micro-organisms such as fungi, bacteria, and viruses. Ozone molecules that have reacted return to form oxygen gas. Ozone not only destroys micro-organisms, but also destroy the cosmetic ingredients, urine, cream, and oil. [3]. Ozone is also able to oxidize most metals and metal compounds. That can not be oxidized by ozone are gold, platinum, and iridium. Ozone can also oxidize NO to NO<sub>2</sub> gas and further oxidize NO<sub>2</sub> to NO<sub>3</sub> follow the following equation:

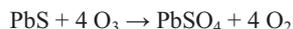


Ozone does not react with ammonium salts, but oxidize ammonia to Ammonium Nitrate  
 Ozone reacts with carbon to form carbon dioxide, even at room temperature

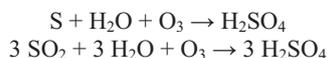


Reaction with sulfur compounds (sulfur)

Ozone oxidize sulfides to sulfates. For example, Pb (II) Sulfide oxidized to Pb (2) Sulfate:



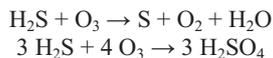
Sulfuric acid can be produced from ozone, water and elemental sulfur or sulfur dioxide



In the gas phase, ozone reacts with sulfide to form sulfur dioxide Hidrigen:

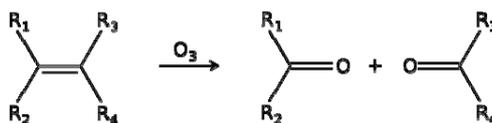


If the above reactions occur in the water, the two reactions will occur simultaneously, one producing elemental sulfur, and other produce sulfuric acid.



#### Reaction with alkenes and alkynes

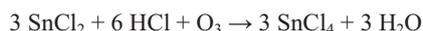
Alkenes can be cleaved by oxidation by ozone, producing alcohols, aldehydes, ketones, and carboxylic acids, depending on the reaction of the two stage



Usually ozonolysis process carried out in dichloro-methane solution at a temperature of -78°C. After cleavage and rearrangement process, will form a ozonide-organic. By the end of the reaction is reductive, (eg Zn in acetic acid or dimethyl-sulfide), will produce ketones and aldehydes. By the end of the oxidative reactions (eg in water or alcohol, air-hydrogen peroxide), will be formed carboxylic acids. [1]

#### Other reactions

All (three) atoms in the molecule of ozone can react, as the reaction with tin (II) chloride with hydrochloric acid and ozone:



Perchlorate iodine can be made by treating iodine dissolved in anhydrous perchloric acid with ozone:



## 4. CONCLUSION

Experiments using ozone and ultraviolet-C reactor to treat laboratory waste of academy of chemical analysis Bogor, obtained as the following results: Chemical Oxygen Demand value dropped from about 750 ppm to about 10 ppm. The reactor showed excellent performance in the lower values of Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The result is a waste processing equipment that looks simple, compact, can be developed and operated at a low cost, and very likely apply to small industrial and household waste that has high value on BOD and COD

## 5. RECOMENDATION

In this experiment, it was observed that the production of waste water is not constant while the processing is constant. To adjust with fluctuations in the wastewater stream, need to complete the waste treatment unit with the container receptacle.

## REFERENCES

- [1]. Wikipedia. 2011-b. *Ozone*. Wikipedia Foundation. Available at: <http://en.wikipedia.org/wiki/Ozone>. 21-02-2011. 20:15.
- [2]. DIY Trade. 2006. Aqua Ozone Generator Air/Water Purifier (SY-G30) Available at: [http://www.diytrade.com/china/pd/2025827/Aqua\\_Ozone\\_Generator\\_Air\\_Water\\_Purifier\\_SY\\_G30.html](http://www.diytrade.com/china/pd/2025827/Aqua_Ozone_Generator_Air_Water_Purifier_SY_G30.html)
- [3]. Blue Lagoon. ---. *Ozon Plus UV-C*. Blue Lagoon UVC. Groningen. Nederland. Available at: [http://www.blue-lagoon-uv-c.com/blue-lagoon-ozone-uv-c/ozon-uv-c-70-000-ltr-/prod\\_4.html](http://www.blue-lagoon-uv-c.com/blue-lagoon-ozone-uv-c/ozon-uv-c-70-000-ltr-/prod_4.html) 12-02-2011. 07:02.

# Photocatalytic degradation of C.I. Reactive Red 2 by using TiO<sub>2</sub>-coated PET plastic under solar irradiation

TutyEmilia Agustina<sup>a,\*</sup>, FitriSuryani Arsyad<sup>b</sup>, and MikrajuddinAbdullah<sup>c</sup>

<sup>a</sup>Chemical Engineering Department Sriwijaya UniversitySouth Sumatera, Indonesia

<sup>b</sup>Physics Department Sriwijaya UniversitySouth Sumatera, Indonesia

<sup>c</sup>Physics Department Bandung Technology InstituteIndonesia

\*tutycurtin@yahoo.com, tuty\_agustina@unsri.ac.id

## ABSTRACT

The synthetic dyes are a refractory and poisonous material. Most of industrial textile today used the synthetic dyes that can be dangerous to the environment because of the colored wastewater produced from their processes. This study concentrates on the application of Advanced Oxidation Processes (AOPs) for synthetic dyes wastewater treatment. Photocatalysis process as one of AOPs was applied for the degradation of organic content of synthetic dyes wastewater. The reactive dye, C.I. Reactive Red 2 (RR 2) was used as the organic pollutant model at the concentration of 100 mg/l. The TiO<sub>2</sub> concentration of 0.05-0.4 g/ml was used as the photocatalyst. The bulk and nano-size of TiO<sub>2</sub> were coating on the PET plastic and the degradation of organic content was examined in the term of color and COD within 0-12 hrs under solar irradiation. By using 0.4 g/ml of bulk TiO<sub>2</sub>, the color degradation of 88% and COD removal of 46% was achieved. Furthermore, by using 0.4 g/ml of nano-size TiO<sub>2</sub>, the enhancement of color degradation and COD removal was observed, that is 98% and 56%, respectively.

## Keywords

*Advanced Oxidation Processes (AOPs), Dyes wastewater, Synthetic dyes, Photocatalysis process, Solar irradiation*

## 1. INTRODUCTION

Annually, textile industries produce a large volume of colored dye effluents which are toxic and non-biodegradable. The color of the effluent released into the water bodies has become a serious environmental problem. This situation was indicated by a lot of minimization and remediation programs around the world has become as one of the most important environmental tasks associated to this area.

Because of the refractory nature of the color of synthetic dyes, conventional biological treatment processes are ineffective, and adsorption and coagulation practices result in secondary pollution[1]. On the other hand, a more promising technology based on advanced oxidation processes (AOPs) has been studied widely for decolorization and degradation of textile dyes. Among the AOPs method, heterogeneous photocatalysis using UVilluminated Titanium dioxide (TiO<sub>2</sub>) semiconductor has received great attention due to its ability to degrade a number of organic and inorganic pollutants [2, 3]. Although TiO<sub>2</sub> suspensions yield higher reaction rates, the use of photocatalyst coated on material surfaces is necessary because the need for separation of TiO<sub>2</sub> from the reacted solutions can be avoided and they would allow application of photocatalysis. By using the sunlight solar photocatalysis has been an intensive area of research [4-6], where the use of large area TiO<sub>2</sub>-coated surfaces is very important.

Nano-scale semiconductors, for instance TiO<sub>2</sub> particles, have a higher surface area-to-volume ratio than their equivalent bulk, and thus allow for greater photon absorption on the photocatalyst surface. Moreover, recombination of the electron hole pair within the semiconductor particle is drastically reduced as particle size decreases. With decreasing particles size of semiconductor to nanometer-scale, the band gap energy greatly increased, which in turn led to higher redox potentials in the system. Therefore, the nano-scale semiconductor is expected to have higher photocatalytic activity than its bulk [7, 8]. Many study have also reported various methods to apply TiO<sub>2</sub> coating on various substrates[9]. TiO<sub>2</sub> was immobilized on ceramic [10], fiber glass[11], sand[12], rigid support (glass, quartz, and stainless steel)[13], pebbles [14], activated carbon[15], polystyrene beads[16], zeolites[17], and acrylic plastic [18]. The TiO<sub>2</sub> immobilized substrates have been successfully used for the photocatalytic degradation of several organic pollutants. However, to the best of our knowledge, the use of thermoplastic polymer resin such as Polyethylene terephthalate (PET) plastic has been limited reported. In the present study the TiO<sub>2</sub>-coated PET plastic was prepared by using the bulk and the nano particle of TiO<sub>2</sub>. Photocatalytic degradation of reactive dye using TiO<sub>2</sub>-coated PET plastic and solar irradiation was investigated.

Reactive dyes have been recognized as the most environmental problematic compounds in textile dye effluents [19, 20]. Research on textile effluent degradation has focused on fiber reactive dyes [21] for the several reasons. First, reactive dyes are a class of dyes with high application rate in the textile industry due to their reactivity with fibers and their color stability [22].

Second, reactive dyes represent an integral market share (almost 45% of all textile dyes produced annually belong to the fiber reactive class). Third, these dyes have low fixation rates, which results in highly colored spent dye-baths whose treatment is insufficient in conventional wastewater treatment plants [23]. Fourth, of special concern is the reactive dyeing process, where on average of 10 times more water is consumed for preparation, dyeing, washing and rinsing stages than for dyeing with other dye types.

Table 1: Properties of C.I. Reactive Red 2

Dye	C.I. Reactive Red 2
Chemical formula	$C_{19}H_{10}Cl_2N_6Na_2O_7S_2$
Molecular weight (g/mol)	615
C.I. number	
$\lambda_{max}$ (nm)	18200
	538

In this study, one of synthetic textile dyes, C.I. Reactive Red 2 (RR2) selected as a model pollutant. The chemical formula and some properties of the reactive dye are presented in Table 1. This type of dye was selected for current study since the chemical structure is known and the dye is frequently being applied for the dyeing of traditional cotton cloth in Indonesia.

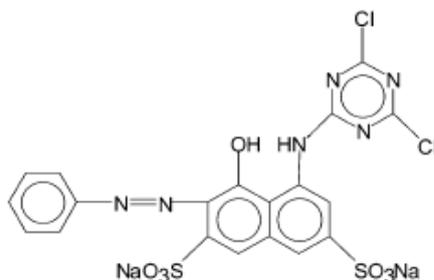


Figure. 1. Chemical structure of C.I. Reactive Red 2

The chemical structure of C.I. Reactive Red 2 can be illustrated in Fig. 1. A dye concentration of 100 mg/l was selected in the present study as previously reported [24-26] because the effluents originating from the cotton and polyamide dyeing factories are usually in the range of 10-200 mg/l and at this concentration the COD value is more than 150 mg/l, beyond the environmental quality standard of industrial wastewater effluent in Indonesia.

The use of solar energy to initiate the photodegradation of some organic pollutants, such as textile effluents, has been widely reported [27]. Although solar energy is a free, renewable and environmentally friendly energy source, it is not widely used in tropical countries like Indonesia. The objective of the research is to study the degradation of C.I. Reactive Red 2 by using the  $TiO_2$ -coated PET plastic under solar irradiation in the term of color and COD degradation.

## 2. MATERIALS AND METHOD

The synthetic dye wastewater was prepared by using C.I Reactive Red 2 (RR 2) obtained from FajarSetia Dyestuff in Jakarta and was used without further purification. The RR2 concentration was varied between 25-110 mg/l. The  $TiO_2$  anatase powder (bulk) and  $TiO_2$ anatase nano-powder were received from Sigma–Aldrich. Solvent (acetone) and adhesive was found from the chemical store.

The coating process was accomplished by mixing the  $TiO_2$ catalyst with acetone in the 300 ml beaker glass. The catalyst concentration was varied from 0 to 0.4 g/ml. The certain amount of catalyst was dissolved in 10 ml of acetone until a homogeneous solution recognized. Add the cyanoacrylate adhesive to the solution and stir slowly, followed by putting the PET plastic then stir until the thick solution obtained. Take the coated PET plastic immediately and place in the room air. Allow the PET plastic dry in the room temperature.

The solarphotocatalytic degradation was carried out in batch operation in a cylinder glass type of reactor. The reactor capacity is 300 ml with 7 cm of inside diameter and 9 cm of height. RR2 dye solution was prepared in distilled water, within the concentration of 25-100 mg/l For every experiment performed, the reactor was initially loaded with 250 ml of RR2 aqueous solution, after putting  $TiO_2$ -coated PET plastic, the color and COD degradation were observed every 3 hrs between 9 am and 3 pm under the sunlight for 2 days. The reactor was retained in the dark place when the experiment pending.

The TiO<sub>2</sub> particles catalysts were characterized by X-ray diffraction (XRD) and scanning electron microscope (SEM). The crystalline phases were determined using an X-ray diffractometer measurement (PC-APD Philip) with Cu tube anode, operated at 40 kV and 30 mA. A Scanning Electron Microscope (SEM), JEOL SEM-330 JAPAN was used to examine the surface morphology of TiO<sub>2</sub> coated PET plastic. Color degradation was measured by HACH Spectrophotometer and COD degradation was determined by titrimetric method. Degradation percentage of dye is defined as follows:

$$\text{Color degradation percentage} = ((C_o - C_t) / C_o) \times 100\% \quad (1)$$

Where  $C_o$  (mg/l) is the initial concentration of dye, and  $C_t$  (mg/l) is the concentration of dye at reaction time  $t$ (hr). The degradation of COD is represented by (2):

$$\text{COD degradation percentage} = ((COD_o - COD_t) / COD_o) \times 100\% \quad (2)$$

Where  $COD_o$  (mg/l) is the initial concentration of COD, and  $COD_t$  (mg/l) is the concentration of COD at reaction time  $t$ (hr).

### 3. RESULTS AND DISCUSSION

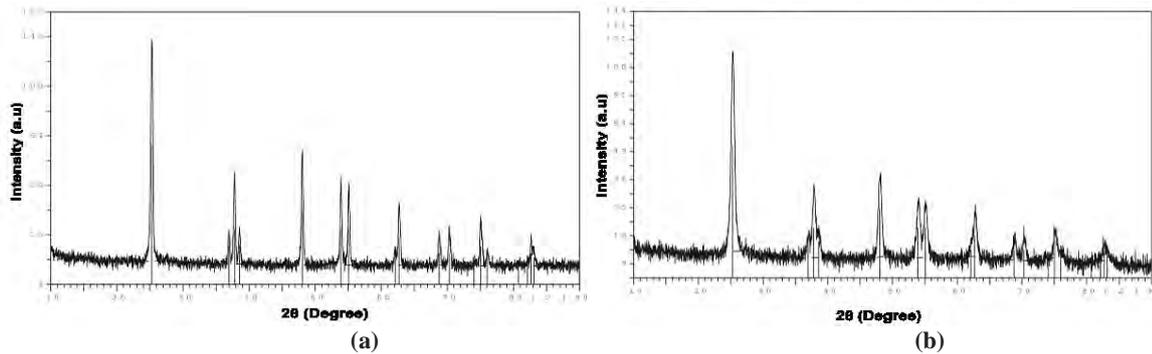


Figure 2: XRD patterns of (a) bulk-TiO<sub>2</sub> (b) nano-TiO<sub>2</sub> powder as-prepared

Figure 2 displays the X-ray diffraction pattern of bulk and nano-TiO<sub>2</sub> particles. It exhibits good crystallinity and all characteristic lines are attributed to the anatase phase in an excellent agreement with a reference pattern[28]. The average crystallite size of bulk and nano TiO<sub>2</sub> sample calculated from XRD line broadening using Scherrer equation is and 51 nm and 37 nm, respectively.

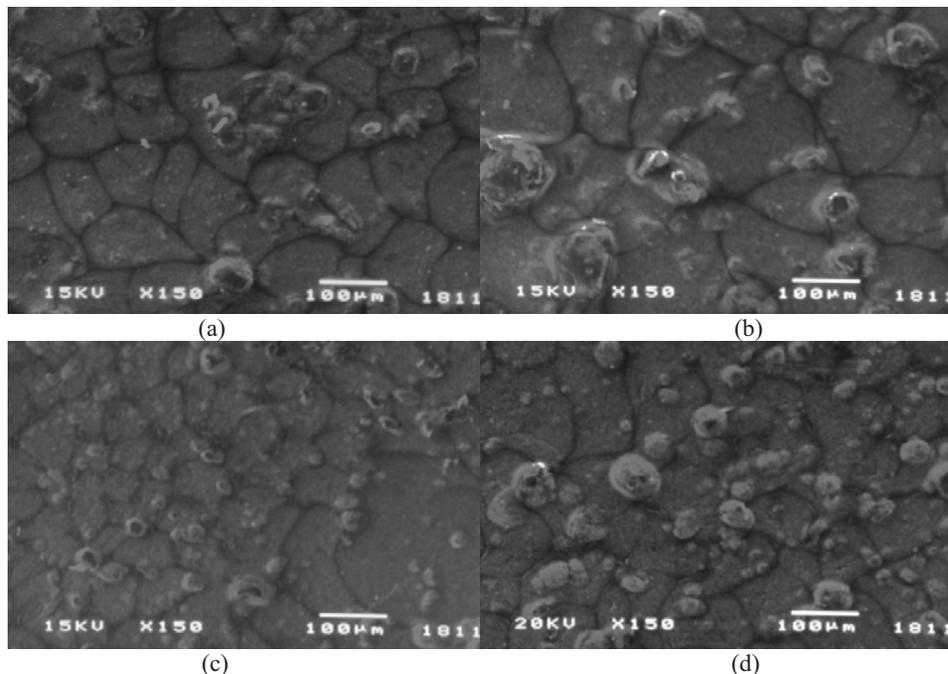


Figure 3. SEM images of TiO<sub>2</sub> anatase powder-coated PET plastic by using the concentration of (a) 0.05 g/ml, (b) 0.1 g/ml, (c) 0.2 g/ml, and (d) 0.4 g/ml

Photocatalysis process was studied by using the coated anatase powder and anatase nano-powder  $\text{TiO}_2$  catalyst on the PET plastic. Concentration of the catalyst used was varied 0, 0.05, 0.1, 0.2, and 0.4 g/ml. By increasing the catalyst concentration, more aggregates of  $\text{TiO}_2$  particles were observed in the SEM image as shown in Fig. 3 (a)-(d).

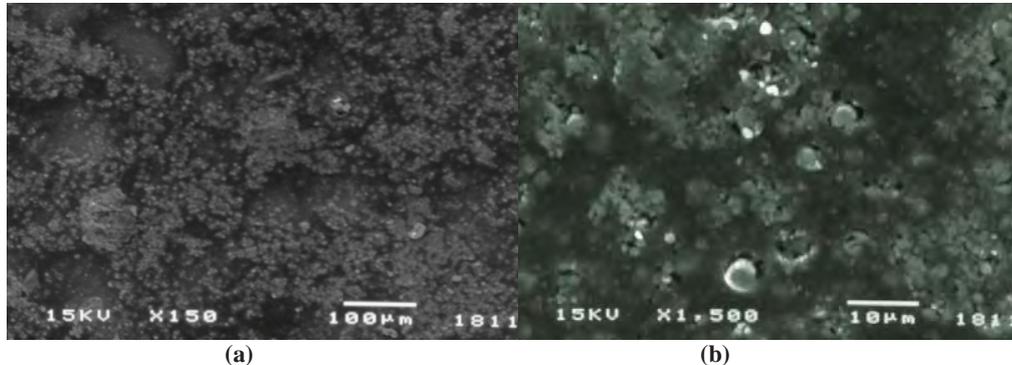


Figure 4. SEM images of  $\text{TiO}_2$  anatase nano-powder-coated PET plastic by using the concentration of 0.4 gr/ml (a) 150 times and (b) 1500 times of magnitude

It is obvious that when use the same concentration of  $\text{TiO}_2$  but with different  $\text{TiO}_2$  crystallite size, the different surface morphology observed as demonstrated in Fig. 3 (d) and Fig.4 (a). By means of the same magnitude of 150 times, the application of anatase nano powder shows more fine aggregate and homogeneity of particles formed than the application of anatase powder.

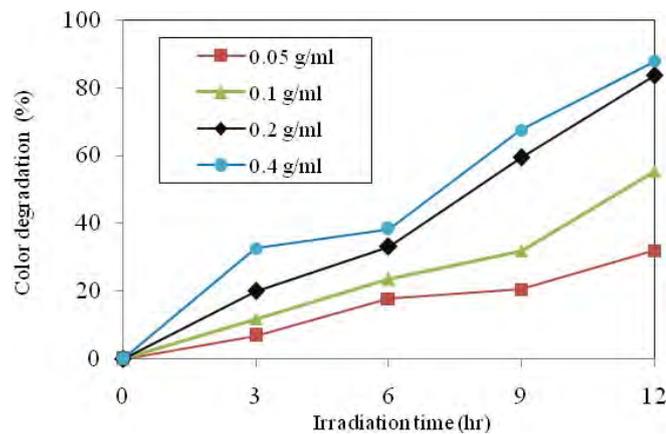


Figure 5. Effect of anatase powder  $\text{TiO}_2$  concentration on the color degradation percentage

The effect of catalyst concentration on the color degradation of RR2 can be illustrated in Fig. 5. In the experiment without using catalyst, there was no color degradation detected. The color degradation percentage increases with increasing catalyst concentration and irradiation time. The highest color degradation of 88% was achieved when use 0.4 g/ml of anatase powder  $\text{TiO}_2$ , as can be seen in the figure. The dosage of  $\text{TiO}_2$ -catalyst plays an important role in the photocatalytic decolorization of dyes [29]. Because the more the amount of catalyst the more of catalyst surface available to the photodegradation reaction take place.

By using the same catalyst concentration of 0.4 g/ml, the higher color degradation percentage was reached when apply the anatase-nano powder  $\text{TiO}_2$ . Almost complete of color degradation was monitored as presented in Fig. 6. Clearly the anatase-nano powder  $\text{TiO}_2$  has the higher effectiveness than anatase-powder  $\text{TiO}_2$ . It can be explained as the nano-structure of catalyst possesses the larger surface area so provide the more active surface to the reaction.

The photocatalytic activity of nano- $\text{TiO}_2$  was accounted to be higher than micron  $\text{TiO}_2$  (Degussa P25) in the degradation of active brilliant red X-3B [30]. Similar findings have been reported in the solar nanophotocatalytic decolorisation of Procion Reactive Red (H-E7B) and Procion Reactive Yellow (H-E6G), that the photocatalytic activity of nano- $\text{TiO}_2$  was found to be almost two times higher than that of micron- $\text{TiO}_2$  [31].

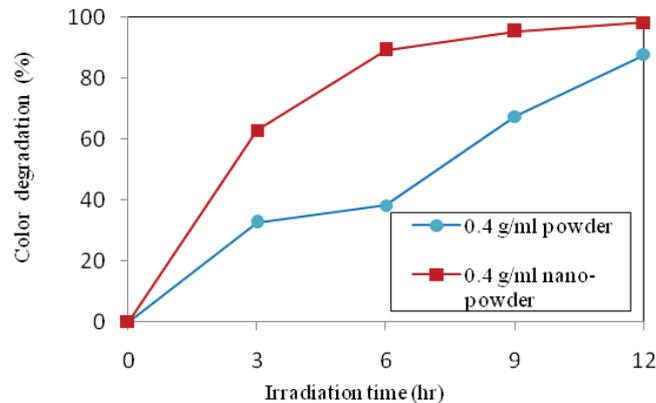


Figure 6. Color degradation of anatase powder and anatase nano-powder of TiO<sub>2</sub>

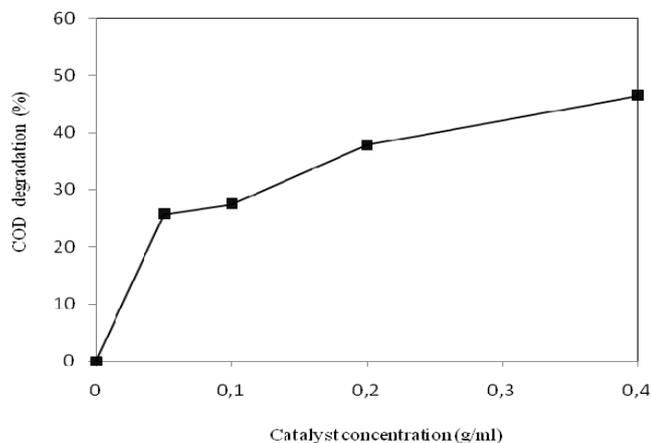


Figure 7. Effect of anatase powder TiO<sub>2</sub> catalyst concentration on COD degradation percentage

The pollutant degradation in the term of COD degradation percentage in the photocatalysis process under the sunlight by using the TiO<sub>2</sub>-coated PET plastic can be reported as exhibited in Fig.7. There was no COD degradation identified without the use of any catalyst. The COD degradation percentage increases with increasing the catalyst concentration. This result is in agreement with Neppolian et al. who conducted the study on solar/UV induced photocatalytic degradation of commercial textile dyes[31]. For the Reactive Yellow 17 (RY 17) dye, they found the percentage degradation of COD increases with the increase in the amount of TiO<sub>2</sub>. But further increase in the amount of TiO<sub>2</sub> from 500 to 600 mg in RY17, the percentage degradation decreases. Although the availability of active sites increases with the suspension of catalyst loading, but not the light penetration, hence the photo activation blocked.

The COD degradation of 46 % was achieved when using 0.4 g/ml of anatase powder TiO<sub>2</sub>. Furthermore, the COD degradation of 56 % was reached when using 0.4 g/ml of anatase nano-powder TiO<sub>2</sub>. The treatment of RR2 dye by photocatalysis process using nano-TiO<sub>2</sub> coated on PET plastic has been fulfilled the requirements of environmental quality standard of industrial wastewater effluent in Indonesia particularly in color and COD parameter. It reduced the color from 1750 to 30 pt-Co and the COD from 191 to 94 mg/l.

## CONCLUSION

The study of RR2 degradation under solar irradiation assisted by the TiO<sub>2</sub> catalyst-coated PET plastic was examined. It is found, by using 0.4 g/ml of bulk TiO<sub>2</sub>, the color degradation of 88% and COD removal of 46% was achieved. Furthermore, by using 0.4 g/ml of nano-size TiO<sub>2</sub>, the enhancement of color degradation and COD removal was observed, that is 98% and 56%, respectively. The results suggest that the use of solar irradiation could be a feasible technique for degradation of reactive dye sample.

## ACKNOWLEDGMENT

The authors would like to express gratitude the Directorate General of Higher Education Ministry of Culture and Education Republic of Indonesia for financial support through HIBAH BERSAING 2012.

## REFERENCES

- [1] A.B. Fang Han, R. Venkata Subba, A.B. Kambala, C. Madapusi Srinivasan, C. Dharmarajan Rajarathnam, and A.B. Ravi Naidu, Tailored titanium dioxide photocatalyst for the degradation of organic dyes in wastewater treatment : a review: *Applied Catalysis A*. Vol. 359 (2009), p. 25-40.
- [2] A. Adesina, Industrial Exploitation of Photocatalysis : Progress, Perspectives and Prospects: *Catal. Surv. Asia*. Vol. 8 (2004), p. 265-273.
- [3] S. Kwon, M. Fan, A. Cooper, and H. Yang, Photocatalytic Applications of Micro- and Nano- TiO<sub>2</sub> in Environmental Engineering: *Crit. Rev. Env. Sci. Technol.* Vol. 38 (2008), p. 197-226.
- [4] S. Malato, J. Blanco, A. Vidal, and C. Richter, Photocatalysis with Solar Energy at a Pilot-plant Scale : An Overview: *Appl Catal. B*. Vol. 37 (2002), p. 1-15.
- [5] E. Bandala and C. Estrada, Comparison of Solar Collection Geometries for Application to Photocatalytic Degradation of Organic Contaminants: *J. Sol. Energy Eng.* Vol. 129 (2007), p. 22-26.
- [6] D. Bahnemann, Photocatalytic Water Treatment : Solar Energy Applications: *Sol. Energy*. Vol. 77 (2004), p. 445-459.
- [7] K. Dai, H. Chen, T. Peng, D. Ke, and H. Yi, Photocatalytic degradation of methyl orange in aqueous suspension of mesoporous titania nanoparticles: *Chemosphere*. Vol. 69 (2007), p. 1361-1367.
- [8] Y. Liu, X. Chen, J. Li, and C. Burda, Photocatalytic degradation of azo dyes by nitrogen-doped TiO<sub>2</sub> nanocatalysts: *Chemosphere*. Vol. 61 (2005), p. 11-18.
- [9] R. Pozzo, M. Baltanas, and A. Cassano, Supported Titanium Dioxide as Photocatalyst in Water Decontamination : State-of-Art: *Catal. Today*. Vol. 39 (1997), p. 219-231.
- [10] J. Määttä, M. Piispanen, H.R. Kymäläinen, A. Uusi-Rauva, K.R. Hurme, S. Areva, A.M. Sjöberg, and L. Hupa, Effects of UV-radiation on the cleanability of titanium dioxide-coated glazed ceramic tiles: *Journal of the European Ceramic Society*. Vol. 27 (2007), p. 4569-4574.
- [11] C.H. Ao, S.C. Lee, and J.C. Yu, Photocatalyst TiO<sub>2</sub> supported on glass fiber for indoor air purification: effect of NO on the photodegradation of CO and NO<sub>2</sub>: *Journal of Photochemistry and Photobiology A: Chemistry*. Vol. 156 (2003), p. 171-177.
- [12] R. Matthews, Photooxidative Degradation of Coloured Organics in Water Using Supported Catalyst TiO<sub>2</sub> on Sand: *Water Res.* Vol. 25 (1991), p. 1169-1176.
- [13] A. Fernandez, G. Lasalletta, V. Jimenez, A. Justo, A. Gonzalez-Ellipe, J. Herrmann, H. Tahiri, and Y. Ait-Ichou, Preparation and Characterization of TiO<sub>2</sub> Photocatalysts Supported on Various Rigid Supports (Glass, Quartz and Stainless Steel). Comparative Studies of Photocatalytic Activity in Water Purification.: *Appl Catal. B*. Vol. 7 (1995), p. 49-63.
- [14] N. Rao and V. Chaturvedi, Photoactivity of TiO<sub>2</sub> Coated Pebbles: *Ind. Eng. Chem.* Vol. 46 (2007), p. 4406-4414.
- [15] Y. Gao and H. Liu, Preparation and Catalytic Property Study of a Novel Kind of Suspended Photocatalyst of TiO<sub>2</sub>-activated Carbon Immobilized on Silicone Rubber Film: *Mater. Chem. Phys.* Vol. 92 (2005), p. 604-608.
- [16] M. Fabyi and R. Skelton, Photocatalytic Mineralisation of Methylene Blue Using Buoyant TiO<sub>2</sub>-coated Polystyrene Beads: *J Photochem Photobiol A*. Vol. 132 (2000), p. 121-128.
- [17] K. Hashimoto, K. Wasada, M. Osaki, E. Shono, K. Adachi, N. Touki, H. Kominami, and Y. Kera, Photocatalytic Oxidation of Nitrogen Oxide Over Titania Zeolite Composite Catalyst to Remove Nitrogen Oxides in the Atmosphere: *Appl Catal. B*. Vol. 30 (2001), p. 429-436.
- [18] N.R. Neti and P. Joshi, Cellulose reinforced-TiO<sub>2</sub> photocatalyst coating on acrylic plastic for degradation of reactive dyes: *J. Coat. Technol. Res.* Vol. 7 (2010), p. 643-650.
- [19] J. Garcia-Montano, N. Ruiz, I. Munoz, X. Domenech, J.A. Garcia-Hortal, F. Torrades, and J. Peral, Environmental assessment of different photo-Fenton approaches for commercial reactive dye removal: *J. Hazard. Mater. A*. Vol. 138 (2006), p. 218-225.
- [20] C.S. Papic, C.D. Vujevi, N. Koprivanac, and D. Sinko, Decolorization and mineralization of commercial reactive dyes by using homogeneous and heterogeneous Fenton and UV/Fenton processes: *J. Hazard. Mater.* Vol. 164 (2009), p. 1137-1145.
- [21] H. Kusic, A.L. Bozic, and N. Koprivanac, Fenton type processes for minimization of organic content in coloured wastewaters: Part I: Processes optimization: *Dyes and Pigments*. Vol. 74 (2007), p. 380-387.
- [22] R.S. Sreedhar and B. Kotaiah, Decolorization of simulated spent reactive dye bath using solar/TiO<sub>2</sub>/H<sub>2</sub>O<sub>2</sub>: *Int. J. Environ. Sci. Tech.* Vol. 2 (2005), p. 245-251.
- [23] J.R. Easton, in: *The dye maker's view* edited by Cooper P, in : *Colour in Dyehouse Effluent*, The society of Dyers and Colourists, Alden Press (1995).
- [24] M.S. Lucas, A.A. Dias, A. Sampaio, C. Amaral, and J. Peres, Degradation of a textile reactive azo dye by a combined chemocatalytic process: Fenton's reagent-yeast: *Water Res.* Vol. 41 (2007), p. 1103-1109.
- [25] N. Tantak and S. Chaudari, Degradation of azo dyes by sequential Fenton's oxidation and aerobic biological treatment: *J. Hazard. Mater.* Vol. B136 (2006), p. 698-705.
- [26] C. O'Neill, F.R. Hawkes, D. Hawkes, N.D. Lourenco, H.M. Pinheiro, and W. Delee, Review colour in textile effluents e sources, measurement, discharge consents and simulation: a review: *J. Chem. Technol. Biotech.* Vol. 74 (1999), p. 1009-1018.
- [27] J.C. Garcia, J.I. Simonato, A.E. Carli da silva, J. Nozaki, and N. Evalzio de Souza, Solar Photocatalytic degradation of real textile effluents by associated titanium dioxide and hydrogen peroxide *Indian Journal of solar energy* Vol. 83 (2009), p. 316-322.
- [28] A. Khataee and G.A. Mansoori, in: *Nanostructured titanium dioxide materials : Properties, Preparation and Application* World Scientific Publishing Co.Pte.Ltd, Singapore (2012)

- [29] J. Jeni and S. Kanmani, Solar Nanophotocatalytic Decolorisation of Reactive Dyes Using Titanium Dioxide: Iran. J. Environ. Health. Sci. Eng. Vol. 8 (2011), p. 15-24.
- [30] M. Liqun, L. Qinglin, D. Hongxin, and Z. Zhijun, Synthesis of nanocrystalline TiO<sub>2</sub> with high photoactivity and large specific surface area by sol-gel method Materials Research Bulletin. Vol. 40 (2005), p. 201-208.
- [31] B. Neppolian, S.R. Kanel, H.C. Choi, M.V. Shankar, and V. Bsnunathi Arabindoo Murugesan, Photocatalytic degradation of reactive yellow 17 dye in aqueous solution in the presence of TiO<sub>2</sub> with cement binder. : Int. J. Photoenergy. Vol. 5 (2003), p. 45-49.

# Effect of Mixing on pH and Conductivity of NaHCO<sub>3</sub> and CaCl<sub>2</sub> Solutions and CaCO<sub>3</sub> Formation

Nelson Saksono <sup>\*</sup>), Yuliusman, Wilda Nur Puspita

Chemical Engineering Department, Faculty of Engineering, University of Indonesia, Depok 16424

<sup>\*</sup>)E – mail: nelson@che.ui.ac.id

## ABSTRACT

Hard water is water which contains high amount of Ca<sup>2+</sup> and HCO<sub>3</sub><sup>-</sup> ions and also many forms in nature. Hard water can cause the formation of crusts deposit in piping system and also can increase the detergent consumption in the washing process. The decrease of hardness can be done by pushing Ca<sup>2+</sup> and HCO<sub>3</sub><sup>-</sup> ions in hard water to precipitate into CaCO<sub>3</sub> by following the mixing process. The model of hard water used is solution of NaHCO<sub>3</sub> and CaCl<sub>2</sub> mixed by using mixer and equipped with rotary speed control. Variable measured are pH and solution conductivity by using pH meter and conductance meter in several mixer rotary speeds. The formation of CaCO<sub>3</sub> is measured by using EDTA complexometric titration. From this research, there is an increase of pH in NaHCO<sub>3</sub> solution by the increase of mixer rotary speed. The increase of NaHCO<sub>3</sub> solution's pH shows that there is migration of HCO<sub>3</sub><sup>-</sup> ions to be CO<sub>3</sub><sup>2-</sup> ions which can precipitate faster to form CaCO<sub>3</sub>. The mixing process can increase the NaHCO<sub>3</sub> and CaCl<sub>2</sub> solution conductivity which shows the decrease of hydrate ion's strength and may trigger the formation of CaCO<sub>3</sub>. The precipitation test result shows the increase of CaCO<sub>3</sub> formation because of the mixing process of NaHCO<sub>3</sub> and CaCl<sub>2</sub> solution. This result proves that the mixing of NaHCO<sub>3</sub> and CaCl<sub>2</sub> solution can increase the pH and conductance of solution, as well as the formation of CaCO<sub>3</sub>.

## Keywords

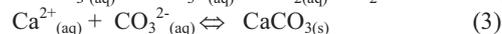
Mixing, CaCO<sub>3</sub> precipitation, Hydrate ion, Hard water

## 1. INTRODUCTION

Water contains a lot of Ca<sup>2+</sup> and HCO<sub>3</sub><sup>-</sup> ions are known as hard water. Calcium and Carbonate compounds are difficult to dissolve in water so that will separate from solution and form CaCO<sub>3</sub> particles which then produce crusts. Crusts in hard water can resist the flow of water in pipe and also can resist heat transfer process in heat exchanger equipment. The high of hardness can also cause the increase of detergent consumption, and also the formation of film layer in household equipment. CaCO<sub>3</sub> formation in hard water as CaCO<sub>3</sub> precipitation process is an equilibrium and slowing process. Increase of pH due to CO<sub>2</sub> release in solution will push precipitation of CaCO<sub>3</sub> as follow (equation 1) :



Saksono [1] found that mechanical agitation process on the CaCO<sub>3</sub> solution fastens the solute CO<sub>2</sub> to the gas phase so the pH solution will increase. The increasing of pH causes HCO<sub>3</sub><sup>-</sup> ion to be converted into CO<sub>3</sub><sup>2-</sup> ion and quickly create CaCO<sub>3</sub> as shown bellow (equation 2 and 3):



Ca<sup>2+</sup>, HCO<sub>3</sub><sup>-</sup>, and CO<sub>3</sub><sup>2-</sup> ions in hard water will be hydrated by polar water molecules as shown in Fig 1. The strength of ionic bonding with hydrate will influence the precipitation process.

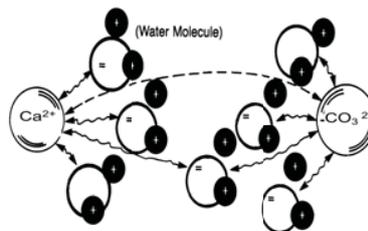


Figure 1: Ca<sup>2+</sup> dan CO<sub>3</sub><sup>2-</sup> ions and their hydrates

The hydrate ions bonding is low in strength and can be influenced by mechanical agitation process [2]. The decrease in hardness by pushing the  $\text{Ca}^{2+}$  and  $\text{HCO}_3^-$  ions to precipitate into  $\text{CaCO}_3$  can be done by mechanical agitation process. The mixing method is a method used in hard water which is cheap, simple, and also safe for human consumption compared to other method such as ion exchange resin or by the addition of  $\text{NaOH}$ . The process conceptual scheme to decrease the  $\text{Ca}^{2+}$  and  $\text{HCO}_3^-$  ions in hard water by using mixing and settling method has already proposed by Saksono [3] as shown in Figure 2 below.

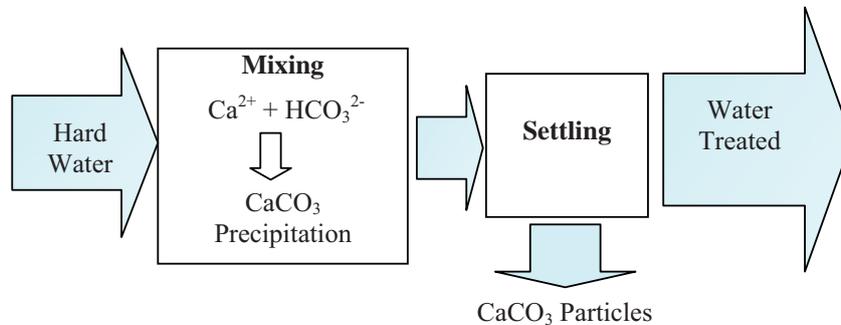


Figure 2: Schematic of mixing and settling process in hardwater treatment [3]

Hard water with high amount of  $\text{Ca}^{2+}$  and  $\text{HCO}_3^-$  ions is mixed in mixer until it precipitates to form  $\text{CaCO}_3$  particles. Hard water which has already mixed is then entered to agitation medium to be separated between water and  $\text{CaCO}_3$  particles. Answering how selective the mixing process can push the formation (precipitation) of  $\text{CaCO}_3$ , will be needed a preliminary study about the effect of mixing to the behavior of  $\text{Ca}^{2+}$  and  $\text{HCO}_3^-$  ions and also to the  $\text{CaCO}_3$  precipitation.

## 2. RESEARCH METHOD

This research used  $\text{CaCl}_2$  and  $\text{NaHCO}_3$  solution to observe the behavior of  $\text{Ca}^{2+}$  and  $\text{HCO}_3^-$  ions as hard water model by analyzing the change in pH and also solution conductivity.

The effect of mixing to pH and conductivity of each solution is observed separately in several rotation speed variations. Then,  $\text{CaCl}_2$  and  $\text{NaHCO}_3$  solution are mixed in a cylinder and the precipitation process is observed. Here are the explanations of this research.

**Hard water solution.** Electrolytes  $\text{CaCl}_2$  and  $\text{NaHCO}_3$  of reagent-grade and deionized water of the resistivity  $\approx 18 \text{ M}\Omega$ , which was obtained from Milli-Q water system were utilized as hardwater model.  $\text{CaCl}_2$  and  $\text{NaHCO}_3$  solutions were prepared by dissolving each electrolyte into the deionized water, and then kept in air-tight bottles in room temperature.

### Mixing process on each solutions.

250 ml of 0.01M  $\text{CaCl}_2$  and  $\text{NaHCO}_3$  are mixed separately in mixing medium (Ika Labortechnik RW 20) which has four 5-cm-blades and also equipped by rotary speed control (rpm). The mixing process is conducted for 30 minutes in plastic-cylinder-medium made from polypropylene with 10 cm inner diameter and 15 cm high and also fulfilled by 3 baffles.

The temperature of the solution in agitation and settling process equal to the ambient temperature of the surroundings (*i.e.*, room temperature, 28 – 29 °C). The pH and  $\text{CaCl}_2$  conductivity measurement is conducted before and after the mixing process by using Orion 250 A+ pH meter and Orion 105 A+ conductance meter. Fig 3 simplified schematic of mixing process in the presented work.

**Precipitation test.** 10 ml each of mixed  $\text{CaCl}_2$  and  $\text{NaHCO}_3$  solution is added together into reaction tube to measure the  $\text{CaCO}_3$  precipitation in a certain range of time by using EDTA complexometry method (accuracy 0.05 mg as  $\text{CaCO}_3$ ), and also the amount of ions  $\text{Ca}^{2+}$  consumed in solution as a measurement of  $\text{CaCO}_3$  precipitation. The flow diagram of this research is shown in Fig 4.

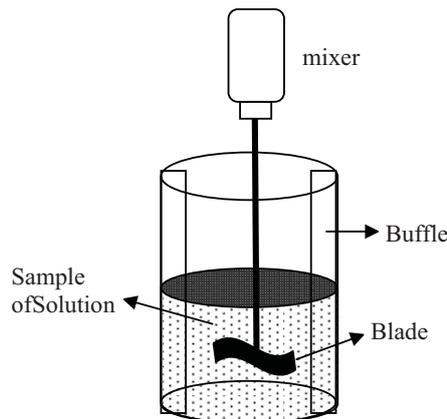


Figure 3: schematic of mixing process

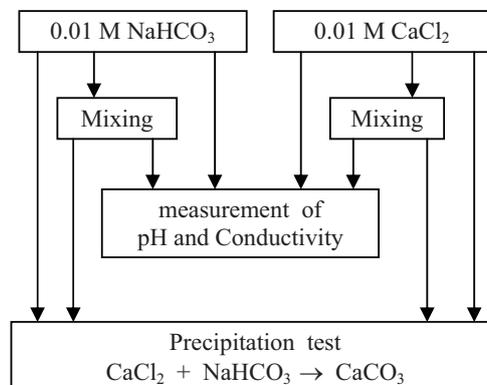


Figure 4: Research Flow Diagram

### 3. RESULTS AND DISCUSSION

The observation result of the effect of mixing to CaCl<sub>2</sub> solution is given in table 1. It can be seen the increase of NaHCO<sub>3</sub> pH after the mixing process which shows that there is releasing of CO<sub>2</sub> dissolved into gas phase and also the shifting of HCO<sub>3</sub><sup>-</sup> ions into CO<sub>3</sub><sup>2-</sup> ions in solution. The increase of rotary speed increases the solution pH of NaHCO<sub>3</sub>. There is no significant change of pH in the mixing process of CaCl<sub>2</sub> solution because of Ca<sup>2+</sup> and Cl<sup>-</sup> ions that is stable in the condition. Solution pH of NaHCO<sub>3</sub> is increase from 8.82 to 9.73 in 1500 rpm (Table 1). Hence, there are shifting of ion fractions of HCO<sub>3</sub><sup>-</sup> from 80% to 72% and increase of ion fractions of CO<sub>3</sub><sup>2-</sup> from 20% to 28% based on balance curve of carbonate solution (Fig 5).

Table 1: Effect of Mixing to 0.01 M NaHCO<sub>3</sub> and CaCl<sub>2</sub> Solution's pH and Conductivity at 30 Minutes Mixing Period

Round Velocity (rpm)	pH		Conductivity (mS.cm <sup>-1</sup> )		Increasing Conductivity (%)	
	NaHCO <sub>3</sub>	CaCl <sub>2</sub>	NaHCO <sub>3</sub>	CaCl <sub>2</sub>	NaHCO <sub>3</sub>	CaCl <sub>2</sub>
Non mixing	8.82	5.71	0.776	2.123	0	0
500	8.94	5.73	0.790	2.131	1.80	0.38
1000	9.52	5.72	0.825	2.163	6.31	1.88
1500	9.73	5.74	0.857	2.194	10.44	3.34

Table 2: Ion Radi (r), Hydrate Ion Thickness (Δr), and Hydration Gibbs Energy (ΔG<sub>Hydration</sub>) [4]

Type of ion	r (Å)	Δr (Å)	- ΔG <sub>Hydration</sub> (kJ.mol <sup>-1</sup> )
Ca <sup>2+</sup>	1.00	1.71	1505
CO <sub>3</sub> <sup>2-</sup>	1.78	0.76	1315
HCO <sub>3</sub> <sup>-</sup>	1.85	0.41	335

Type of ion	r (Å)	$\Delta r$ (Å)	$-\Delta G_{\text{Hydration}}$ (kJ.mol <sup>-1</sup> )
Na <sup>+</sup>	1.02	1.16	365
Cl <sup>-</sup>	1.81	0.43	340

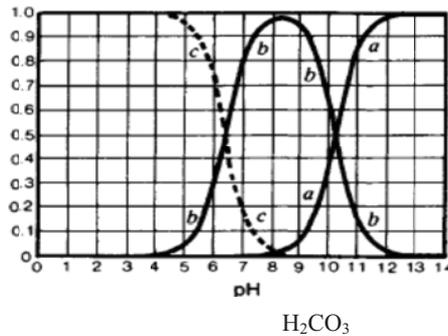


Figure 5: Carbonate and Bicarbonate ion fraction in solution vs pH Solution.[5]

The conductivity of electrolyte solution is able to show the mobility of the existing hydrates ions inside of the solution. The escalating of the conductivity of electrolyte on constant concentration, pressure, and temperature shows that there is a decreasing of hydrate ion diameter which comes with an decreasing of hydrate bond strength [6]. With other words, as the escalating of the conductivity increases, the strength of the hydrate ion bond will decrease and precipitation of ions is easier.

Ions, like Ca<sup>2+</sup> and CO<sub>3</sub><sup>2-</sup>, were covered by H<sub>2</sub>O molecules forming hydrated ion (Fig 1). The increasing of the conductivity of CaCl<sub>2</sub> and NaHCO<sub>3</sub> solution after the mixing process on Table 1 shows that there was a decreasing of the hydrate ion strength. The increase of NaHCO<sub>3</sub> conductivity is higher than CaCl<sub>2</sub>. It can be explained from data of ion's characteristic in Table 2. The thicker the hydrate ions ( $\Delta r$ ) will lead to the stronger the hydrate ions. The hydrate ions strength can be seen from the amount of the Hydration Gibbs Energy ( $\Delta G_{\text{Hydration}}$ ). Table 2 shows Ca<sup>2+</sup> have highest hydrate thickness and Hydration Gibbs Energy-nya. It shows that the strength of HCO<sub>3</sub><sup>-</sup> and CO<sub>3</sub><sup>2-</sup> hydrate ions was lower than CaCl<sub>2</sub>'s so it was easier to be effected by mixing process. This argument becomes the explanation why The increase of NaHCO<sub>3</sub> conductivity was much bigger than the increase of CaCl<sub>2</sub>'s conductivity.

Fig 5 shows the precipitation of CaCO<sub>3</sub> taken from higher mixed NaHCO<sub>3</sub> solution than mixed CaCl<sub>2</sub>. This result strengthens the previous explanation which states that the effect of mixing in NaHCO<sub>3</sub> solution is stronger in the weakening of its hydrate ions than the mixing of CaCl<sub>2</sub> solution. The mixing of un-mixed NaHCO<sub>3</sub> and un-mixed CaCl<sub>2</sub> solution shows the smallest CaCO<sub>3</sub> precipitation result. It happens because there is no increase of solution conductivity and also pH (Table 2), so the formation of CO<sub>3</sub><sup>2-</sup> is low and the strength of hydrate ions is relatively bigger/more stable compared to the mixed solution. Fig 6 shows that the rate of CaCO<sub>3</sub> precipitation from mixing sample in the first 30 minutes (nucleation zone) is higher than the un-mixed sample.

The preliminary step of CaCO<sub>3</sub> precipitation is the formation of CaCO<sub>3</sub> nuclei which is called as homogenous precipitation. Then, the nuclei will grow bigger to form CaCO<sub>3</sub> crystal which is called as heterogeneous precipitation. Fathi [7] got the super-saturation value needed to let the CaCO<sub>3</sub> homogenous precipitation is 40 times higher than its critical super-saturation, while for the heterogeneous precipitation is only 20 times higher than its critical super-saturation. It shows that the crystal growth of CaCO<sub>3</sub> (heterogeneous precipitation) is much easier to conduct than the nuclei formation of CaCO<sub>3</sub> (homogenous precipitation). The increasing pH shows that the amount of CO<sub>3</sub><sup>2-</sup> ions formed is higher, while the decreasing solution conductivity shows the weakening of hydrate in CO<sub>3</sub><sup>2-</sup> and Ca<sup>2+</sup> so that it will push the rate of CaCO<sub>3</sub> homogenous precipitation. Fig 6 shows the precipitation in the first 30 minutes (nucleation zone) that is about 8.1% for mixed NaHCO<sub>3</sub> sample which is much higher than the mixed sample of CaCl<sub>2</sub> that is only 2.7%, while the un-mixed sample is not yet precipitated.

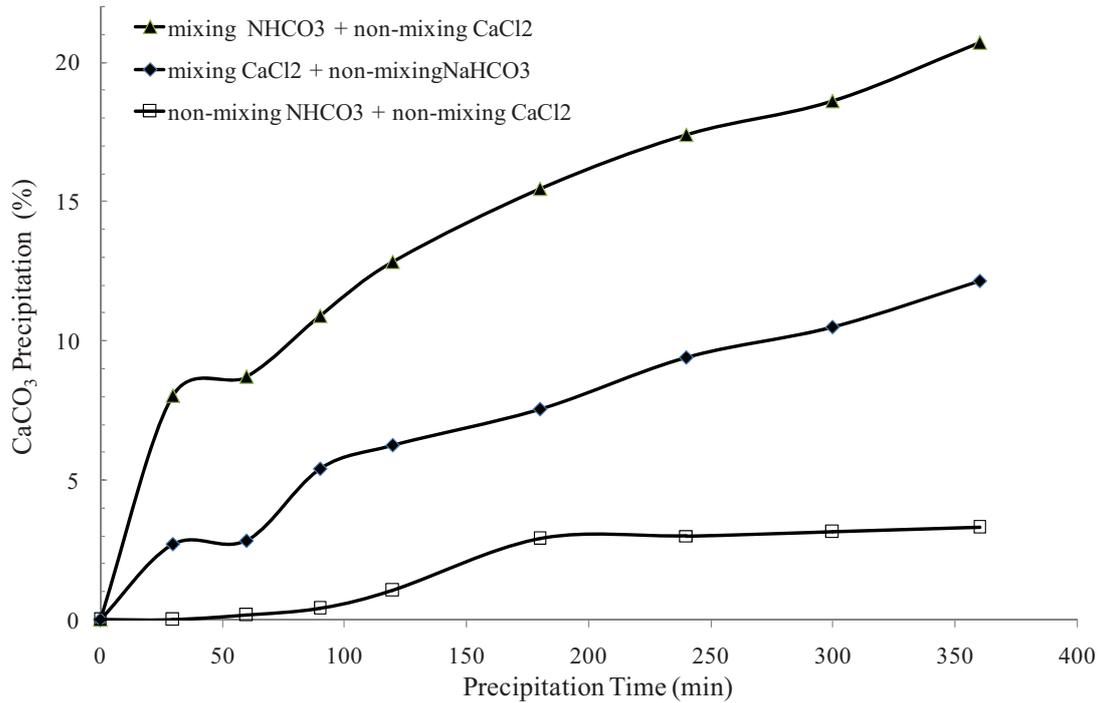


Figure 6: CaCO<sub>3</sub> Precipitation from 0.01 M NaHCO<sub>3</sub> and CaCl<sub>2</sub> by 30 Minutes Mixing at 1000 RPM.

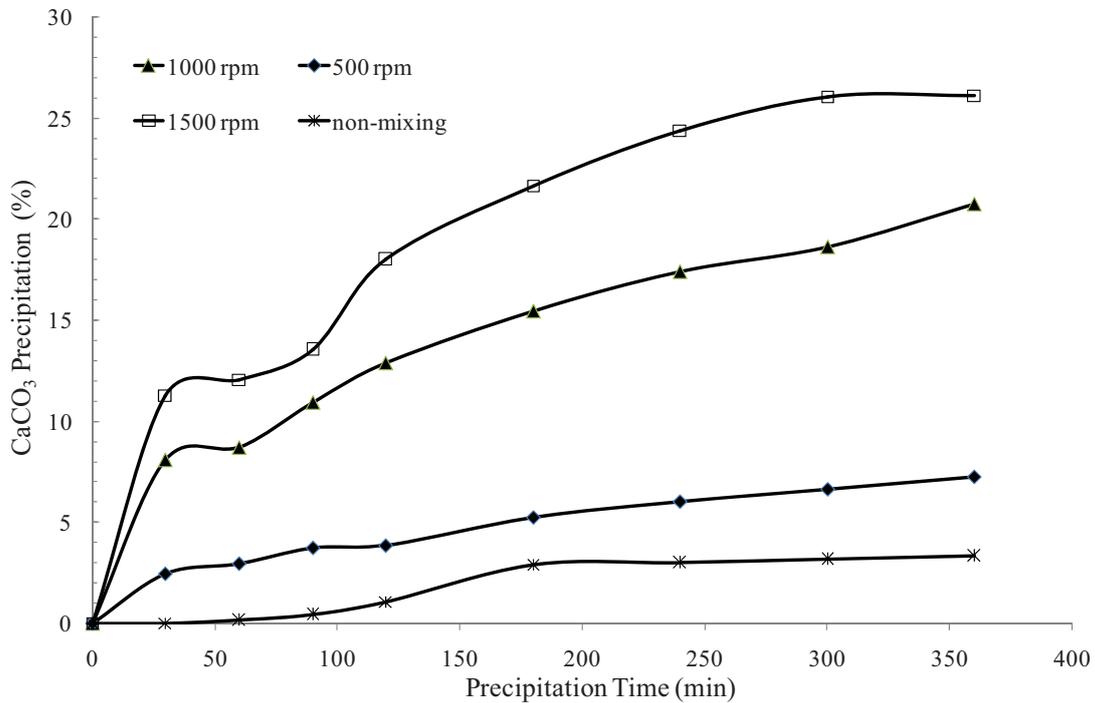


Figure 7: Presipitasi CaCO<sub>3</sub> Precipitation from 0,01 M NaHCO<sub>3</sub> mixing and dan CaCl<sub>2</sub> non mixing

Fig 7 shows that in the first 30 minutes zone of precipitation (nucleation zone), the precipitation of CaCO<sub>3</sub> flow rate increases significantly by increasing rotary speed (RPM). For process without mixing (un-mixed sample), it can't be seen that there is precipitation until the first 60 minutes, while in the 1500 rpm reaches 12% of precipitation. It shows that the mixing process is

effective to increase the precipitation of  $\text{CaCO}_3$  and rotary speed of mixer is the most influencing process variable to the rate of  $\text{CaCO}_3$  precipitation.

Table 2 shows that the increase of rotary speed of mixer in the solution of  $\text{NaHCO}_3$  causes the increase of solution pH and conductivity. It will affect to the increase of  $\text{CaCO}_3$  precipitation as shown in Figure 7. The higher the rotary speed of mixer can cause the increase of  $\text{CO}_2$  gas changed into gas phase and push the increase of  $\text{NaHCO}_3$  solution's pH. The increase of  $\text{NaHCO}_3$  solution conductivity by increasing of rotary speed of mixer shows that the strength of  $\text{HCO}_3^-$  hydrates ions is easy to be influenced by the mixing process (Table 1).  $\text{HCO}_3^-$  ionic bonding by its hydrates which is less strength by increasing the rotary speed of mixer causes the  $\text{HCO}_3^-$  ions is easier to interact by  $\text{Ca}^{2+}$  ions to form  $\text{CaCO}_3$ .

Other aspects which happened is the increase the rotary speed can increase the releasing of  $\text{CO}_2$  dissolved into gas phase from  $\text{NaHCO}_3$  solution, so the conversion from  $\text{HCO}_3^-$  ions into  $\text{CO}_3^{2-}$  ions happened (Equation 2). Furthermore, it will force the precipitation of  $\text{CaCO}_3$  (Equation 3).

#### 4. CONCLUSION

This research has already answered the hypothesis that mechanical agitation (mixing) in  $\text{NaHCO}_3$  and  $\text{CaCl}_2$  solution can cause the weakening of hydrates ions showed by the increase of solution conductivity and also the increase of  $\text{CaCO}_3$  precipitation. The mixing in  $\text{NaHCO}_3$  is also proved to increase the  $\text{HCO}_3^-$  ions conversion to form  $\text{CO}_3^{2-}$  which shows by the increase of solution pH.

The increase of rotary speed mixer causes the increase of solution conductivity, pH, and also  $\text{CaCO}_3$  precipitation.

The mixing conducted in this research is before the precipitation of  $\text{CaCO}_3$ . The next step needed to be observed is the mixing effect when the  $\text{CaCO}_3$  precipitation happened.

#### 5. ACKNOWLEDGEMENT

This research is financed by High Education Directorate (DIKTI) of Department of National Education of Republic of Indonesia on Fundamental Strategic Research Grant program 20012.

#### REFERENCES

- [1] N. Saksono, Yuliusman, S. Bismo, R. Widaningroem, "Effects of pH on Calcium Carbonate Precipitation Under Magnetic Field," J. Makara Seri Teknologi, vol 15 No 2 (2009) 79-85.
- [2] N. Saksono, S. Bismo, R. Widaningroem, A. Manaf, J. "Formation of  $\text{CaCO}_3$  Particle and Conductivity of  $\text{Na}_2\text{CO}_3$  and  $\text{CaCl}_2$  Solution Under Magnetic Field on Dynamic Fluid System," Makara Seri Teknologi, vol 15 No 1 (2011) 89 - 95.
- [3] N. Saksono, M. Gozan, S. Bismo, E. Krisanti, R. Widaningrum, S. Song, "Effects of Magnetic Field On Calcium Carbonate Precipitation: Ionic and Particle Mechanisms" Korean J. Chem. Vol 25, No. 5 (2008), 1145 – 1150.
- [4] Y. Marcus, "A simple empirical model describing the thermodynamics of hydration of ions of widely varying charges, sizes, and shapes," Biophysys. Chemistry 51 (1994) 111-127.
- [5] F. N. Kemmer, The NALCO Water Handbook 2<sup>nd</sup> ed. New York: McGraw-Hill. (1998).
- [6] L. Holysz, A. Szezes, E. Chibowski, "Effects of A Static Magnetic Field on Water and Electrolyte Solutions," J. Colloid Interface Sci. (2007) 316.
- [7] A. Fathi, M Tlili, C. Gabrielli, G. Maurin, M.B. Amor, "Effect of magnetic water treatment on homogeneous precipitation of calcium carbonate". Water Res. 40 (2006)

# Formation of KCl in Prolonged Heating of Coconut Shell

Adhi Y. Perkasa, Fandi A. Prasetya, Frischa M. Wachid, Darminto

Department of Physics, Faculty of Mathematics and Natural Sciences, Institut Teknologi Sepuluh Nopember, Kampus ITS Sukolilo, Surabaya 60111, Indonesia

E-mail : Darminto@physics.its.ac.id

## ABSTRACT

Study of heating effect on coconut shell with a variety of holding time (10-50 hours) has been conducted at 350°C. After the heat treatment, samples were characterized using XRD and analyzed by employing “Match” software. A qualitative XRD analysis showed that the longer holding time has led to the phase formation of KCl, besides the amorphous carbon. The highest content of KCl phase, and the consequently lowest amorphous carbon, was achieved by the sample heated for 50 hours at 350°C. According the EDX analysis, the corresponding sample was dominated by the first five elements of C, O, K, Cl and Mg, signifying the presence of crystalline KCl, minor MgO and amorphous carbon.

## Keywords

Coconut shell, Heat treatment, KCl phase.

## 1. INTRODUCTION

Data of Asian Pacific Coconut Community (AAPC) provide information that Indonesia is a widest country with a growing area of coconut (*Cocos nucifera*): 3.86 million hectare with a production of 15.20 million items, equivalent to 3.03 million tonnes of copra per year. From copra production figures, there is a product in the form of coconut shell charcoal that can be used as fuel [1]. However, until now the coconut shell only used as fuel in a traditional manner, so it is necessary to produce coconut shell that has a higher value. The chemical composition of coconut shell includes lignin 29.4%, pentosans 27.7%, cellulose 26.6%, moisture 8%, 4.2% solvent extractives, uronic anhydrides 3.5% and ash 0.6% [2]. The coconut shell mainly contains water with Fe (0.01 mg/100mg), Mg (30mg/100g), P (37mg/100g), K (312mg/100g), Na (105mg/100g), Cu (0.04 mg/100mg), Cl (183mg/100g), and S (24mg/100g) [3].

The chemical compound of potassium chloride (KCl) is a metal halide salt composed of potassium and chlorine. In a pure state, KCl is odorless and has a white or colorless crystalline form of vitreous, the shaped of crystal structure is face centered cubic. Potassium chloride is widely used in scientific applications, one of them for making multilayer organic light-emitting diode (OLED) [4]. Previous studies provide information that the heat treatment process on a coconut shell resulted in KCl, but this compound was disappeared by heating at temperatures above 770°C [5-7]. To further study the presence of KCl, a research was conducted with young coconut shell heated at 350°C with variation of holding time from 10 to 50 hours. Characterization using X-ray diffraction (XRD) and energy dispersive X-ray microanalysis (EDX) were performed to study the phase formation during the heat treatment of coconut shell.

## 2. METHODS

The waste of coconut shell was dried naturally under of the sunshine and then thoroughly ground to be the 200 mesh powder using a mortar and pestle. After testing with DSC-TGA, the sample was placed on a crucible and heated at 350°C with a holding time for 10, 20, 30, 40 and 50 hours in an oxygen atmosphere. Samples were then characterized using XRD and analyzed by a Match software to search and match the phase content. To study the elemental composition, a characterization by EDX was carried out.

## 3. DISCUSSION

Coconut shell must be tested with DSC-TGA to know the mass changes toward temperature. The test results are shown in Figure 1. It shows that at temperatures above 350°C, the mass changes then persists up to temperature of 1200°C. At the temperature range of 100-120°C the water is evaporated, and at the temperature of 270°C the cellulose decomposition occurs. Acetic acid is formed at a temperature of 200-270°C. At the temperature of 270-310°C exothermic reaction takes has occurred. This phase, cellulose decomposition occurs intensively of into solution piroligant, wood gas and tar. Acid is an organic acid

with a low boiling point such as acetic acid and methanol were wood gas consists of CO and CO<sub>2</sub>. The temperature of 310-500°C occurs lignin decomposition, generated more tar while pirolignat solution decreases, CO<sub>2</sub> gas decreases while CO and CH<sub>4</sub> and H<sub>2</sub> increased. At the temperature of 500-1000°C is the phase of purification charcoal or carbon content [8]. DSC-TGA results can be determined that the heating to the heat treatment process was 350°C and this study used a variety of holding time: 10, 20, 30, 40, and 50 hours. After the coconut shell through the process of heat treatment with specified of temperature and holding time, carried out X-ray diffraction testing.

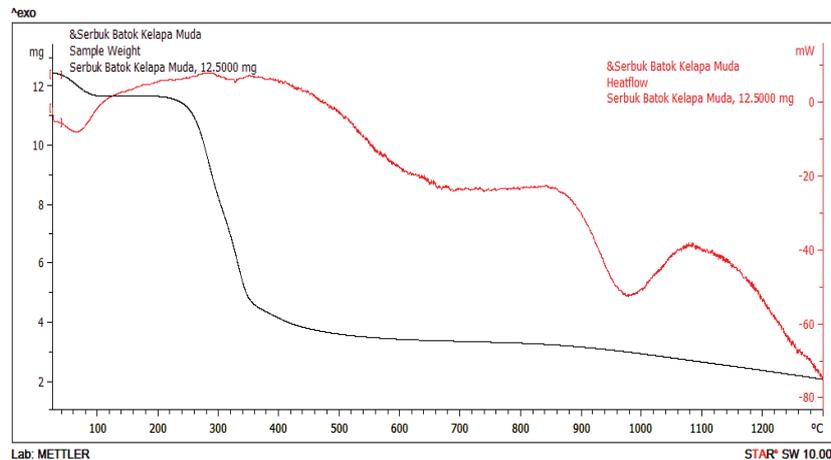


Figure 1: Result of DSC-TGA testing on young coconut shell.

From the results of the qualitative analysis of the diffraction data heating to 350°C and holding time during 10 hours obtained diffraction pattern is dominated by the phase "amorphous". Two diffraction peaks at 28°2θ and 41°2θ are KCl phase. Coconut shell with holding time during 20 hours, "amorphous" phase decreased but the KCl be more crystalline. Phase forming at holding time for 30, 40 and 50 hours identified the "amorphous" phase decreasing and increasing of potassium chloride (KCl) phase, as seen in Figure 2 with mark "x" as the crystalline phase of KCl. The longer of holding time, the sample showed KCl crystalline phases is higher and phase "amorphous" is more decrease. Holding time during 50 hours indicates the highest KCl crystalline phases and the formation of another phase with \* mark as MgO phase, then EDX testing required on samples upon heating with holding time in 50 hours.

Based on known results of EDX testing is the dominant element of carbon and oxides, with the percentage of atoms at the C and O elements in a row is 50.53% and 40.95%. There are impurities elements such as Na, Mg, Al, Si, P, S, Cl and K, which has the atomic percentage of 0.18%, 1.21%, 0.12%, 0.43%, 0.73%, 0.25%, 0.88 and 4.72%. The amorphous phase present in the sample identified an element of C, O, Na, Mg, Al, Si, P, and S. The most dominating element is the amorphous carbon phase. Increasing KCl phase was influenced by oxygen as atmospheric gas when using furnaces. The presence of elements of C in the sample can bind to the atmospheric then transformed become CO<sub>2</sub> bonding and other hydrocarbons bond released in the air. When the holding time is enhanced so the pyrolysis reaction is more perfect that of carbon decreases but liquids and gases (impurities) increase. Heat treatment time is optimal for purifying carbon coconut shell is 3 hours and the optimal temperature for heat treatment of coconut shell is 600°C [9]. So that the crystalline phase of KCl obtained when the holding time more than 3 hours. The highest of KCl crystalline phases obtained holding time during 50 hours.

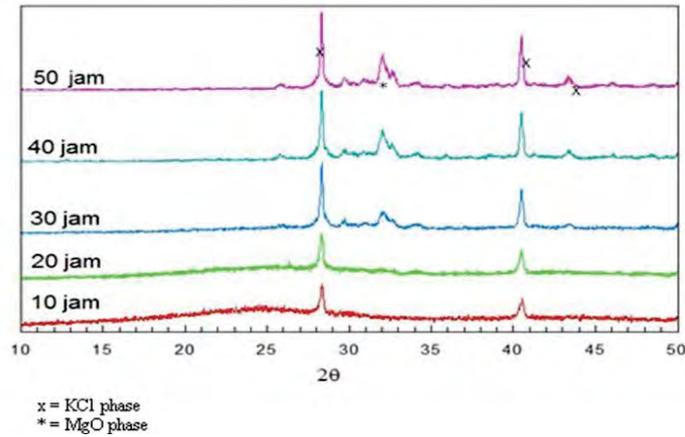


Figure 2: X-Ray Diffraction pattern on coconut shell at 350°C with holding time: 10, 20, 30, 40 and 50 hours.

Table 1: Result of EDX testing

Elements	Mass ratio (%)	Atomic ratio (%)
C	38.97	50.53
O	42.06	40.95
Na	0.26	0.18
Mg	1.89	1.21
Al	0.21	0.12
Si	0.77	0.43
P	1.45	0.73
S	0.52	0.25
Cl	2.00	0.88
K	11.86	4.72

For future research, heat treatment is needed at the optimal temperature (no more than 770°C) and holding time for obtain KCl in a higher percentage. There must be a method needed to separate the pure KCl from coconut shell, because there are some application of KCl for scientific applications, medicine, and food processing. Fortunately, this can be obtained from inexpensive materials such as coconut shells.

#### 4. CONCLUSION

Mass changes toward temperature in a young coconut shell can be determined by using DSC-TGA testing. Obtained at 350°C there is a change in the mass of the material. When a young coconut shell was heated at 350°C with a holding time for 10 hours, 20 hours, 30 hours, 40 hours and 50 hours obtained qualitative analysis results diffraction data is dominated by the phase "amorphous" and crystalline phases of KCl. Higher holding time, crystal growth occurs so that KCl phases increased. So holding time for 50 hours, there is the highest KCl crystalline phase. With EDX testing, unknown elements contained in the sample with 50 hour holding time are C, O, Na, Mg, Al, Si, P, S, Cl, and K. Elements of the most dominating and indicates the formation of an amorphous phase is the element of C. There is crystalline phase of KCl and C elements that identify the phases is amorf.

## REFERENCES

- [1] Rustan Hadi, "Sosialisasi teknik pembuatan arang tempurung kelapa dengan pembakaran sistem suplai udara terkendali," vol. 16, pp. 77–80, 2011.
- [2] S. Husseinsyah and M. Mostapha, "The Effect of Filler Content on Properties of Coconut Shell Filled Polyester Composites.," *Malaysian Polymer Journal*, vol. Vol. 6, no. 1, pp. 87–97, 2011.
- [3] Tulecke, W, Weinstein, L, Rutner, A, and Laurencot, H, "The biochemical composition of coconut water (coconut milk) as related to its use in plant tissue culture," *Contrib. Boyce Thompson Inst*, vol. 21, pp. 115–128., 1961.
- [4] Z. Lü, Z. Deng, J. Zheng, E. Zhou, Z. Chen, D. Xu, and Y. Wang, "Organic light-emitting diodes using potassium chloride as efficiency and stability enhancers," *Displays*, vol. 31, no. 1, pp. 54–58, Jan. 2010.
- [5] F. Destyorini, A. Suhandi, A. Subhan, and N. Indyaningsih, "Pengaruh suhu karbonisasi terhadap struktur dan konduktivitas listrik arang serabut kelapa," *jurnal fisika Himpunan Fisika Indonesia*, vol. 10, no. 2, pp. 122–132, Dec. 2010.
- [6] J. Chandrasekaran, P. Ilayabarathi, P. Maadeswaran, S. Balaprabakaran, K. Sathishkumar, and B. Babu, "Synthesis, crystal growth and characterization of a semiorganic material: Thiosemicarbazide potassium chloride," *Optik - International Journal for Light and Electron Optics*, vol. 124, no. 1, pp. 31–34, Jan. 2013.
- [7] J. Lehmusto, B.-J. Skrifvars, P. Yrjas, and M. Hupa, "Comparison of potassium chloride and potassium carbonate with respect to their tendency to cause high temperature corrosion of stainless 304L steel," *Fuel Processing Technology*, vol. 105, no. 0, pp. 98–105, Jan. 2013.
- [8] R. Sudrajat and Salim S., *Petunjuk Pembuatan Arang Aktif*. Badan penelitian dan pengembangan kehutanan. 1994.
- [9] K. Elly, "Pemanfaatan cangkang kelapa sawit sebagai arang aktif," *Jurnal Penelitian Ilmu-Ilmu Teknik*, Dec-2008. [Online]. Available: <http://eprints.upnjatim.ac.id/2805/>. [Accessed: 20-Nov-2012].

## Influence of Flow Rates and $\text{Cu}^{2+}$ on Kinetics of Gypsum Scale Formation In Pipes

S. Muryanto<sup>a</sup>, A. P. Bayuseno<sup>b</sup>, W. Mangestiyono<sup>c</sup>, Sutrisno<sup>c</sup>, W. Sediono<sup>c</sup>

<sup>a</sup>Department of Chemical Engineering & Office of Research (LEMLIT)  
Universitas 17 Agustus 1945 (UNTAG) Semarang, Bendhan Dhuwur, Semarang 50233, Indonesia  
tel: +62 24 8441771 fax: +62 24 8441772,

E-mail : [technologypark28@yahoo.com.au](mailto:technologypark28@yahoo.com.au) (corresponding author)

<sup>b</sup>Mechanical Engineering Graduate Program  
Diponegoro University, Tembalang, Semarang 50275, Indonesia

<sup>c</sup>Mechanical Engineering Diploma (D3) Program  
Diponegoro University, Tembalang, Semarang 50275, Indonesia

### ABSTRACT

Experiments were performed in a piping system to examine the effects of flow rate and  $\text{Cu}^{2+}$ , a common metal ion in wastewater, on kinetics of gypsum ( $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ ) scale formation. The scaling was monitored by measuring the decrease in  $\text{Ca}^{2+}$  concentrations,  $[\text{Ca}^{2+}]$ , of the scaling solution. AAS analysis shows that  $[\text{Ca}^{2+}]$  reduces progressively after a certain induction time, during which time the concentration remains steady. Thus, the gypsum scale in pipes does not form spontaneously. Higher impurity concentrations (0.00 to 10.00 ppm  $\text{Cu}^{2+}$ ) result in longer induction time (26 to 42 min), which indicate that  $\text{Cu}^{2+}$  prohibit the scale formation. Moreover, the higher the impurity concentrations the less the scale mass produced. Reduction in scale mass was as high as 61% depending on impurity concentrations and flow rates. Data of  $[\text{Ca}^{2+}]$  versus time were used to calculate the reaction rate of the scale formation. It was found that the reaction follows a first order with rate constants between 5.83 and 7.63 per hour.

### Keywords

*Gypsum, impurities, kinetics, scale prevention, wastewater*

**This paper is published in International Journal of Technology (IJTech)**

## Decomposition of Carbon Dioxide in the Three-Pass Flow DBD Non-Thermal Plasma Reactor

Widiatmini Sih Winanti<sup>a</sup>, Widodo Wahyu Purwanto<sup>b</sup> and Setijo Bismo<sup>c</sup>

<sup>a</sup>Department of Chemical Engineering  
Faculty of Engineering University of Indonesia, Depok 16424  
Tel : (021) 7863516, Fax : (021) 7863515  
E-mail : widiatmini@yahoo.com

<sup>b,c</sup>Department of Chemical Engineering  
Faculty of Engineering University of Indonesia, Depok 16424  
Tel : (021) 7863516, Fax : (021) 7863515  
Corresponding Author E-mail : bismo@che.ui.ac.id

### Keywords

CO<sub>2</sub>, three-pass flow NTP reactor, DBD, CO, synthesis gas.

### INTRODUCTION

The increase of CO<sub>2</sub> emission is believed to cause climate change. One of the efforts to reduce the CO<sub>2</sub> emission is to decompose it into CO and O<sub>2</sub>, where CO can further be used as feedstock in the production of various useful chemicals. CO, along with H<sub>2</sub> gas known as synthesis gas (syngas) is a main component of industry gas, which has a significant role in producing various chemicals, such as urea, methanol, inorganic and organic carbonate, polyurethane and polycarbonate. DBD Non-thermal plasma has tremendous capability to decompose CO<sub>2</sub> gas at low pressures and low temperatures. The aim of this research is to observe the decomposition of CO<sub>2</sub> into CO and O<sub>2</sub> using three-pass flow configuration of DBD Non-thermal Plasma (NTP) reactor.

### METHOD

This experiment used three-pass flow DBD NTP reactors, that has the advantage could simultaneously cool the High Voltage Electrode (HVE) and preheat the gas feed flow before entering the plasma zone. The existence of this cooling process made this reactor did not require a separate cooling device in its operation.

The research parameters were feed flow rates and plasma reactor electric voltage. The experiment was carried out at reaction time of 2.1, 4.2, 6.3 and 8.4 minutes in R1, R2 and R3. The feed flow rates was 500, 1000 and 1500 cm<sup>3</sup> / min and the electric voltage was 5.44 to 9.5 kV.

### RESULTS AND DISCUSSION

Figure 1 indicated that the CO<sub>2</sub> conversion reached the peak at 2.1 minute and then decreased again after that. The decrease might be taken place due to the reverse reaction, that caused by the very high temperature inside the plasma reactor.

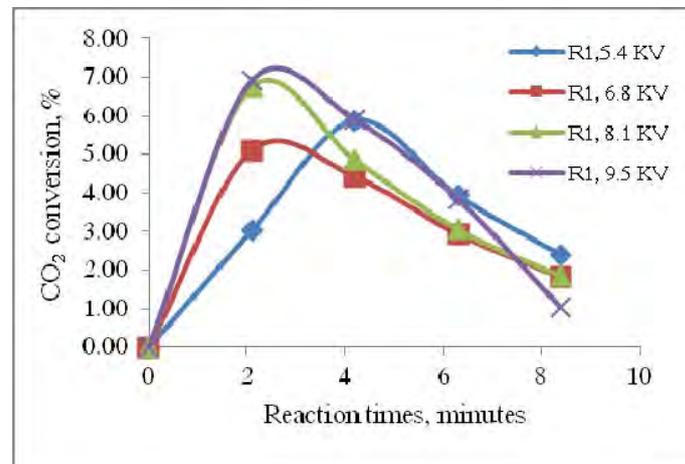


Figure 1: CO<sub>2</sub> conversion in R1 for various electric voltages and reaction times.

The highest conversion was reached for residence time of 5.01 minutes in the lowest feed flow rates.

The Specific Energy (SE) was about 270 kJ/mole, which is lower than previous experiments as well as its energy bonding.

## CONCLUSION

The decomposition of CO<sub>2</sub> in three-pass flow DBD NTP reactor were reached the peak of conversion at the reaction time 2.1 minute, and then declined again after that. This was caused by the reverse reaction due to the high temperature of plasma reaction. The CO<sub>2</sub> conversion increased with the increasing of electric voltage and residence time as well as decreasing the feed flow rate. The SE was 270 kJ/mole, being lower than previous experiment and its energy bonding as well.

## ACKNOWLEDGMENT

Grateful thanks conveyed to Prof. Dr. Ir. Setijo Bismo, DEA. and Prof. Dr. Ir. Widodo Wahyu Purwanto, DEA. who gave guidance in preparation of this paper.

## REFERENCES

- [1] S. Bismo, "Aspek produktivitas generator ozon bertekanan berdasarkan pola aliran gas umpan yang melewati elektroda koaksial", *Jurnal teknologi*, Edisi khusus No 1, Teknik Kimia dan Proses, 2000, Tahun XVIII, pp. 46-51.
- [2] Istadi, "Aplikasi teknologi hibrid katalisis-plasma dalam pengembangan reaktor kimia masa depan", *Bulletin of reaction engineering & catalyst*, 2006, 1(2), pp. 15-20.

## The Hydrogen Gas Effect to the Efficiency Fuel by the 135 cc Motorcycle Engine

Setiyono<sup>a</sup>, Wina Libyawati<sup>b</sup>, Yohannes Dewanto<sup>c</sup>.

<sup>a</sup>Faculty of Engineering, University of Pancasila, South Jakarta 12640  
E-mail : syst@yahoo.com

<sup>b</sup>Faculty of Engineering, University of Pancasila, South Jakarta 12640  
E-mail : simondewanto@gmail.com

### ABSTRACT

Since the energy crisis in 1973, the problem of energy into the world topic. Developed countries began to contest the new breakthrough in generating alternative energy which is much cheaper than oil and gas. Beside, sooner or later will run out of fossil fuels. One example of alternative energy is that hydrogen gas content of substance very much in nature. Hydrogen gas obtained by the process of electrolysis of water.

The water in the electrolysis into oxygen and hydrogen. Hydrogen gas that had levels above 4% and below 75% will explode more terrible than 3 kg LPG cylinder blast in the absence of fire when mixed with oxygen. Hydrogen gas as an alternative energy used to fuel the 135 cc motorcycle engine. Intended use Hydrogen gas is to conserve fuel. From the results of research on the use of hydrogen gas to be mixed with fuel obtained 135 cc motorcycle engine that the engine can blow sparks with the same power as before hydrogen gas mixed with the use of less fuel. Noted that the use of a mixture of hydrogen gas and gasoline fuel in the combustion chamber of gasoline can save fuel up to 50-60%.

### Keywords

*Electrolysis, hydrogen gas, mixed hydrogen with fuel*

### 1. INTRODUCTION

In the era of globalization, technology was evolves so rapidly, especially in the mining sector (gas and oil) and chemicals, the most important thing is the thermal efficiency of the engine and fuel used. Currently, the depletion of fuel the world has started to trigger upheaval in society. The government's decision to raise the price of fuel (BBM) certainly adds to the burden of the community in an already difficult economic condition. While there were no bright spots developing alternative energy fuel. The best solution in dealing with the problem is trying to find a good step toward an energy crisis that is expected to appear later when we are still dependent on fossil fuel use or fuel oil (BBM). Some researchers have been researching and developing materials dung and human waste which is processed an aerobically to produce methane gas called biogas. But alternative energy is widely used as a household fuel, and have not been developed in the automobile industry. Alternative energy is quite widely used in motor vehicles today is hydrogen gas.

Hydrogen can serve as energy for all uses as appropriate petroleum and natural gas, other than that it was only found in nature in the form of compounds. Hydrogen is available in water and organic compounds in the form of hydrocarbons, such as natural gas, coal, and biomass. Therefore, hydrogen must be produced through the use of energy before the hydrogen itself is available as an energy source. Decomposition of the chemical bonds in water will produce hydrogen that can be used as fuel. Hydrogen can be produced by several processes, including the process of electrolysis, photo electro chemical cells, photochemical, steam reforming, and the photo biology.

In the testing to be performed, use of hydrogen gas as a fuel blended with gasoline as a fuel can save, the 135 cc motorcycle engine up to 40%. How to produce hydrogen is by the process of electrolysis to separate water  $O_2$  and  $H_2$ . Hydrogen is obtained mixed with the fuel used so getting a new octane rating higher.

## 2. BASIC THEORY

### 2.1 Sections and Subsections

The fuel is a material that can be used to generate energy and produce mechanical work in a way that can be controlled. [5] In other words, the fuel is a substance that produces heat energy is mainly used. Most of the fuel produces energy when burned in air. The process used to convert fuel into energy include chemical reactions, such as combustion, and nuclear reaction (nuclear fission or nuclear fusion). Fuel is also used in the cells of organisms in a process known as metabolism. Hydrocarbon fuel source is most commonly used today, but many other substances can be used as well.

Comparison of gasoline and air mixture must be determined in such a way in order to obtain efficient and complete combustion. On the right ratio mix of gasoline and air are ideal (stoichiometric ratio) for the combustion process in the engine is 1: 14.7. [4] However, in practice, the optimum mixture ratio can not be applied continuously at every operational situation, for example: round when idle (slow) and a full load of vehicles consume fuel air mixture that fat, whereas in other circumstances the use of air petrol mixture can approach the ideal. It says mixed thin / poor, when in a mixture of gasoline and air there are more than 14.7 percentage of the air, whereas if it is less than that number is called a rich mixture / fat.

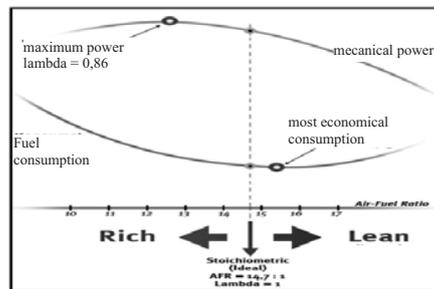


Figure1: Effect of water - fuel ratio on consumption and engine power

Each fuel combustion characteristics and values are different. Characteristics that determine the properties of the combustion process, which is less favorable properties can be perfected by way of adding chemicals to the fuel, with the hope of influencing the anti-knocking letup of power or fuel, and in this case pointed to what is called the octane number. The process of burning fuel in a gasoline motor or internal combustion engine greatly influenced by a number, whereas in Diesel motors greatly influenced by the cetane number.

The purpose of combustion of fuel to obtain energy is called the thermal energy (heat energy). Burning fuel results in the form of thermal energy can be in the form of energy into another, such as: energy for lighting, mechanical energy, and so on. Thus each of the burning fuel would be in getting some other form of energy that can be adjusted as needed. The remains of the burning of the fuel need to be noticed. Therefore the rest of the imperfect combustion products will be negatively affect the environment. This residue will contain toxic gases, which are mainly in the motor caused by the combustion of gasoline. While the results of that caused by the burning of diesel motors can lead to gas, dark smoke that will pollute the environment. But in fact, the pollution caused by the combustion in Diesel motors are not harmful to the environment, when compared with the residual gas combustion in motor gasoline.

### 2.2 Liquid Fuels

#### 2.2.1 Gasoline (petrol) - a standard 87 RON

Petrol is a liquid mixture derived from petroleum and is mostly composed of hydrocarbons and used as a fuel in internal combustion engines. The term gasoline is widely used in the oil industry, even in the company is not America. Sometimes the term gasoline motor is used to distinguish it from avgas, gasoline used by light aircraft. Fuel Type Gasoline is a common name for several types of fuel intended for combustion engines with ignition. In Indonesia there are several types of fuel type petrol which has a different quality of combustion. Quality value type of gasoline is calculated based on the value of RON (Octane Random Number). By RON gasoline is then divided into 3 types:

- 1) Premium (RON 88): Premium is a kind of distillate fuel oil yellowish clear. The yellow color is due to the additional dye (dye). The use of premium is generally to fuel gasoline-powered vehicles, such as cars, motorcycles, outboard motors and others. Fuel is often also called motor gasoline or petrol.

- 2) Pertamax (RON 92): intended for vehicles that require the use of high-octane fuel and unleaded (unleaded). Pertamax also recommended for vehicles produced over the year 1990 primarily been using similar technology with electronic fuel injection and catalytic converters.
- 3) Pertamax Plus (RON 95): This type of fuel is in compliance with the performance standards of the International World Wide Fuel Charter (WWFC). Intended for advanced technology vehicles that require the use of high-octane fuel and environmentally friendly. Pertamax Plus is highly recommended for vehicles with a compression ratio > 10.5 and also the use of technology Electronic Fuel Injection (EFI), Intelligent Variable Valve Timing (VVTi), (VTI), Turbochargers and catalytic converters.

### 2.2.2 Solar (high speed diesel)

Diesel, in Indonesia, better known as solar, is an end product which is used as a fuel in a diesel engine invented by Rudolf Diesel. Diesel is similar to heating oil, which is used in central heating. Diesel is used in diesel engines (cars, boats, motorcycles, etc.), a type of internal combustion engine. Rudolf Diesel originally designed the diesel engine to use coal as a fuel, but it is more effective oil. Diesel car trips completed on January 6<sup>th</sup>, 1930. The trip starts from Indianapolis to New York City - distance (1300 km). This proves the usefulness of the internal combustion engine.

## 2.3 ELECTROLYSIS OF WATER

The Separating hydrogen and oxygen using electricity. Water molecules can be broken down into the elements of the source by flowing electric current. This process is called electrolysis of water. At the cathode, two water molecules react with the capture of two electrons, reduced to H<sub>2</sub> gas and hydroxide ions (OH<sup>-</sup>). Meanwhile at the anode, two other water molecules break down into oxygen gas (O<sub>2</sub>), release 4 H<sup>+</sup> ions and electrons flow to the cathode. Ions H<sup>+</sup> and OH<sup>-</sup> experienced neutralization forming back some water molecules. Equal overall reaction of electrolysis of water can be written as follows.

Hydrogen and oxygen  $2H_2O(l) \rightarrow 2H_2(g) + O_2(g)$  gas produced from this reaction to form bubbles on the electrodes and can be collected. This principle is then used to produce hydrogen and hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), which can be used as fuel for hydrogen vehicles.

## 2.4 FUEL CONSUMPTION

*Fuel consumption* (FC) is a parameter which is used in the system to describe the combustion engine fuel consumption. Fuel consumption is defined as the amount of the resulting fuel consumption per unit time (cc / min). A low value indicates FC, economical fuel consumption. Therefore, a low FC values is very desirable to achieve fuel efficiency. Fuel consumption (FC) can be calculated using the following formula:

$$FC = \frac{V}{t} \quad (1)$$

where:

FC	: Fuel Consumption	[cc / min]
V	: Volume of the combustion chamber	[cc]
t	: time	[minutes]

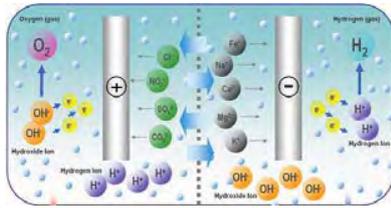
The things that affect the amount of fuel consumption as follows:

improper vehicle use, fuel system defective (leaking gasoline, gasoline dikarburator surface is too high, the air filter is dirty and low speed setting is not good), faulty ignition system (ignition time is not right, popping plugs incorrectly, damaged circuit breaker contact point) , low engine compression pressure.

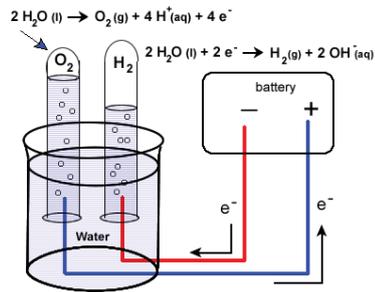
## 3. MAKING AND TRIAL

### 3.1 Tools and Materials

In manufacturing, the use of water electrolysis process using DC electric current to split water (H<sub>2</sub>O) into HHO gas is then used for combustion gases in the combustion chamber. The tools and materials that will be used to conduct research ways to produce hydrogen consist of two main parts:



(a)



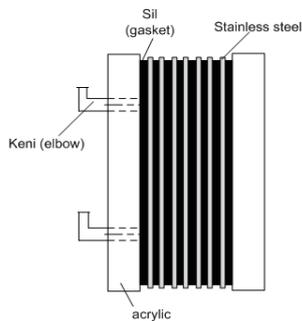
(b)

Figure 2: (a) Electrolysis I, (b) Electrolysis II

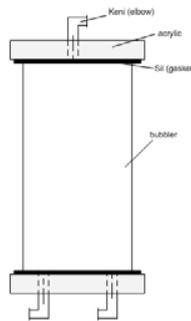
### 3.1.1 Generator Hidrogen

The components of the hydrogen generator are:

- |   |   |
|---|---|
| <p>1. Mica Plate (<i>acrylic</i>)<br/>         Quantity: 2 pieces<br/>         Size: 155 x 125 mm<br/>         Thickness: 10 mm</p> | <p>2. Plat Stainless steel<br/>         Total: 7 plate<br/>         Dimensions: 150 x 75 mm<br/>         Thickness: 1 mm, type: 316 L</p> |
| <p>3. Seals (gaskets)<br/>         Quantity: 8 pieces<br/>         Size: 150 x 75 mm<br/>         Thickness: 5 mm</p>               | <p>4. Elbow<br/>         Amount: 2 pieces<br/>         Size Do: 6 mm</p>  |
| <p>5. Nuts and Bolts<br/>         Quantity: 6 pieces<br/>         Size: M12<br/>         Length: 95 mm</p>                          |   |



(a)



(b)

Figure 3: (a) 6 cell hydrogen generator scheme is made, (b) scheme bubbler made

### 3.1.2 Bubbler

The components of the bubbler is (see figure 3 (b)):

- |   |  |
|---|--|
| 1. Bubbler<br>Quantity: 1 piece<br>Size: 175 mm diameter x 58 mm<br>Type: PVC   | 2. Acrylic<br>Quantity: 2 pieces<br>Size: 85 x 80 mm<br>Thickness: 10 mm |
| 3. Seals (gaskets)<br>Quantity: 2 pieces<br>Size: 65 x 65 mm<br>Thickness: 5 mm | 4. Nuts and Bolts<br>Quantity: 4 pieces<br>Size: M10<br>Length: 220 mm   |
| 5. Elbow<br>Total: 3 pieces<br>Do Size: 6 mm                                    |  |

### 3.1.3 The Other

- Hose are , diameter size: 6 mm, length: 2 m
- Distilled water
- KOH

The Explanation tool: This tool uses the media distilled water that has been mixed with KOH and then put in a bubbler to almost fill half the bubbler. Water that has been incorporated in part will lead to a hydrogen generator through one hose. Stainless steel that serves as conductor of the current deal.

### 3.2 Preparation tool

As for how to make hydrogen generator tool are:

- Give 3 holes on all stainless steel plates each with 2 holes are aligned on top and 1 bottom hole.
- Give a very large hole in the middle on all the seals (gaskets) size 150 x 75 mm.
- Provide 6 holes grooves on both the acrylic plate with 3 holes on the left side and 3 holes on the right side parallel to the size M12 bolt size. Then give the plot holes in the middle of two pieces the size elbow size 3/8 inch on one plate of mica.
- Align 7 pieces stainless steel plate in between the 8 seals (gaskets) size 150 x 75 mm and then sandwiched between two pieces of mica plate size 155 x 125 mm.
- Then between 2 mica mounted M12 bolts and nuts firmly to prevent leakage.
- For 2 holes in the mica plate, put 2 pieces of elbow 3/8 inch.



(a)



(b)

Figure 4: (a) Hydrogen Generator, (b) Bubbler

- Give one big hole on both seals (gaskets) size 65 x 65 mm.
- Give the plot holes 4 pieces at 2 mica plate size 85 x 80 mm the size of the nuts and bolts of M10 and 1 piece of plot holes in the middle of the plate-sized elbow 3/8 inch.

9. Give two pieces of hole groove on one mica plate size 85 x 80 mm the size of elbow 3/8 inch and 1 plot holes in other mica plate size 85 x 80 mm size Keni 3/8 inch.
10. Replace the seals at the top and bottom of the bubbler and the wedge using 2 pieces of mica plate size 85 x 80 mm and bolted using M10 bolts and nuts firmly to prevent leakage.
11. Then attach the two pieces of mica plate perforated elbow in 2 and 1 piece elbow in perforated acrylic plate 1.

#### 4. TRIAL AND ANALYSIS

After testing the device fabrication, testing consists of two phases, namely:

1. Testing to test out whether or not the HHO gas.
2. Tests on the vehicle to test the fuel savings.

##### 4.1. Testing to test out whether or not the HHO gas.

In this test experiment performed as in Figure 5 (a), and the resulting table 1 as follows:

Table 1: The test results came out much HHO gas

Current (Amperes)	Testing I (Litres / Minutes)	Testing II (Liters / Minutes)	Testing III (Litres / Minutes)	Average (Litres / Minutes)
5	0,13	0,14	0,13	0,133
7	0,2	0,21	0,22	0,21
8	0,25	0,26	0,24	0,25

##### 4.2. Tests on the vehicle to test the fuel savings.

The series of tests can be seen in Figure 5 (b), while the trial is divided into two parts, namely:

1. The test on the motor before replacing a hydrogen generator, while the attached test results in Table 2 below:

Table 2: The test results mileage on the motor vehicle without a gas mixture of hydrogen

Examination	Fuel Consumption (ml)	Mileage (km)	The Average Speed (km / h)
I	170	6,25	30-40
II	170	6,1	30-40
III	170	6,65	30-40
Average		6,33	30-40

2. Testing the motor after a hydrogen generator installed, while tests are carried out on the motorcycle brand "type Yamaha Jupiter MX 135 cc", after a hydrogen generator fitted with a speed of 30-40 km / h, would result in Table 3 as follows:

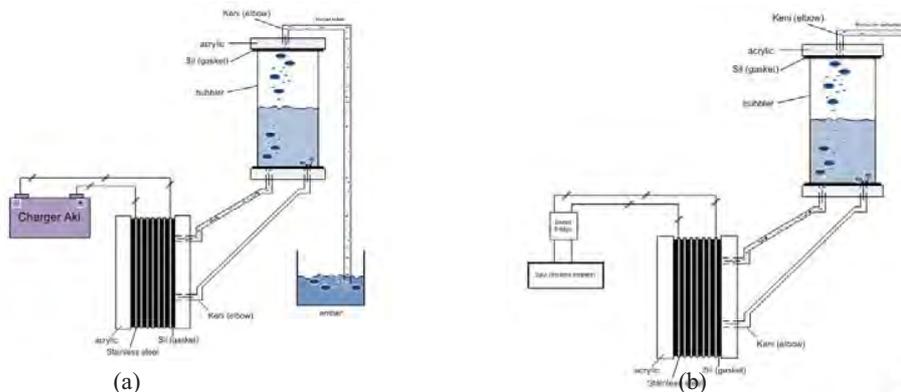


Figure 5: (a) hydrogen testing testing scheme, (b) testing scheme expenditure has hydrogen gas flowmeter and ampere meters

Table 3. The test results mileage on the motor vehicle with a gas mixture of hydrogen

Examination	Fuel Consumption (ml)	Mileage (km)	The Average Speed (km / h)
I	170	10,25	30-40
II	170	9,7	30-40
III	170	10,3	30-40
Average		10,08	30-40

### 3. Advanced testing mileage on the motor away

Do the test again in the motor at a sufficient distance away with using 3 liters of gasoline with and without HHO gas mixture with each test performed 3 times, we got the result as shown in Table 4 as follows:

Table 4 The comparison of mileage with and without the use of HHO gas mixture with 3 liters of gasoline consumption

Examination	Fuel consumption (litres)	Mileage without using gas mixtures HOH (km)	Mileage by using a gas mixture of BB + HOH (km)	The average speed (km / h)
I	3	105,65	165,85	40-60
II	3	107,20	163,25	40-60
III	3	108,25	166,70	40-60
Average		107,033	165,266	40-60



Figure 6: (a) When testing to determine the amount of HHO gas that comes out, (b) Installation of hydrogen in the motor generator tool

## 5. CONCLUSION

- From the manufacture of tools derived hydrogen generator turns out that water can produce hydrogen gas by electrolysis using electricity DC current which connect the electrodes in the form of stainless steel in a hydrogen generator. Equal overall reaction of electrolysis of water can be written as follows.



Hydrogen and oxygen gas produced from this reaction to form bubbles on the electrodes and can be collected.

- After testing the motor fuel without using a gas mixture of hydrogen and hydrogen gas mixture can be seen the difference. Without a gas mixture of hydrogen in the fuel can only be a distance of 37.2 km with one liter of gasoline. With a mixture of hydrogen in the fuel gas with only 1 liter of gasoline to a distance of 59.29 km. Efficiency means that not wasteful in fuel consumption has been fulfilled.

## REFERENCES

- Ariffin, Ir Eddy, "HHO Generator PDF", Fakultas Teknik Universitas Nasional, Jakarta, 2010
- Kadir, Abdul, "Energi", Penerbit Universitas Indonesia, Jakarta, 1982
- Soenarta, Nakoela, "Motor Serbaguna", PT Pradnya Paramita, Jakarta, 1985
- Suprpto M.Pd, "Bahan Bakar dan Pelumasan PDF", Teknik Mesin Fakultas Teknik Universitas Negeri Semarang, Semarang, 2004
- Wartawan, Anton L., "Bahan Bakar Bensin Otomotif", Penerbit Universitas Trisakti, Jakarta, 1997.

## Anatase TiO<sub>2</sub> enrichment from Bangka Ilmenite (FeTiO<sub>3</sub>) and its photocatalytic test on degradation of Congo Red

Sariman<sup>a</sup>, Yuni K. Krisnandi<sup>\*b</sup>, Budi Setiawan<sup>c</sup>

<sup>a</sup>Center for Coal and Mineral Technology (Puslitbang TekMira)  
Jl. Jendral Sudirman No. 623, Bandung 40211  
Tel : (022) 6030483. Fax : (022) 6003373  
E-mail : sariman@tekmira.esdm.go.id

<sup>b</sup>Department of Chemistry, FMIPA  
Universitas Indonesia, Depok 16424  
Tel : (021) 7270027 Fax : (021) 7863432  
E-mail : yuni.krisnandi@sci.ui.ac.id

<sup>c</sup>Department of Chemistry, FMIPA  
Universitas Indonesia, Depok 16424  
Tel : (021) 7270027 Fax : (021) 7863432  
E-mail : budisetiawan1326@gmail.com

### ABSTRACT

Anatase TiO<sub>2</sub> enrichment from Bangka ilmenite (FeTiO<sub>3</sub>) has been conducted. First, ilmenite was mechanically activated using a planetary ballmill to obtain sub-micron sized particle followed by magnetic separation. Chemical treatment, dissolution of iron using hydrochloric solution, was performed to obtain titania rich residue. EDX data shows that the iron content was reduced in the titania residue. Ammonium hydroxide (NH<sub>4</sub>OH) solution was added to the washed precipitate, before adding H<sub>2</sub>O<sub>2</sub> solution (10%) that acted as a coordination agent to leach titanium from the residue in the form of ammonium peroxy titanate solution. The peroxy titanate powder was obtained by evaporating the ammonium peroxy titanate solution. XRD data show that TiO<sub>2</sub> anatase was formed after peroxy titanate powder was calcined at the temperature of 600°C. EDX data also shows that the obtained anatase TiO<sub>2</sub> still has impurities, such as silicon (0.98%) and iron (2.75%). Its photocatalytic activity was studied on photodegradation of Congo Red and compared with the photocatalytic activity of commercial TiO<sub>2</sub>, Degussa P-25. The photoreactivity test on degradation of Congo Red solution with the as-prepared Anatase gave 20% degradation which is still inferior compared to the results given by Degussa P25 (92%). This indicates that the impurities in as-prepared Anatase may cover the titania surface hindering the contact between Congo Red as well as UV-light and the active titania species.

### Key words

*Ilmenite, HCl leaching, ammonium peroxy titanate, anatase TiO<sub>2</sub>, photoreactivity*

### 1. INTRODUCTION

The use of titanium products has been increasing from year to year. Rutile TiO<sub>2</sub> is one of titanium structure which is oftenly used as a white pigment in paint, food industry and cosmetics industries[1]. Rutile TiO<sub>2</sub> as pigment has non-corrosive properties, inert and resistant to UV rays. Besides rutile, TiO<sub>2</sub> has another structure, anatase, usually is applied as photocatalyst in various oxidation process and degradation of pollutant organic in water and air.

Until now, Indonesia imports various products of titanium although Indonesia has tons of ilmenite (FeTiO<sub>3</sub> mineral) with reserves about 40 million tons deposits which are naturally the main source of titanium. Ilmenite was formed as a primary mineral in maficigneous rocks, concentrated in a layer and found as waste from mining tin or zirconium sand. In Indonesia, Ilmenite is usually found as side product in tin mining [2]. Many works have been carried out to remove the iron from ilmenite in order to upgrade titanium in the compound which usually results in an increased quantity of rutile TiO<sub>2</sub>.

Recent developments show that a lot of research concerned in improving the extraction of TiO<sub>2</sub> from ilmenite as well lower energy consumption [3]. Nowadays about 60% of the world's TiO<sub>2</sub> pigments are manufactured by the chlorination route, in which natural, synthetic rutile and titanium-rich slag are used as feedstocks. In industry, chlorination process includes elevated temperature and use of chlorine gas, which require high energy and relatively dangerous condition. Hydrochloric acid treatment (also named as hydrochloric leaching) in the present of hydrogen peroxide was an alternative route that recently reported [4].

Two preliminary treatments on ilmenite, such as oxidation and mechanical activation were mostly conducted in order to increase the amount of iron to be removed from the ilmenite structure [5]. Mechanical activation was reported to assist the elimination of iron from ilmenite becomes more effective [5]. Its effectiveness was influenced by the physical and chemical properties, compositions and textures of ilmenite itself.

In this work, an attempt to obtain anatase type of  $\text{TiO}_2$  from Bangka ilmenite was reported, which is different to the target usually aimed in ilmenite extraction, rutile type of  $\text{TiO}_2$ . Extensive characterization on Anatase  $\text{TiO}_2$  properties as well as photocatalytic test in degradation of Congo Red in water environment were reported. The results in Anatase  $\text{TiO}_2$  enrichment process as well as photocatalytic test are discussed.

## 2. MATERIALS

Ilmenite ( $\text{FeTiO}_3$ , with Fe:Ti ratio of 12.10/22.5) was supplied from Bangka island as a side product at PT Timah Indonesia. HCl,  $\text{H}_2\text{O}_2$  30%,  $\text{NH}_4\text{OH}$ , and Congo Red dye were p.a. grade from Merck.  $\text{TiO}_2$  Degussa P-25 was supplied from Department of Chemical Engineering, Universitas Indonesia.

## 3. EXPERIMENT

Certain amount of raw Ilmenite was placed into planetary ball mill at 400 rpm for 3h followed by treatment with magnetic separator prior to iron separation. The sub-micron sized ilmenite powder then was reacted with HCl 20% solution and heated at 105 °C in the three-neck flask equipped with a condenser under stirring condition for 2 days. Variations were conducted by oxidizing Ilmenite and adding NaCl. Then  $\text{NH}_4\text{OH}$  12.5% was added until the solution reached pH 9, followed by addition of  $\text{H}_2\text{O}_2$  10% under continuous stirring. The pH must be maintained at pH 9. This mixture was stirred for 40 min at 40°C and the filtrate was separated from the residue and heated at 100°C to precipitate titanate peroxo. The precipitate then was dried at 80°C for 1 h followed by calcination at 400 dan 600°C to give anatase  $\text{TiO}_2$ . Finally photocatalytic test was carried out in degradation of Congo Red dye using the as-prepared Anatase, and commercially available  $\text{TiO}_2$  Degussa P-25, as photocatalysts.

## 4. ANALYSIS

XRD analysis characterized the structure of the residue and precipitation by referring to JCPDS (Joint Committee of Powder Diffraction Standards) files for related mineral, while analysis of the elemental compositions was performed both on solids (using EDX) and the filtrate (using AAS). The image of precipitation was observed by SEM. Bandgap energy of the titania was measured using UV-vis DRS. Concentration of Congo Red during photocatalytic study was determined using UV-vis spectrophotometer.

## 5. RESULT AND DISCUSSION

### Mechanical Activation

Bangka Ilmenite has a composition as shown in Table 1. It appears that it has a high content of titanium with impurities such as aluminium, calcium and silicon. It can be seen that after ilmenite was treated using magnetic separator (MS), the non-magnetic content (such as C, Al, Ca, Si and S) were decreased even not detected using EDX.

Table 1: Ilmenite composition determined with EDX

% wt	C	O	Al	Ca	Si	S	Ti	Fe
Raw Ilmenite	3.35	52.40	3.66	1.07	1.35	0.42	25.22	12.10
After treated with Magnetic-Separator	2.06	58.02	2.70	-	0.92	-	26.87	12.18

The XRD patterns of Bangka Ilmenite are shown in Fig. 1. Mechanical activation was carried out in order to breakdown the Ilmenite into finer particulate (up to submicron after planetary ball mill treatment) and physically separate nonmagnetic impurities from Ilmenite using magnetic separator. It is reported that the ball mill treatment increased the effectiveness of the ilmenite leaching reaction due to the increase in surface area and reactivity on surface after treatment that may be caused by a change in the crystal structure [6]. It can be seen in Fig. 1 that the intensity of some peaks increased and some new peaks

appeared which indicating that the crystallinity of ilmenite structure was enhanced after mechanically activated through ballmill treatment.

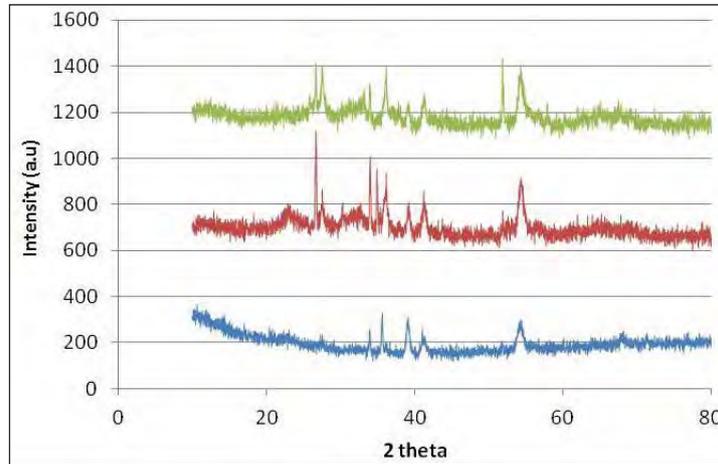


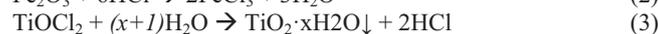
Figure 1: XRD pattern of Ilmenite: raw, mechanically activated, oxidized (top to bottom), referring to JCPDS file No. 29-0733 for Ilmenite, syn, Iron Titanium Oxide FeTiO<sub>3</sub>

### Oxidation

Oxidation of ilmenite is expected to change the Ilmenite surface because modification of surface due to diffusional processes occurs at high temperatures. In this case, the iron species is moving faster than titanium and tend to migrates toward area with oxygen high content. Thus, Fe cations in Ilmenite will migrate to the surface in hematite structure forming eggshell, so Fe will be leaching easily [7]. However, in this work, as shown by the XRD pattern in Fig. 1, no phase of hematite (Fe<sub>2</sub>O<sub>3</sub>) was identified, referring to JCPDS file No. 33-0664. This may due to only small amount of hematite was formed.

### HCl Leaching

Leaching process was carried out in order to dissolve iron from ilmenite (FeTiO<sub>3</sub>) and leave Rutile type of TiO<sub>2</sub> as solid part. In this process, hydrochloric acid was used because it has capability to dissolve impurities, e.g. iron as ferric chloride, and the acid solution can undergo regeneration. Plausible mechanism reactions that occur are listed below.



In this work, 6 variation of HCl leaching processed were conducted. The details of the experiments and results are listed in Table 2. The iron content in the filtrate was analyzed and the results were summarized in Fig. 2.

Table 2: Variation of HCl Leaching Process on Ilmenite

Process No.	Experiment
1	HCl leaching (8 h)
2	Oxidation & HCl leaching (8 h)
3	HCl leaching (48 h)
4	Oxidation & HCl leaching (48 h)
5	HCl leaching (48 h)+ NaCl
6	oxidation & HCl leaching (48 h)+ NaCl

It can be seen in Fig. 2 that oxidation process prior HCl leaching (Process 2 and 4) caused small increase in iron content in the filtrate, compared to their direct HCl leaching counterpart (Process 1 and 3, respectively). This results is in agreement with work reported by Janssen and Putnis [8]. Furthermore, the addition of NaCl to fresh HCl solution was not the best way to provide Cl<sup>-</sup> ions to attract iron that intact to ilmenite structure. Successful extraction of iron is a key factor in obtaining TiO<sub>2</sub> enriched ilmenite, because the more soluble Fe indicates that the more TiO<sub>2</sub>·xH<sub>2</sub>O or TiO<sub>2</sub> rutile (*synthetic* rutile) formed. The

ratio of Important elements (Ti, Fe and O) contained by the residue from leaching process are displayed in Fig. 3. Residue 4 is a result from the 48-h HCl leaching of oxidized ilmenite provided the highest Ti/Fe ratio. This is supported by the AAS data from Filtrate 4, in which it has the highest leached-Fe content. Therefore, Residue 4 was selected for further extraction to get the perokso titanate compound.

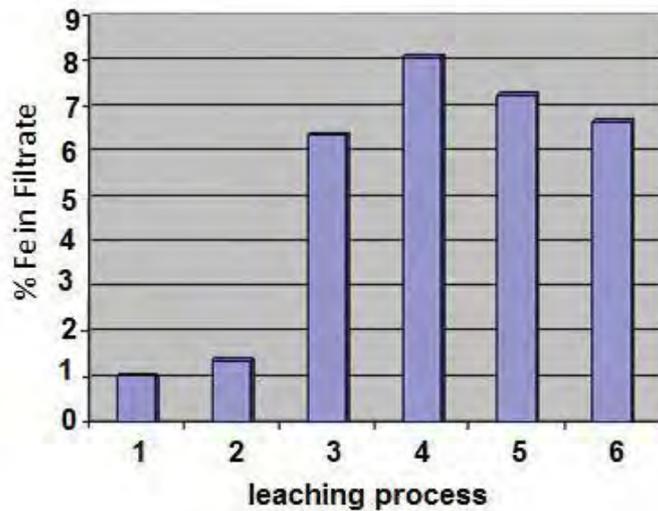


Figure 2: Fe content in the filtrate from HCl leaching process (determined from AAS analysis)

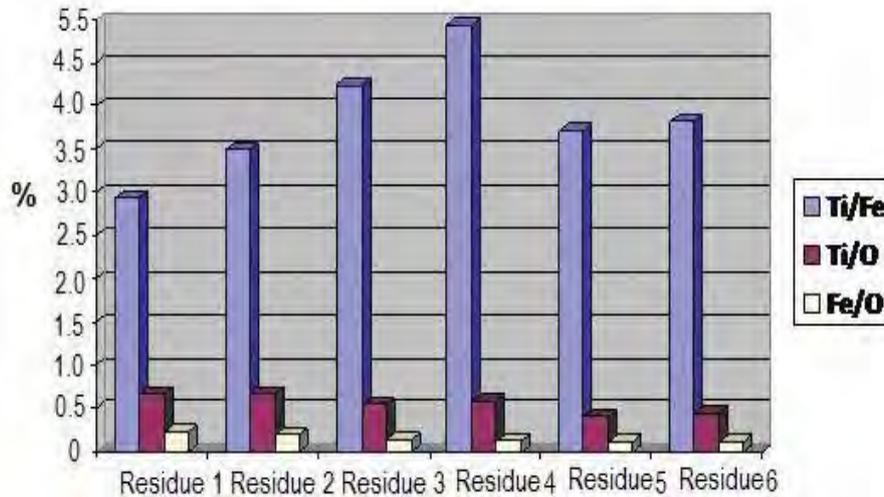


Fig. 3: Elemental composition in the Residue obtained after various HCl leaching process.

**Peroxo Titanate Solid**

EDX data shows the composition of peroxo titanate solid such as Table 3. It can be seen that the solid is Ti-rich with Fe and Si remain as impurities. In this solid, the titanium is still amorphous so that calcinations is necessary to obtain crystalline TiO<sub>2</sub>.

Table : Elemental composition of ammonium peroxo titanate powder (EDX measurement)

Element	Ti	O	Cl	Fe	Si
% wt	53.55	41.14	1.58	2.75	0.98

Fig. 4 shows the XRD patterns of TiO<sub>2</sub> after calcined at 400°C and 600°C. After calcination at 400°C, the typical peaks of TiO<sub>2</sub> anatase appeared weakly, indicating that at this temperature TiO<sub>2</sub> anatase crystal was not yet formed. Whereas the calcination at 600°C the peaks of TiO<sub>2</sub> anatase crystal have appeared clearly. Based on the SEM (Fig. 5) The Crystal was growing unevenly and hasn't a uniform size of particle. Generally, The size crystal is about 9-12 μm and has a rhombus shape or square

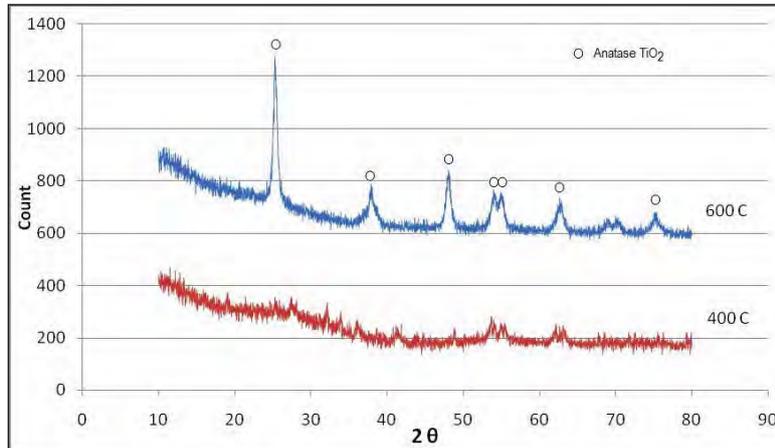
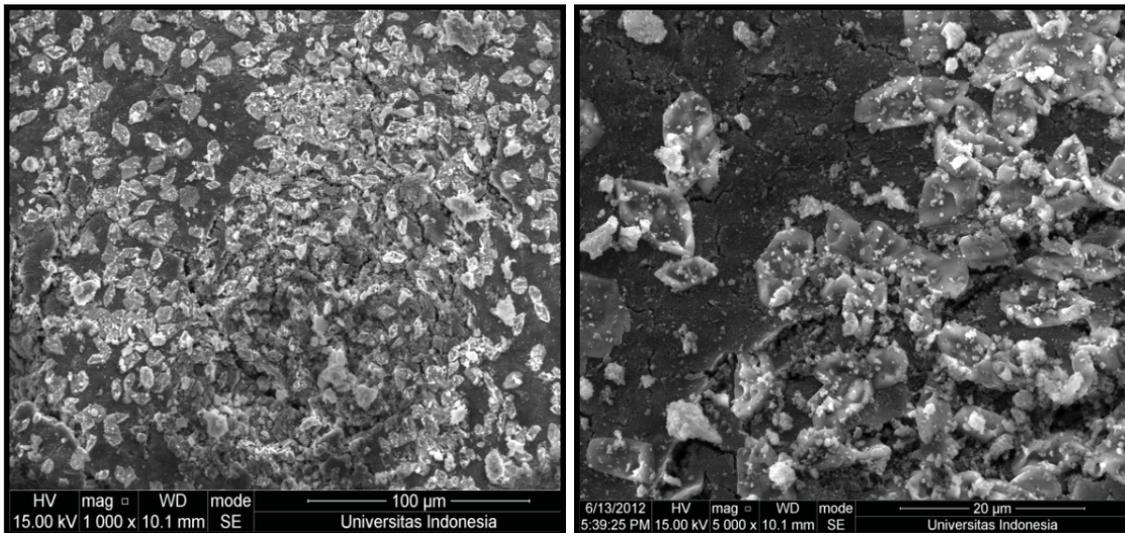


Figure 4: XRD patterns of TiO<sub>2</sub> prepared from calcinations of ammonium peroxy titanate salt, referring to JCPDS file for TiO<sub>2</sub> anatase, No. 04-0477.



Figutr 5: SEM TiO<sub>2</sub> Anatase (Calcination at 600°C)

From UV-DRS data (KM factor vs Energy (eV)) the value of band gap energy was determined, and it is found that the as-prepared TiO<sub>2</sub> has bandgap energy (3,08 eV) lower than that of *degussa P25* (3,34 eV). This could be due to the impurities intact to the structure as explained earlier.

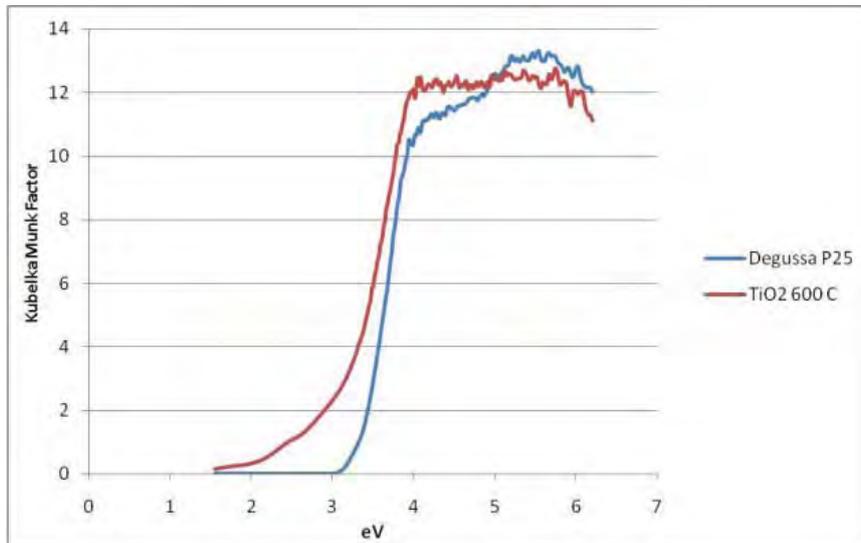


Figure 6: Plot of Kubelka Munk factor vs energy (eV) from TiO<sub>2</sub> dan Degussa P25

### Photocatalyst Test

Photocatalyst Test of TiO<sub>2</sub> anatase (calcination at 600°C) was carried out in photodegradation of congo red dye, and Degussa P25 was also employed for comparison. Fig. 8 shows that photocatalytic activity of Degussa P25 is still superior compared to that of the as-prepared anatase TiO<sub>2</sub>. After 3h, the as-prepared TiO<sub>2</sub> was only able to degrade 20% from the entire dye solution, whereas more than 80% of Congo Red concentration was degraded using P25 photocatalyst. This poor performance, again, may due to the presence of impurities such as silicon and iron extracted from ilmenite and covering the surface of TiO<sub>2</sub>. Thus, it is difficult for UV-light penetrate to TiO<sub>2</sub> surface and excite the electrons in Ti-d orbital.

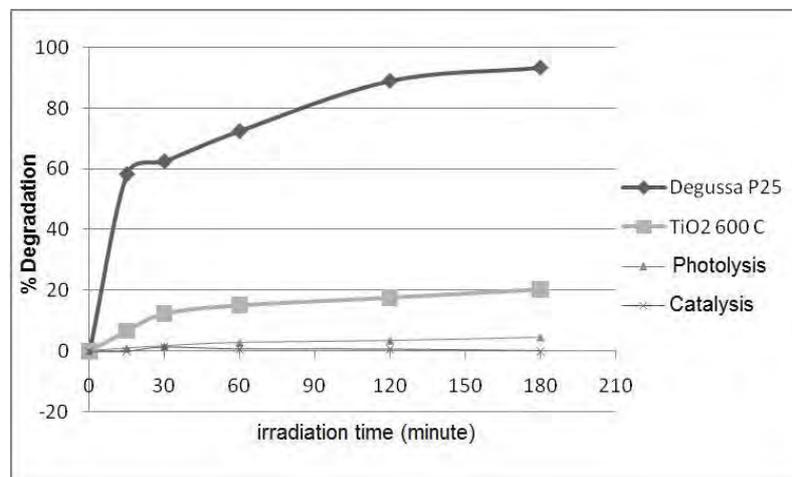


Figure 7: Degradation of CongoRed Solution under various catalytic condition

### 6. CONCLUSION

Anatase TiO<sub>2</sub> has been extracted from ilmenite Bangka after subjected to mechanical activation, HCl leaching and formation of intermediate ammonium titanate peroxo compound; although it still has impurities such as silicon and iron. Anatase TiO<sub>2</sub> from ilmenite Bangka has an inferior photocatalytic activity in photodegradation of CongoRed dyes compared with Degussa P25. Further investigation should be conducted in order to obtain higher quality of Anatase TiO<sub>2</sub>. Nevertheless, this result shows that Bangka Ilmenite is promising to be used as natural resource to obtain anatase TiO<sub>2</sub> photocatalyst.

## ACKNOWLEDGMENT

This research was partially funded by HPTP (Postgraduate Research Grant from Higher Directorate of Education, RI) year 2012.

## REFERENCES

- [1] U. Diebold, *The Surface Science of Titanium Dioxide* Surface, Science Report, vol 48, pp 53-229, 2003.
- [2] Firdiyono, *Percobaan Ekstraksi Bijih Ilmenit Australia dengan Pemanggangan Reduksi dan Pelarutan Sulfat*, Metalurgi, vol. 20, pp. 12-20. 2005.
- [3] Wu, Feixiang. Et al. "Hydrogen peroxide leaching of hydrolyzed titania residue prepared from mechanically activated Panzhihua ilmenite leached by hydrochloric acid" *International Journal of Mineral Processing*, vol 98, pp 106–112, 2011.
- [4] L. Zhang, H. Hu, Z. Liao, Q. Chen, J. Tan, Hydrochloric acid leaching behavior of different treated Panxi ilmenite concentrations, *Hydrometallurgy*, vol. 107, pp. 40–47, 2011.
- [5] T.Ping, H. Hui-ping, Z. Li, Effects of mechanical activation and oxidation-reduction on hydrochloric acid leaching of Panxi ilmenite concentration, *Trans. Nonferrous met. Soc. China*, vol 21, pp 1414-1421, 2011.
- [6] Zhang, Li. Et al. "Hydrochloric Acid Behavior of Mechanically Activated Panxi Ilmenite" *Separation and Purification Technology*, vol. 73, pp. 173-178, 2010.
- [7] M.H.H. Mahmoud, A.A.I. Afifi, I.A. Ibrahim, *Reductive leaching of ilmenite ore in hydrochloric acid for preparation of synthetic rutile*, *Hydrometallurgy*, vol. 73, pp. 99–109, 2004
- [8] A. Janssen, A. Putnis, Processes of oxidation and HCl-leaching of Tellnes ilmenite, *Hydrometallurgy*, vol. 109, pp. 194–201, 2011.

## The Na<sup>+</sup> Cationic Effect Towards Iron Sand's Ilmenite Crystals Destruction

Dwi Wahyu Nugroho<sup>ab</sup>, Fitria Roli Irawan<sup>c</sup>, Tito Prastyo Rahman<sup>ab</sup>, Fitri Suryani Arsyad<sup>c</sup>,  
Radyum Ikono<sup>ad</sup>, Nurul Taufiq Rochman<sup>ae</sup>

<sup>a</sup>Nano Center Indonesia  
Tangerang Selatan, 15314  
Tel : (021)75870479  
Email : wahyu@nano.or.id

<sup>b</sup>Faculty of Mathematics and Natural Sciences, University of Indonesia  
University of Indonesia, Depok 16424  
Tel : (021) 7270011 ext 51. Fax : (021) 7270077  
E-mail : wahyu@nano.or.id

<sup>c</sup>Faculty of Mathematics and Natural Sciences, University of Sriwijaya  
Palembang, 30622

<sup>d</sup>Faculty of Engineerin, University of Technology Sumbawa  
Sumbawa

<sup>e</sup>Research Center for Metallurgy, Indonesian Institute of Sciences  
Tangerang Selatan, 15314  
Tel : (021) 7560911. Fax : (021) 7560553

### ABSTRACT

Iron sand contains magnetite, hematite, ilmenite, alumina, silica, and other minerals. The presence of titania in ilmenite gives value-addedness to iron sand. This research is intended to see the effect of Na<sup>+</sup> cation in the destruction process of ilmenite crystal in Titania extraction.

In this research, magnetically separated iron sand was mixed with NaCl or NaOH, and burned with temperature variation: 400, 600, and 800°C. After that, characterization with XRD of sample before and after roasting and with SEM of sample after magnetic separation were conducted. The results of XRD measurement of roasted iron sand-NaCl mixture showed no destruction of ilmenite crystal structure. It can be observed that peak was resulted from Fe<sub>3</sub>O<sub>4</sub>, Fe<sub>2</sub>O<sub>3</sub>, TiO<sub>2</sub>, and NaCl compound. While result of SEM mapping on concentrate and tailing showed that area Fe and Ti atoms were closely arranged. The results of XRD measurement on roasted iron sand-NaOH mixture showed the destruction of the iron sand ilmenite crystals, as seen by the formation of new compounds. New peaks from NaFeO<sub>2</sub>, NaTiO<sub>2</sub>, Na<sub>0.75</sub>Fe<sub>0.75</sub>Ti<sub>0.25</sub>O<sub>2</sub>, and TiO<sub>2</sub> compounds were seen obviously. Also, result of SEM mapping showed that Na<sup>+</sup> cations could penetrate into ilmenite's crystal. One of the proposed mechanisms was that, NaOH has an ability to damage ilmenite crystals due to the fact that NaOH has lower melting point compared to that of NaCl, thus making NaOH much more reactive. Also, it can be deduced that the mobility of ion is larger than mobility of solid. When iron sand is roasted in high temperature, NaOH was melted and Na<sup>+</sup> cationic could penetrate easily.

### Keywords

Iron sand, ilmenite, titania, NaCl, NaOH

### 1. INTRODUCTION

Indonesia is a rich country in natural resources. One of the abundant natural resources in Indonesia is iron sand. Iron sand with total more than 2 billion tons (Kemenperin, 2007) spread along the southern coast of Java, Sumatera, West Nusa Tenggara, etc. Iron sands contain magnetite (Fe<sub>3</sub>O<sub>4</sub>), hematite (Fe<sub>2</sub>O<sub>3</sub>), ilmenite (FeTiO<sub>3</sub>), alumina (Al<sub>2</sub>O<sub>3</sub>), silica (SiO<sub>2</sub>) and small amounts of other mineral, with variation content in different location.

Various methods have been made in the making of titania's concentrate from ilmenite such as magnetic separation, roasting, milling, etc. However, the method still has disadvantage because strong bond between Fe-O-Ti in ilmenite crystals ( $\text{FeO} \cdot \text{TiO}_2$ ). Thus, titania as ilmenite is tough separated with iron.

One method in concentrate titania making is adding chemical compounds. The addition of chemical is expected to assist in the destruction of the crystal structure, E. Foley and Kathryn P. Mackinnon (1970), using  $\text{Na}_2\text{CO}_3$  and  $\text{K}_2\text{CO}_3$  in ilmenite. TA Lasheen (2008) using soda caustic ( $\text{Na}_2\text{CO}_3$ ) on titania slag from rosetta ilmenite and roasted at  $850^\circ\text{C}$ .

In this research, a  $\text{Na}^+$  cationic effect towards iron sand's ilmenite crystal destruction is investigated.  $\text{NaOH}$  and  $\text{NaCl}$  is used in this research as source of  $\text{Na}^+$ .

## 2. EXPERIMENTAL

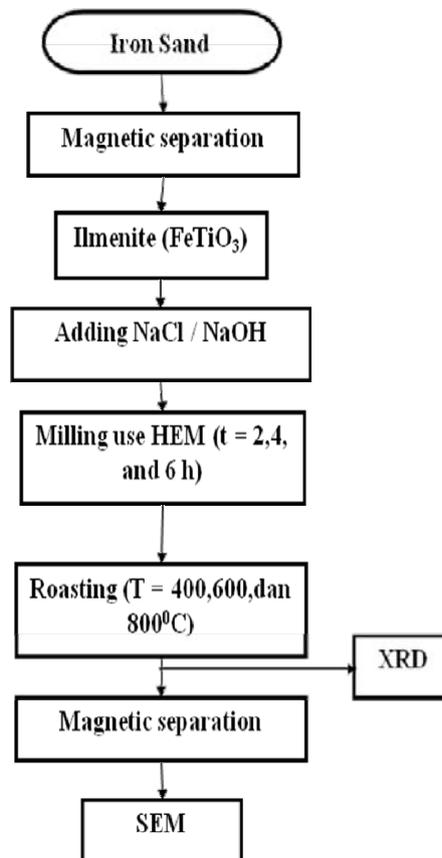


Figure 1. Experimental scheme

In this research, iron sand come from Sukabumi, Jawa Barat. Iron sand is separated by washing with water to remove impurities such as dust, gravel. Iron sand that has been washed, is separated using magnetic separator to remove silica and other nonmagnetic impurities. Titania concentrate in ilmenite is added  $\text{NaCl}$  or  $\text{NaOH}$  with a mole ratio ilmenite: $\text{NaCl}/\text{NaOH}$  at 1:2. A mixture of 10 grams, is milled using High Energy Milling E3D (HEM E3D) for 2 hours, 4 hours, and 6 hours. After the mixture was milled, is roasted at temperature  $400^\circ\text{C}$ ,  $600^\circ\text{C}$ , and  $800^\circ\text{C}$ . before and after combustion, sample was characterized using XRD to see changes in the crystal structure and the effect of chemical reagent on ilmenite. The result of magnetic separation is characterized by Scanning Electron Microscope (SEM).

## 3. DISCUSSION

Figure 1 shows a roasted mixture ilmenite- $\text{NaCl}$  and ilmenite- $\text{NaOH}$ . Figure shows that the colour of the sample after roasted changes from black into red.

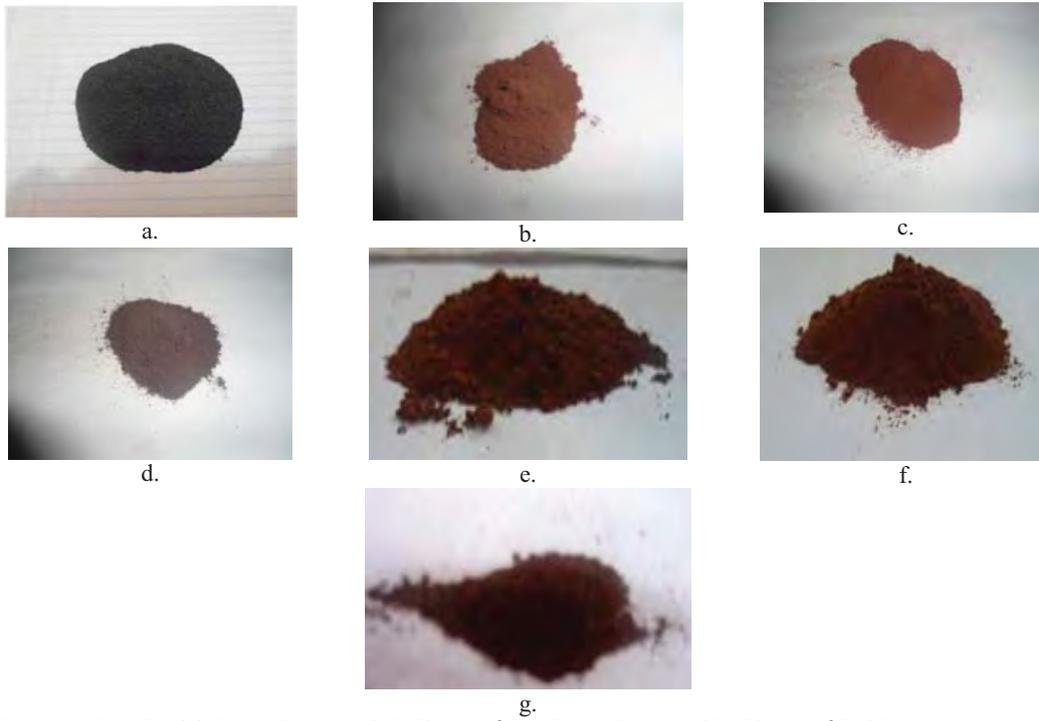


Figure 1: a. Iron Sand, b. Roasted iron sand-NaCl at 400 °C, c. Roasted iron sand-NaCl at 600 °C, d. Roasted iron sand-NaCl at 800 °C, e. Roasted iron sand-NaOH at 400 °C, f. Roasted iron sand-NaOH at 600 °C, g. Roasted iron sand-NaOH at 800 °C.

The red colour on roasted iron sand-NaCl, indicate that contain iron oxide  $Fe_2O_3$ , result of oxidation from iron sand because of effect of heating.  $Fe_2O_3$  intensity increases with increase of roasted temperature. It can be caused due to the oxidation reaction on Fe as follows:

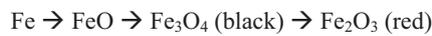
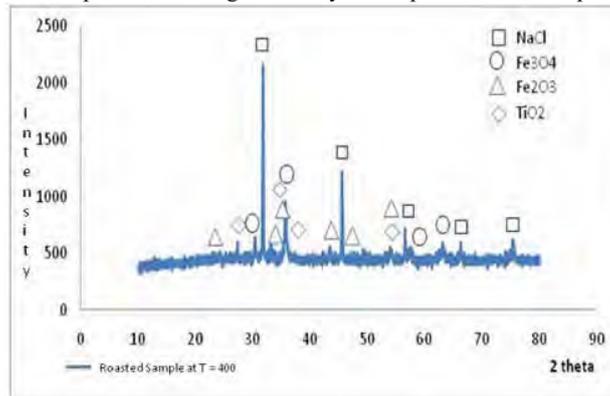
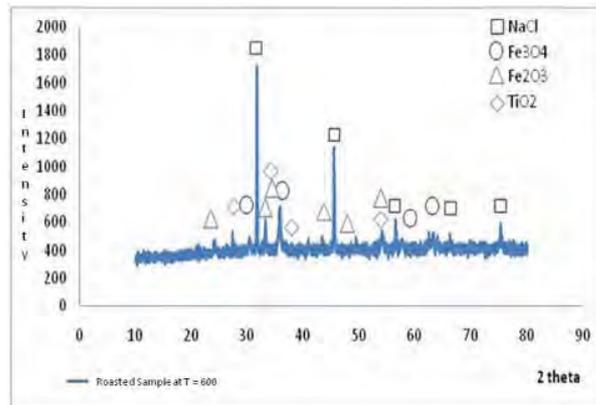


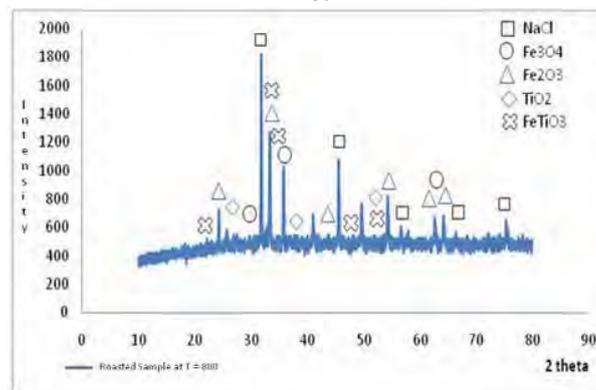
Figure 2 shows XRD characterization of roasted iron sand-NaCl where there are four main compound in the sample, i.e NaCl,  $Fe_2O_3$ ,  $Fe_3O_4$ , and  $TiO_2$ .  $TiO_2$  intensity has increased in temperature 600°C but decreased at 800°C. Magnetite ( $Fe_3O_4$ ) intensity decreased along with increasing temperature due to oxidation to  $Fe_2O_3$ . The existence of peaks from NaCl, showed that not all NaCl can react with iron sand. It can be proved with high intensity of the peak of each temperature.



a.



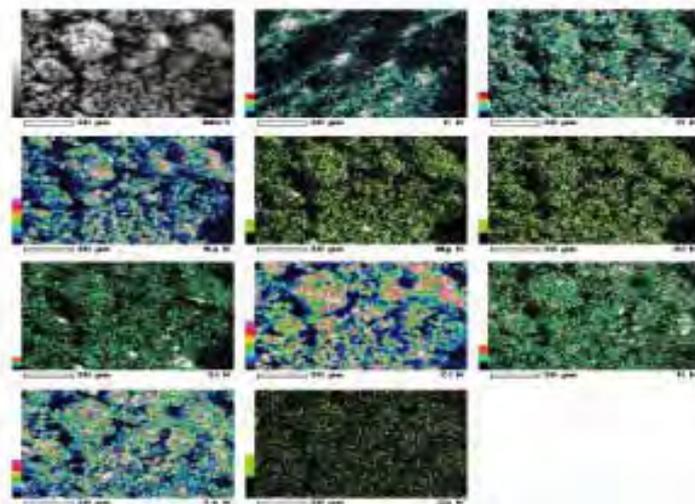
b.



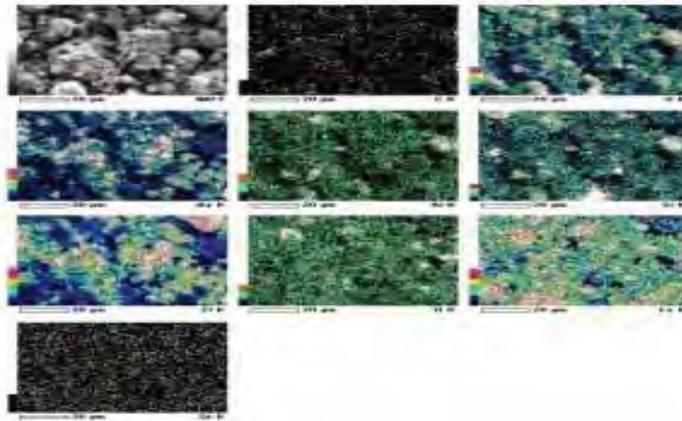
c.

Figure 2: XRD measurement of roasted iron sand-NaCl at a. 400°C, b. 600°C, and c. 800°C.

The result of mapping the concentrate and tailings on iron sand-NaCl after magnetic separation is showed in figure 3. Seen in the results of mapping, distribution Fe and Ti atoms adjacent and occupy the same area so it can be expected the bonds between atoms of Fe-Ti-O can't be separated by NaCl.



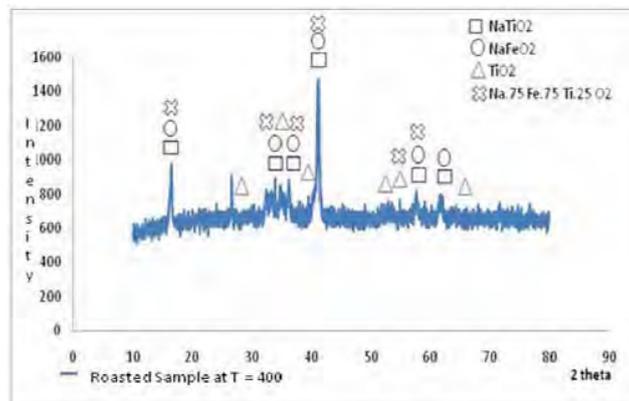
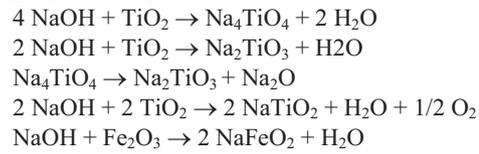
a.



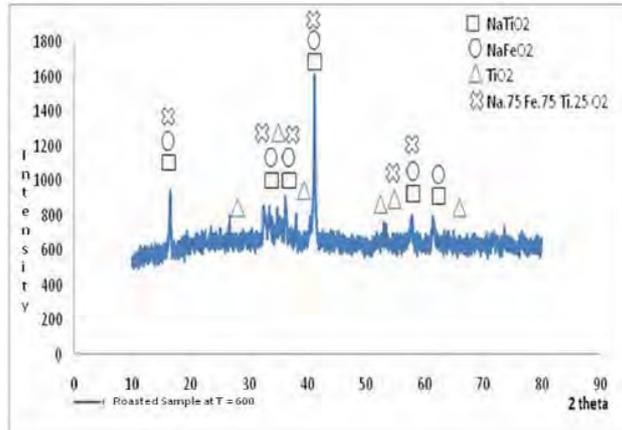
b.

Figure 3: Mapping of roasted iron sand-NaCl at a. concentrate, b. tailings.

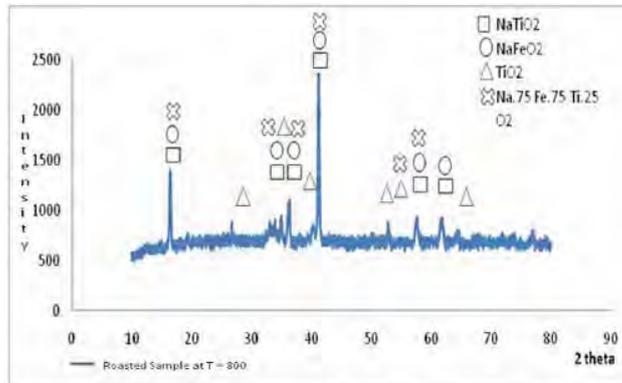
In figure 4 shows XRD results on roasted iron sand-NaOH. The reaction between iron sand with NaOH form novel compound i.e NaFeO<sub>2</sub>, NaTiO<sub>2</sub>, Na<sub>0.75</sub>Fe<sub>0.75</sub>Ti<sub>0.25</sub>O<sub>2</sub>, and TiO<sub>2</sub> as follows:



a.



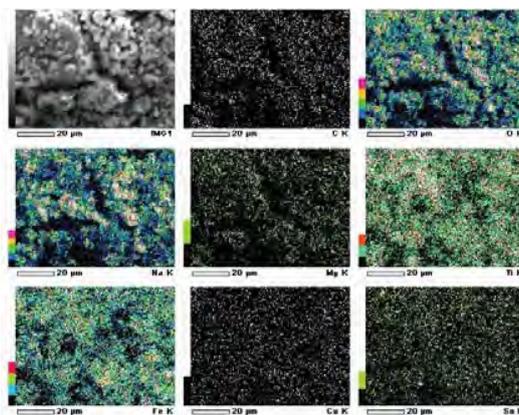
b.



c.

Figure 4: XRD results of roasted iron sand-NaOH at a. 400°C, b. 600°C, and c. 800°C.

Intensity of the three compound are  $\text{NaFeO}_2$ ,  $\text{NaTiO}_2$ , and  $\text{Na}_{0.75}\text{Fe}_{0.75}\text{Ti}_{0.25}\text{O}_2$  increase along with increasing temperature.  $\text{Na}^+$  cationic can destruct ilmenite crystal because it can penetrate between crystal and bind to Fe and Ti to form  $\text{NaFeO}_2$ ,  $\text{NaTiO}_2$ , and  $\text{Na}_{0.75}\text{Fe}_{0.75}\text{Ti}_{0.25}\text{O}_2$  (Figure 5). The possibility why NaOH is able to provide a better reaction than NaCl due to NaOH has a melting point at  $318^\circ\text{C}$ , resulting in temperature above  $400^\circ\text{C}$  will be more readily reacts with iron sand than NaCl that has a melting point of  $801^\circ\text{C}$ .



a.

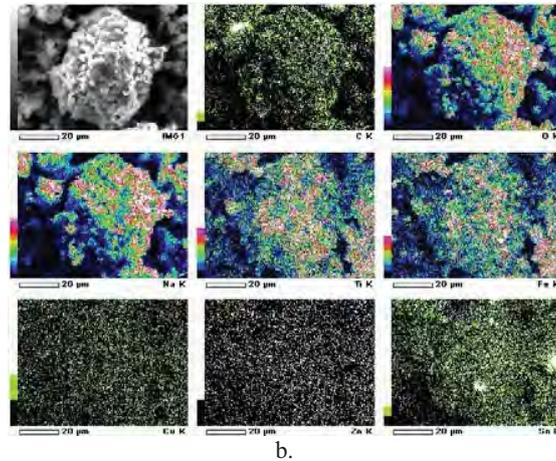


Figure 5. Mapping of roasted iron sand-NaOH at a. concentrate, b. Tailings

#### 4. CONCLUSION

NaOH has an ability to damage ilmenite crystals due to the fact that NaOH has lower melting point compared to that of NaCl, thus making NaOH much more reactive. Also, it can be deduced that the mobility of ion is larger than mobility of solid. When iron sand is roasted in high temperature, NaOH was melted and  $\text{Na}^+$  cationic could penetrate easily.

#### 5. ACKNOWLEDGMENT

This work was financially supported in Insentif SINAS programme by ministry of research and technology, Indonesia

#### 6. REFERENCE

- [1] E. Foley and Kathryn P. Mackinnon. 1970. Alkaline roasting of ilmenite. *journal of solid state chemistry* 1:566-575.
- [2] TA. Lasheen. 2008. Soda ash roasting of titania slag product from Rosetta ilmenite. *Hydrometallurgy* vol. 93: 24-128
- [3] Gueguin, Michel and Francois cardarelli, 2007, ilmenite ore beneficiation and upgrading, *Mineral processing and extractive metallurgy*, rev.28, page: 1-58.
- [4] Herianto, Edi, 2009, Potensi Pengembangan Sumber Daya Mineral Pasir Besi di Indonesia, *Prosiding Seminar Material Metalurgi 2009*, hal:69-74.
- [5] Fouda, M.F.R., et al. 2010. *Extraction of Ultrafine Titania from Black Sands Broaden on the Mediterranean Sea Coast in Egypt by Molten Alkalies*. Australian Journal of Basic and Applied Sciences, 4 (9): 4256-4265, 2010.

# Adsorption of Carbon Monoxide (CO) Gas And Clearing of Fire Smoke Using Activated Carbon From Coconut Shell Impregnated TiO<sub>2</sub>

Yuliusman<sup>a</sup>, Diana Augusta<sup>b</sup>

<sup>a,b</sup> *Departement of Chemical Engineering, Faculty of Engineering  
University of Indonesia, Depok 16424  
E-mail : usman@che.ui.ac.id*

## ABSTRACT

The study was conducted to determine the performance of activated carbon adsorbent and influence of TiO<sub>2</sub> on the insertion of activated carbon in adsorbing gas combustion CO and smoke cleared. Activated carbon is made with raw coconut shell charcoal is chemically activated by the activating agent ZnCl<sub>2</sub> 65% with a mass ratio of ZnCl<sub>2</sub>/charcoal 4:1. Activation process is performed to a temperature of 700<sup>o</sup>. The incorporation of activated carbon with TiO<sub>2</sub> through the insertion method. Including the process undertaken by impregnation with stirring and sonication followed by calcinations at a temperature of 400<sup>o</sup>C. Smoke to be tested is the result of burning a mixture of sawdust, paper, cables, and charcoal. Varied the size of activated carbon are 74 μm, 125 μm and 420 μm. While the varied mass are 1 gram, 3 grams and 5 grams. The fastest time in clearing of smoke is up to the value of opacity is 10% achieved by the activated carbon adsorbent is inserted as much as 3 grams of TiO<sub>2</sub> is for 28 minutes. Activated carbon is inserted TiO<sub>2</sub> can increase the clearing of smoke performance by an average of 12.50% and the adsorption of CO gas of 12.12%. Highest adsorption capacity is achieved by AC-TiO<sub>2</sub> adsorbent as much as 1 gram is equal to 29.568 mg /mg adsorbent.

## Keywords

*Activated carbon, coconut shell, TiO<sub>2</sub>, adsorption, smoke, carbon monoxide*

---

## 1. INTRODUCTION

Fire is an event that can not be avoided. Statistics in Jakarta noted that there are hundreds of cases of fires every year. In addition to causing losses of hundreds of billions of dollars, fires can also cause casualties. According to data from 1998 to 2007, an average of 30% of the fire victim's life can not be saved [8]. In the case of fire, smoke poisoning death rate is much greater than the deaths due to burns injury. In the world, 85% of deaths in cases of fires are caused by heavy smoke and toxic gases [1].

Cases smoke from fires contains many compounds that are harmful to health. Some of the content of the smoke produced, among others, carbon dioxide (CO<sub>2</sub>), carbon monoxide (CO), water vapor, particulates, and some toxic compounds such as NO<sub>x</sub> and SO<sub>x</sub>. Although not described quantitatively, CO including many gas produced during a fire. Carbon monoxide does not irritate but very dangerous (toxic) gas CO dubbed the "silent killer" (the silent killer). The presence of CO gas can be very dangerous if inhaled by humans because it would replace the gas of oxygen associated with hemoglobin in the blood. CO gas will flow to the heart, brain, and vital organs. Bonding between CO and hemoglobin to form carboxyl hemoglobin is 200 times much stronger than the bond between oxygen and hemoglobin. The result is fatal. First, the oxygen will not compete with current CO binds to the hemoglobin molecule. This means that oxygen levels in the blood will be reduced. Second, the CO gas will inhibit oxidation of cytochrome complex. This cause intracellular respiration becomes less effective. Finally, the CO can bind directly to the heart muscle, and bone cells. The most serious effect is poisoning occurs directly on the cells, also cause disturbances in the nervous system [2]. Limit carbon monoxide exposure allowed by OSHA (Occupational Safety and Health Administration) is 35 ppm for 8 hours/working days. Exposure to 1000 ppm CO gas for a few minutes can cause death. Hence the fact that some people have described about the dangers of CO gas, smoke from fires should be reduced or clarified. Several researchers have conducted research related to the clearing of smoke on the content of CO gas. A study is ever to evaluate the potential of nanoparticles in clearing of smoke in an enclosed space with multiple uses nanoparticles and ordinary powder [3]. Previous research has also been carried out clearing of smoke and fire extinguishing using MgO which has been patented by Mulukutla et al, 2007 [4]. However, the results of these studies can not be said to be effective with CO gas adsorbed percentage which is still low.

One way to reduce the levels of CO gas is in the process of adsorption by the adsorbent, where the absorption of CO gas that

accumulates on the surface of adsorbent. In the adsorption process, the adsorbent surface area is a major parameter in considering the adsorbent to be used. Activated carbon adsorbent is one potential use as an adsorbent because it has large surface area. One of the potential natural materials for its manufacture is coconut shell. Coconut shell charcoal has a large surface and hollow with a layered structure. Another plus is not toxic, easily available, economical, and effective.

In this study, activated carbon from coconut shell charcoal impregnated with  $\text{TiO}_2$  for use as adsorbent in adsorbing CO gas and fire fumes clear. Merging is done to increase the performance of adsorption of CO and smoke clearing. Coconut shell charcoal media inserted  $\text{TiO}_2$  affect the adsorption of CO and  $\text{NO}_2$  gas, and more optimal in reducing the concentration of CO and  $\text{NO}_2$  gas, compared to coconut shell charcoal medium without insertion of  $\text{TiO}_2$  [5]. The presence of  $\text{TiO}_2$  is abundance in Indonesia, especially in the province of Bangka Belitung.

In its usefulness as a purifying fire smoke and gases absorb CO, is expected to activated carbon from coconut shell charcoal combined with  $\text{TiO}_2$  this will be a technique that is more effective and efficient than other adsorbents that have been used previously.

## 2. EXPERIMENT

There are several stages in this study, including preparation of activated carbon, CO gas adsorption test of fire smoke, and data processing. Preparation of activated carbon -  $\text{TiO}_2$  done with two main activities, namely the stage of making activated carbon from coconut shell later stage pasting  $\text{TiO}_2$  on activated carbon.

### 2.1 Production of Activated Carbon

Coconut shell as the manufacture of activated carbon first through carbonization conducted in a furnace at a temperature of  $400^\circ\text{C}$  for 2 hours. After that, coconut shell charcoal which has been turned into a crushed and sieved to the size variation of  $74\mu\text{m}$ ,  $125\mu\text{m}$  and  $420\mu\text{m}$ . Furthermore, each with various sizes of charcoal enters the activation stage. Activation is done by activating the chemical activation agent in the form of  $\text{ZnCl}_2$ . Charcoal obtained from carbonization process  $\text{ZnCl}_2$  solution are mixed with 65% by comparison activating agent / charcoal at 4:1. The mixture is then stirred (stirrer) on a hot plate with a temperature of  $200^\circ\text{C}$  to form a slurry and harden.

Furthermore carbon follows the pyrolysis process at a temperature of  $700^\circ\text{C}$  for 1 hour activation (after the activation temperature is reached). Activation process on activated carbon was carried out without the presence of free oxygen with  $\text{N}_2$  gas flow during the activation process with a flow rate of  $100\text{ cm}^3/\text{min}$ . In the absence of air or free oxygen is not expected to damage the pore structure of the raw material which will result in losses occurred (loss of material) on the final results of activated carbon.

Subsequently the sample was washed with 0.1 N HCl solution to remove alkali compounds on carbon. Washing is done at a temperature of  $85^\circ\text{C}$  for 30 minutes. When finished washing with HCl and then do the washing or rinsing with distilled water until neutral pH, and then dried at  $110^\circ\text{C}$  for 24 hours.

### 2.2 Insertion of $\text{TiO}_2$ on Activated Carbon

Preparation of  $\text{TiO}_2$  on activated carbon insertion begins by dissolving the amount of  $\text{TiO}_2$  Degussa P-25 to 100 ml of demin water and stirred for 10 min sonication. Furthermore activated carbon is added to a solution of  $\text{TiO}_2$  (Active Carbon comparison with  $\text{TiO}_2$  Degussa P-25 was 75:25) and followed by sonication for 20 minutes. After that, the mixture was heated on a hot plate with a temperature of  $110^\circ\text{C}$  to dry mixture. Coconut shell charcoal layer structure formed after the insertion of  $\text{TiO}_2$  molecule is still fragile, so it is necessary to further warming or calcined at  $400^\circ\text{C}$  for 1 hour to stabilize the layer structure of coconut shell charcoal.

### 2.3 Characterization

To measure the surface area of the adsorbent, BET testing was conducted. Tests used the BET brand Autosorb 6B Quantochrome in Chemical Reaction Engineering and Natural Gas Convention Laboratory, Department of Chemical Engineering, FTUI, Depok. Afterwards, FE-SEM testing was done to see patterns and pores on the surface of adsorbent. Furthermore, EDX analysis was carried out for the chemical composition of surface elements on adsorbent. FESEM-EDX test performed in SEM Laboratory Department of Metallurgical and Materials Engineering Faculty of Engineering University of Indonesia. EDX test equipment system works as an integrated feature of the FE-SEM and can not operate alone.

### 2.4 Adsorption Test and Smoke Saturation

Smoke and CO gas adsorption test were performed in a testing chamber made of acrylic material with a size of 40 cm x 40 cm x 120 cm. Testing chamber scheme can be seen in Figure 1. Adsorption smoke test performed at three different points in the testing chamber. Point 1 is the point of testing within 105 cm from the bottom of the testing chamber. Point 2 is the midpoint of the testing chamber, which is at a height of 60 cm from the bottom of the testing chamber. Point 3 is the lowest point of testing, 15 cm from the bottom of the testing chamber. Furthermore, the location of the sensor CO<sub>2</sub> is around the point of opacity testing, it is attached to the wall within 60 cm from the bottom.

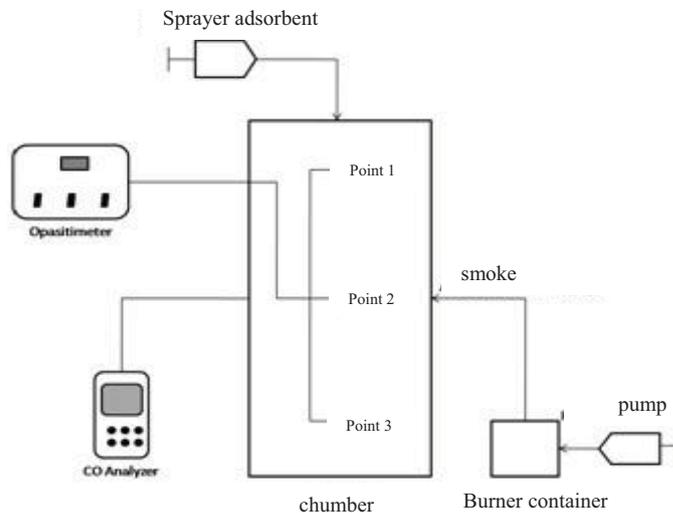


Figure 1: Testing chamber scheme

Adsorption of CO gas and fire fumes clearing was performed by activated carbon and activated carbon with inserted TiO<sub>2</sub> adsorbent. Activated carbon size was varied for 74 μm, 125 μm, and 420 μm. Each size is then varied for 1 gram, 3 gram and 5 gram of mass. Nevertheless, AC-TiO<sub>2</sub> varied for 1 gram and 3 grams of mass.

At first the test chamber was cleaned and leak checking conducted. Burned material is paper, wires, plastic, sawdust and charcoal. So that combustion takes place uniformly, kerosene was added into material tested. Burning is done in a container inside the combustion fumes pumped into the testing room until the smoke reaches the percentage saturation > 90% and levels of CO gas in the smoke chamber stable. After that, to test the ability of the adsorbent in CO gas adsorption, adsorbent was sprayed through a hole located at the top of the testing chamber. Then, observation is done to see changes in the value or level of clarity smoke opacity and changing levels of CO gas in the test chamber. Observation of the changes made to the value of opacity value reaches the value of 0.1 or 10%, where the darkness of smoke reaching 10%. Otherwise, the observation of CO gas levels change every minute for 30 minutes.

### 3. RESULTS AND DISCUSSION

#### 3.1 Adsorbent Characterization

Some characterization performed on the adsorbent surface structures include analysis using FE-SEM testing, analysis of the chemical composition of the adsorbent sample using EDX testing, analysis of the adsorbent surface area using BET analysis methods.

##### 3.1.1 Surface Structure (FE-SEM Test)

FE-SEM testing was done to see a pattern or surface structure of the adsorbent, especially pore formed. Surface structure of the test results with FE-SEM can be seen the basic structure of the surface of carbon materials that have been activated as in Figure 2.

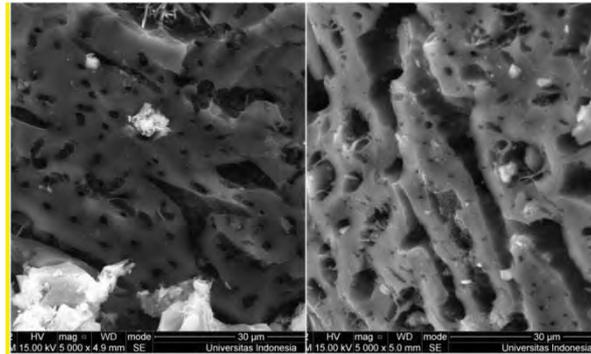


Figure 2: FE-SEM results of activated carbon with a magnification of 5000 times

From Figure 2 can be seen the carbon formed after activation or pore space, with pore diameters varying the micro pores, meso pores and macro pores. These pores are formed during the process in which carbon reacts with activating agent ( $\text{ZnCl}_2$ ). Ability to activate  $\text{ZnCl}_2$  (pore forming) carbon is based on functions of dehydration. During the activation process,  $\text{ZnCl}_2$  eliminate hydrogen and oxygen atoms from the carbon material as water rather than as an organic component of oxygen, so it is good for porosity generation and increasing carbon content. Additionally,  $\text{ZnCl}_2$  is an activating agent that can alter the behavior of the pyrolysis of carbon precursors.  $\text{ZnCl}_2$  will be interspersed into the carbon matrix by impregnation. When pyrolysis causes dehydration of  $\text{ZnCl}_2$  impregnation of carbon precursors leads to authoring and aromatization along with the creation of pores. During the activation process, molten  $\text{ZnCl}_2$  formed above the boiling point of  $\text{ZnCl}_2$ . Activation temperature increases further, the interaction between the carbon atoms and Zn occur resulting in a significant widening of carbon interlayers and creates pores in the carbon matrix. During the interaction with carbon,  $\text{ZnCl}_2$  helps removal of water from the structure by cutting carbon hydrogen and oxygen from carbon precursors. Result of  $\text{ZnCl}_2$  activation is the formation of micro pores.

Further tests of FE-SEM was conducted back on activated carbon that has been inserted  $\text{TiO}_2$ . FE-SEM test results can be seen in Figure 3.

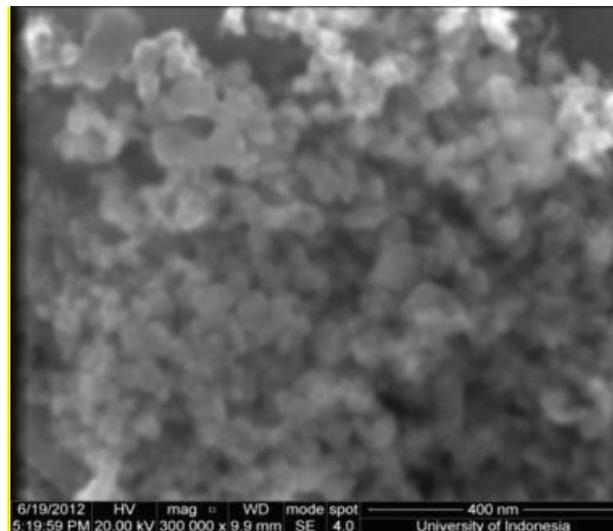


Figure 3: FE-SEM results of activated carbon-  $\text{TiO}_2$  with a magnification of 300000 times

Figure 3 shows the change of the activated carbon material performed after the insertion process. These changes can be observed clearly by comparing the surface structure is formed. Image with 300000 times magnification is more focused on  $\text{TiO}_2$  that has been inserted in the activated carbon.

### 3.1.2 Composition (EDX Test)

EDX analysis was conducted to identify the elemental composition of specimens (samples tested). In this case, EDX is used to compare the elemental composition of the activated carbon pre-activated, after activated and activated carbon that has been inserted  $\text{TiO}_2$ . EDX test results on the adsorbent shown in Figure 4.

On activated carbon, it is detected that there is Cl and a few of Zn element. Cl element existed comes from the rest of activating agent of  $ZnCl_2$  which is not vaporized when pyrolysis process and residual leaching with HCl occur. Zn contained in the carbon after activation is less than 1%. This indicates that almost all of  $ZnCl_2$  entrained and lost during washing. Visible element of Ti and O is contained in many of the most active carbon inserted by  $TiO_2$ . This indicates that  $TiO_2$  has been successfully inserted on the surface of activated carbon. The elements Fe and Al in the activated carbon that has been inserted  $TiO_2$  are impurities produced at the time of preparation.

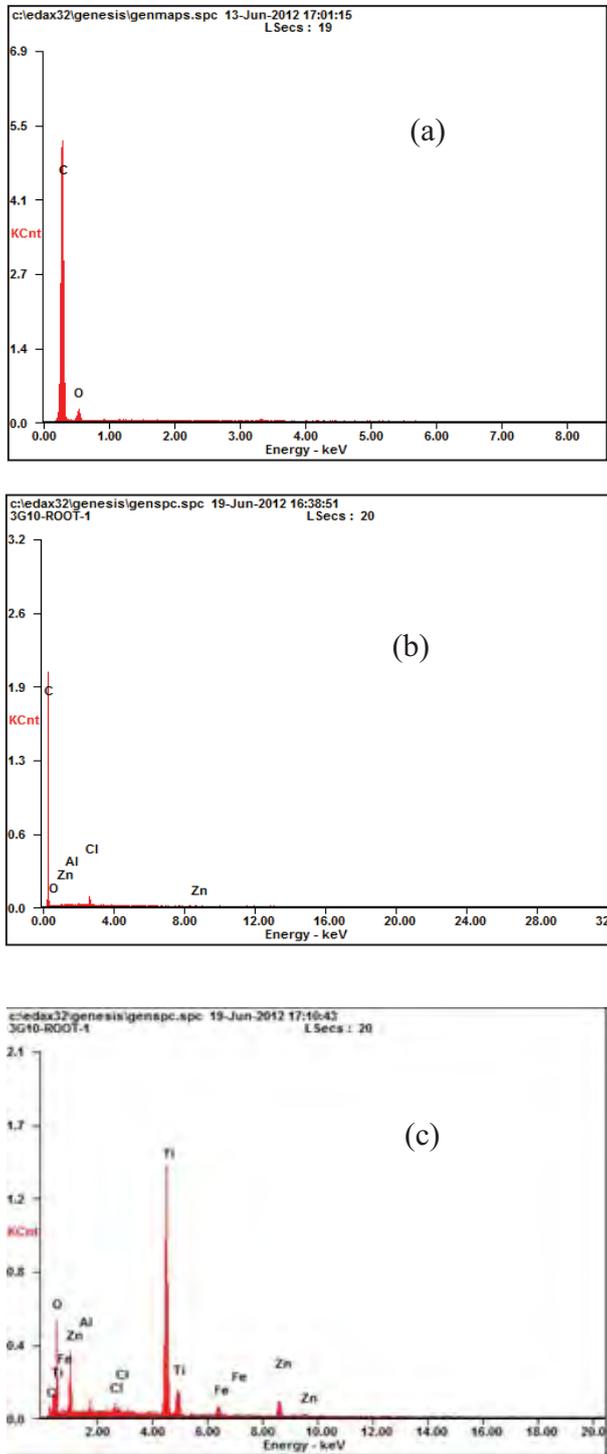


Figure 4: EDX Result of element composition in carbon  
 (a) Before activation (b) After activation (c) After activation with  $TiO_2$  insertion

### 3.1.3 Surface Area (BET Test)

To find the surface area of the adsorbent, BET analysis methods were conducted. BET test is done to look for changes in the surface area of the activated carbon and activated carbon were inserted TiO<sub>2</sub>. From the BET test results in Figure 5, an increase in the surface area of activated carbon after insertion of TiO<sub>2</sub>. This is because the insertion of TiO<sub>2</sub> molecule will increase the volume of the space between the layers of coconut shell charcoal coconut shell so that the surface area increases.

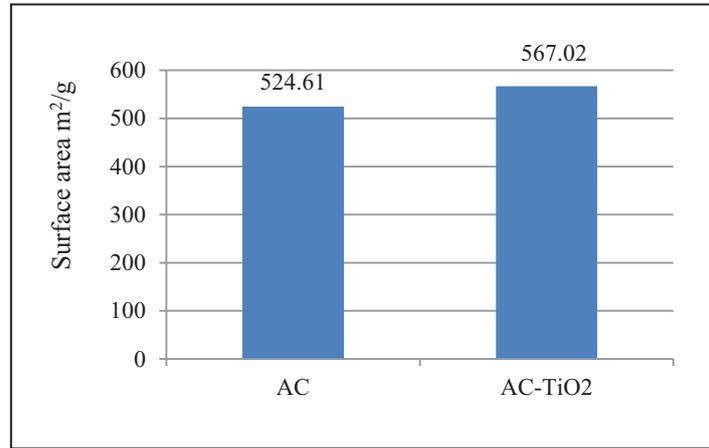


Figure 5: BET test result

## 3.2 Adsorption Test Result

### 3.2.1 Clearing of Smoke

$t_{10}$  value of each point for each adsorbent with variations in the size and mass are summarized in the chart in Table 1.  $t_{10}$  value indicates the time needed to reach the 10% level of clarity.

Table 1: Mass and size of activated carbon effect to  $t_{10}$  value

	$t_{10}$ (minutes)								
	Point 1			Point 2			Point 3		
	1 g	3 g	5 g	1 g	3 g	5 g	1 g	3 g	5 g
AC 420 $\mu\text{m}$	35	38	42	38	40	44	40	43	46
AC 125 $\mu\text{m}$	33	34	36	34	35	37	36	37	40
AC 74 $\mu\text{m}$	31	32	35	32	33	36	33	35	38
AC -TiO <sub>2</sub>		28	33		30	34		32	36

Based on Table 1, it can be concluded that point 1 for each adsorbent has a value of  $t_{10}$  is smaller than point 2 and point 3.  $t_{10}$  values are small, suggests that the time required to achieve opacity value of 10 is shorter. This is because the smoke inside the test chamber will fill the entire room moving then collided and caused sprayed adsorbent will absorb the smoke that drops down. From the results of Table 1, when compared with the variation of the mass of activated carbon and particle size, the best adsorbent in clarifying the smoke is activated carbon with the largest mass is 5 grams and the smallest particle size is 74 $\mu\text{m}$ . This indicates that the size of the adsorbent affects the time to achieve a certain level of clarity ( $t_{10}$ ). The smaller the particle size of the adsorbent and the adsorbent mass, the better the smoke cleared. This is due to the smaller size of the adsorbent surface area will become larger. Contact with the smoke particles are also becoming more widely, so that more smoke particles are absorbed, resulting in a faster clear smoke. While more and more mass is sprayed, would make the number of particles in contact with the smoke more and more.

When compared with activated carbon that has been inserted TiO<sub>2</sub>, it can be seen that the AC-TiO<sub>2</sub> adsorbent is better than activated carbon to clear smoke without TiO<sub>2</sub>. This is consistent with the results of surface area AC-TiO<sub>2</sub> greater than activated carbon without TiO<sub>2</sub>. The greater the surface area of the adsorbent, the greater the adsorption performance. Results achieved AC-TiO<sub>2</sub> as much as 3 grams to achieve opacity value at point 1 is 10 for 28 minutes while the AC-sized TiO<sub>2</sub> reached 74  $\mu\text{m}$

without opacity value of 10 in 32 minutes. From these results, it can be concluded insertion of  $\text{TiO}_2$  can increase job performance of activated carbon in the smoke cleared at 12.50%. The difference is not very significant, is consistent with the results of extensive tests on AC- $\text{TiO}_2$  surface that is not much different than the surface area of activated carbon without  $\text{TiO}_2$ .

### 3.2.2 CO Gas Adsorption

CO gas reduction results in 30 minutes can be seen in Table 2. CO gas can be adsorbed because it has a smaller particle size of the adsorbent pore size. CO particle diameter is 0.376 nm, whereas it is known that the activated carbon has a pore size of an average diameter of 117.2 Å and activated carbon (AC) were inserted  $\text{TiO}_2$  has the size of an average pore diameter of 86.17 Å or equal to 8.62 nm.

Table 2: The Effect of mass and size particle of activated carbon to CO gas adsorption

	5 grams Adsorbent		3 grams Adsorbent		1 grams Adsorbent	
	Lowering Level of CO for 30 minutes					
	%	ppm	%	ppm	%	ppm
AC 420 $\mu\text{m}$	9.21	88	8.49	74	5.62	50
AC 125 $\mu\text{m}$	11.73	141	9.31	98	7.22	76
AC 74 $\mu\text{m}$	11.92	187	11.01	165	8.95	129
AC - $\text{TiO}_2$			14.83	185	10.67	154

From Table 2 it can be seen that the mass of adsorbent and adsorbent particle size affects the results of the adsorption of CO gas. The best activated carbon on lowering CO levels is them with the largest in mass and smallest in particle size, which is 5 grams and 74  $\mu\text{m}$ . The smaller the particle size of the adsorbent and the adsorbent mass, the better the CO gas adsorbed. This is due to the smaller size of the adsorbent, surface area will become larger. Contact with CO gas particles are also becoming more widely, so that more particles are absorbed CO gas. While more and more mass is sprayed, would make the number of particles in contact with CO gas is more so the adsorbed CO particles is more to. Table 2 also shows that the insertion of  $\text{TiO}_2$  on activated carbon adsorption have an influence in the performance. AC- $\text{TiO}_2$  as much as 1 gram can lower the CO level is better, for about 154 ppm, compared with AC 74  $\mu\text{m}$  as much as 1 gram of which is only able to reduce levels of CO for about 129 ppm. From these results it can be said that the insertion of  $\text{TiO}_2$  on activated carbon adsorption can increase the performance of CO gas that is equal to 19.38%. The difference is not very significant, is consistent with the results of extensive tests on AC- $\text{TiO}_2$  surface that is not much different than the surface area of activated carbon without  $\text{TiO}_2$ .

To view the ability of the adsorbent to adsorbate binding molecules can be seen from the adsorption capacity. Adsorption capacity is obtained by calculating the mass of adsorbed CO gas (mg) per unit mass of adsorbent (mg). Adsorbent adsorption capacity by any of the test results is shown in Table 3. From the results of the adsorption capacity in Table 3 shows that the adsorption capacity of the adsorbent is best achieved by the smallest particle size but with the smallest mass. The smaller the particle size, the better adsorbent adsorption capacity, according to the results of the influence of particle size on adsorption performance has been discussed in the previous section. CO gas adsorption capacity of the largest obtained AC- $\text{TiO}_2$  1 g, amounting to 29.57.

Table 3: Adsorption capacity for each adsorbent

	5 grams Adsorbent	3 grams Adsorbent	1 grams Adsorbent
	Adsorption Capacity (mg adsorbat/mg adsorbent)		
AC 420 $\mu\text{m}$	3.3792	4.736	9.6
AC 125 $\mu\text{m}$	5.4144	6.272	14.592
AC 74 $\mu\text{m}$	7.1808	10.56	24.768
AC- $\text{TiO}_2$		12.224	29.57

#### 4. CONCLUSION

From the discussion above, it can be concluded as follow:

1. Activated carbon can be used as adsorbent of CO gas and smoke purification medium.
2. The decrease level of CO is increase as the mass of activated carbon increase and the size of activated carbon particles decrease.
3. The insertion of TiO<sub>2</sub> can wider the surface area of activated carbon from 524,612 m<sup>2</sup>/g to 567,02 m<sup>2</sup>/g.
4. The insertion of TiO<sub>2</sub> in activated carbon for 1 gram adsorbent mass can increase the smoke purification for about 12.50%.
5. The insertion of TiO<sub>2</sub> in activated carbon for 1 gram adsorbent mass can increase CO gas adsorption for about 19.38%.
6. The highest adsorption capacity can be reached by 1 gram AC-TiO<sub>2</sub> adsorption for about 29.57 mg/mg adsorbent.

#### 5. REFERENCES

- [1] Wang, W., H. Zhang, "Experimental Study On CO<sub>2</sub>/CO Of Typical Lining Materials In Full-Scale Fire Test", *Chinese Science Bulletin*, vol. 52, no. 9, pp. 1282-86, 2007.
- [2] G. Mark, "Carbon Monoxide Poisoning", *Journal of Emergency Nursing*, vol. 34, no. 6, pp. 538-42, 2008.
- [3] Yadav, R., R. G. Maghirang R, "Laboratory Evaluation Of The Effectiveness Of Nanostructured And Conventional Particles In Clearing Smoke In Enclosed Spaces", *Fire Safety Journal*, vol. 43 no. 1, pp. 36-41, 2008.
- [4] M.S. Ravichandra, Paul, S.M, Ronaldo, M., John, S. K, Kenneth, J. S., and Olga, K., "Metal Oxide Nanoparticles for Smoke Clearing and Fire Suppression", *Manhattan: NanoScale Corporation*, 2005.
- [5] B.T. Kris, "Penurunan Konsentrasi CO Dan NO<sub>2</sub> pada Emisi Gas Buang dengan Menggunakan Media Penyisipan TiO<sub>2</sub> Lokal pada Karbon Aktif", *Jurnal Rekayasa Lingkungan*, 2008.
- [6] S.M. Manocha, "Porous Carbons", *Sadhana* vol.28, pp. 335-348, 2003.
- [7] Pujiyanto, "Pembuatan Karbon Aktif Super dari Batubara dan Tempurung Kelapa", Depok, *Universitas Indonesia*, 2010.
- [8] S. Reza, "Adsorption of Carbon Monoxide (CO) gas and Clearing Fire Smoke Using Lampung Natural Zeolite Modified TiO<sub>2</sub>", Depok: Universitas Indonesia, 2011.

## Dissolved Oxygen Removal through Polyvinylchloride Hollow Fiber Membrane Contactor via Vacuum Degassing Process

Sutrasno Kartohardjono<sup>1\*</sup>, Hutama Pastika<sup>1</sup> and Samantha Juliana<sup>1</sup>

<sup>1</sup>Chemical Engineering Department, Universitas Indonesia, Depok 16424, Indonesia  
\*Email: sutrasno@che.ui.ac.id

### ABSTRACT

This research utilized polyvinylchloride (PVC) hollow fiber membrane to remove dissolved oxygen from water. This process is very important in producing ultra pure water that is widely used in industries such as semiconductor, pharmaceutical, food and steam power plant. In steam power industry for example, dissolved oxygen in water has to be reduced to the level below 0.5 ppm in order to prevent corrosion in the piping system in the boiler. Meanwhile, in the steam power plant dissolved oxygen in water has to be reduced to the level below 10 ppb in order to prevent wafer oxidation. This research aims to evaluate the performance of PVF hollow fiber membrane contactor to remove dissolved oxygen from water via vacuum degassing process. The fiber used in the experiments has pore size of 0.025  $\mu\text{m}$ . Number of fibers in the contactor and water flow rates is varied in the dissolved oxygen removal process through membrane contactor via vacuum degassing process. Meanwhile, there were two feed flow system for water in the membrane contactor namely shell side flow and tube side flow. Experimental results show that mass transfer in the liquid phase controls the overall mass transfer coefficients. The overall mass transfer coefficients as well as oxygen fluxes increase with increasing water flow rate and decreasing number of fibers in the membrane contactor. Friction factor of the fluids in the shell side and tube side flows are higher than predicted by theoretical value indicating that the fiber did not behave as smooth pipe. Overall mass transfer coefficients in the tube side were higher than in the shell side due to channeling effect.

### Keywords

*Hollow fiber, mass transfer coefficient, membrane contactor, PVC, vacuum degassing*

## Natural Zeolite Modification by TiO<sub>2</sub> for NO<sub>2</sub> Gas Adsorption from Vehicles Emission

Yuliusman<sup>a</sup>, Rendi Akbar Hasibuan<sup>b</sup>

<sup>a,b</sup> *Departement of Chemical Engineering, Faculty of Engineering  
 University of Indonesia, Depok 16424  
 E-mail : usman@che.ui.ac.id*

### ABSTRACT

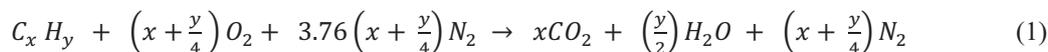
In this study carried out the reduction of NO<sub>2</sub> gas from motor vehicles. The increase number of motor vehicle produce high level of air poluting gas, particularly nitrogen dioxide (NO<sub>2</sub>). Instalation of adsorbent at the exhaust line can overcome this problem. This study use natural zeolite modified with TiO<sub>2</sub> as adsorbent. Zeolite was activated with HF 1%, HCl 6M, and NH<sub>4</sub>Cl 0,1M solution. Next, it was calcinated and modified with TiO<sub>2</sub> using sol-gel method. In this study, some phenomenons related with NO<sub>2</sub> adsorption is explained, such as influence of initial gas concentration, duration of contact, loading of TiO<sub>2</sub>, and application at motor vehicle. For pure NO<sub>2</sub> gas, the adsorption test shows the increase of adsorbed NO<sub>2</sub> by zeolite which is modified by TiO<sub>2</sub>. Zeolite with 10%, 20%, and 30% of TiO<sub>2</sub> loading has better adsorption capacity than zeolite which is unmodified by TiO<sub>2</sub>. The increase of TiO<sub>2</sub> loading up to 20 wt% in natural zeolite will increase the adsorption capacity of natural zeolite. However, the decrease of adsorption capacity is occurred between natural zeolite/TiO<sub>2</sub>-30% and natural zeolite/TiO<sub>2</sub>-20%. The adsorption test of modified natural zeolite to NO<sub>2</sub> gas from vehicles emission results information that natural zeolite/TiO<sub>2</sub>-20% can adsorb NO<sub>2</sub> gas up to 45–49% from its initial concentration. Natural Zeolite/TiO<sub>2</sub> 20% can adsorb pure NO<sub>2</sub> gas until 70% from its initial concentration.

### Key words

*Natural zeolite, TiO<sub>2</sub> adsorption, NO<sub>2</sub>, Vehicles Emission*

### 1. INTRODUCTION

Air quality, especially in big cities like Jakarta, is now highly contaminated by pollutants and has reached the threshold which is very harmful to human health. 70% of air pollutants in major cities contributed by the transportation sector. Pollution seems to have an inescapable result of continued swelling number of vehicles each year. In Jakarta, it is amounted to 6.5 million units with a growth rate of 10% per year [4]. The high consumption of fossil fuels (hydrocarbons) as a vehicle fuel and the lack of alternative energy sources is the cause. Combustion is a complex chemical reaction between a fuel and an oxidant accompanied by the production of heat which is sometimes accompanied in the form of fluorescent light or fire. If burning is done by using air as the oxygen source, the nitrogen was also added to the equation though it does not react to show the composition of the exhaust gases, is presented in Equation 1.



However, in reality the combustion of hydrocarbons produces other products, such as CO and NO<sub>x</sub>. Formation of NO and NO<sub>2</sub> occurs in internal combustion engines, where the reaction between nitrogen and oxygen in the air at high temperatures to form NO, then further reaction between NO with more oxygen to form NO<sub>2</sub>, as shown in the folowing equations:



In some major cities are known NO<sub>x</sub> levels in the air are as follows: 0.063 ppm in Bandung, 0.017 ppm in Surabaya, 0.054 ppm in Yogyakarta, and 0.067 ppm in Medan, with a threshold value of ambient air quality standard for NO<sub>x</sub> are: 0.05 ppm corresponding Kep. 02/MENKLH/1998 [1]. Air containing NO gas can cause interference with nerves system that causes seizures. If this continues to poisoning can cause paralysis. Meanwhile, toxicity (toxicity) of NO<sub>2</sub> gas is four times more powerful than the toxicity of NO gas. The most sensitive organs to NO<sub>2</sub> gas pollution is the lungs. Lung contaminated by NO<sub>2</sub> would swell so people breathing difficulty that can lead to death. Air pollution by NO<sub>2</sub> gas can also cause the formation of

Acetil Peroxy Nitrates which are abbreviated as APN. APN is irritating to the eyes so that the eyes sting and watery. To overcome the dangers of environmental degradation caused by motor vehicle exhaust, control of pollutant gases can be done by adding a catalyst in motor vehicle exhaust. This catalyst is a media decoder of CO and NOX result of combustion and converted into CO<sub>2</sub> and N<sub>2</sub>. One of the materials that can be used is the natural zeolite (NZ) modified with TiO<sub>2</sub>. Results of previous studies showed that natural zeolite can reduce NO<sub>2</sub> gas significantly [1]. Other research suggests that the insertion of TiO<sub>2</sub> into the activated carbon can increase the power of activated carbon adsorption of the NO<sub>2</sub> gas than without the insertion of TiO<sub>2</sub> [3].

This study aims to determine the optimal conditions on a combination of natural zeolite modified with TiO<sub>2</sub>, which is used to reduce NO<sub>2</sub> from motor vehicle exhaust. This study used natural zeolite as adsorption media. Zeolite is a natural mineral or rocks which chemically belonged to the mineral silica and alumina expressed as hydrated silica, finely shaped, and the result of secondary products that are stable at surface conditions as derived from the process of sedimentation, weathering or hydrothermal activity. Zeolite is a compound of alumina silica (Si/Al) having pores and a relatively large surface area, so it has a high adsorption properties. Before being used as an adsorbent, zeolite must be activated in order the number of the pores are more opened so that the pore surface area increases. Zeolite which is suitable for adsorbent is the one when it is enabled, it will give Si/Al high ratio (10-100). Zeolite with the high ratio of Si/Al is hydrophobic [6]. So that the adsorption capacity of zeolite did not undergo reduction, water molecules must be removed from the cavity of zeolite, namely by heating to a temperature 150°C. Adsorption can occur due to the interaction between the forces on the surface of a solid adsorbent with adsorbate molecules. From the results of previous studies it is known that the mineral of zeolite can absorb the gases CO<sub>2</sub>, H<sub>2</sub>S, and H<sub>2</sub>O as much as 25% [6]. Therefore, zeolites are used as adsorbents because of porous crystal structure, have a large surface area, high thermal stability, non-toxic, and effective. The catalyst used is TiO<sub>2</sub>. TiO<sub>2</sub> is one kind of metal oxide semiconductor catalysts in the photocatalytic process. TiO<sub>2</sub> plays a leading role in the photocatalytic processes due to the various advantages of physical and chemical properties such as high photo catalytic activity, stable, and non-toxic. Commercially, TiO<sub>2</sub> is also readily available and widely produced.

## 2. EXPERIMENTAL

There are several steps that are conducted to prepare natural zeolite adsorbent- TiO<sub>2</sub> (NZ/TiO<sub>2</sub>) and also the testing procedure of NZ/TiO<sub>2</sub> to reduce NO<sub>2</sub> gas.

### 2.1 NZ/TiO<sub>2</sub> Preparation

NZ is firstly crushed and filtered to get ± 420 μm in size. NZ is then soaked in 2% HF solution for 10 minutes, and stirred frequently. Furthermore, NZ is immersed in a 6 M HCl solution at 90 °C for 30 minutes. After that, NZ soaked in a solution of 0.1 M NH<sub>4</sub>Cl for 5 days, with stirring for 3 hours / day at a temperature of 90°C. Lastly, NZ calcined at 500 °C for 5 hours. TiO<sub>2</sub> sol was prepared by sol-gel method using TiO<sub>2</sub> Degussa P-25. TiO<sub>2</sub> is sonicated in water for 20 minutes. Furthermore, NZ is soaked in a solution of TiO<sub>2</sub> for 10 minutes. Then mix of NZ/TiO<sub>2</sub> are evaporated, and then followed by calcination at a temperature of 400 °C for 2 hours.

### 2.2 Adsorption Test of NZ/TiO<sub>2</sub>

Experimental of adsorption is done by using the following equipment configuration:

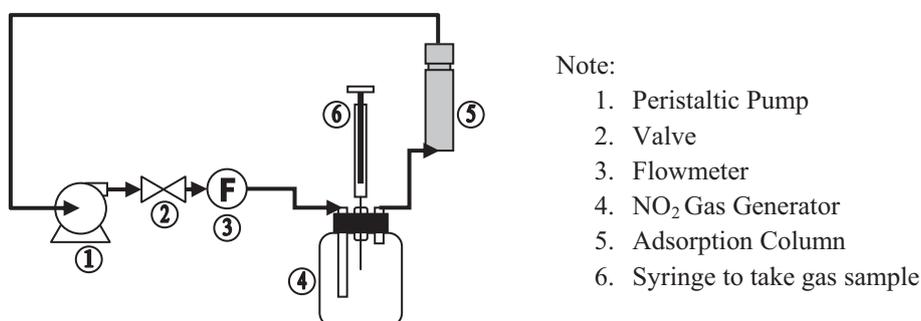


Figure 1: Equipment scheme for pure NO<sub>2</sub> gas adsorption

NO<sub>2</sub> gas analysis was performed by the method of Griess-Saltzman. NO<sub>2</sub> gas was generated from a standard solution of NaNO<sub>2</sub> and was treated with 6 M HCl, while the adsorbent was placed on the adsorption column. Gas flow formed NO<sub>2</sub> for 1 hour with a flow rate of 0.1 L/min. NO<sub>2</sub> gas samples were taken before and after doing the experiment and passed into a solution of

Griess-Saltzman. Qualitative method was adapted from ASTM procedure D1607. A number of the absorbed  $\text{NO}_2$  oxidized and dissolved in the Griess-Saltzman reagent containing N-(1-naphthyl) ethylenediamine dihydrochloride. Griess-Saltzman test solution will change color to red-purple when there is  $\text{NO}_2$  in the sample gas. Then the test solution was analyzed using UV-Vis spectrophotometer at a wavelength of 550 nm. The experiments were conducted for each of the NZ with  $\text{TiO}_2$  loading variations at different initial concentrations. Adsorbent with the best reduction capability is then used to test the adsorption on motor vehicles. Equipment scheme for  $\text{NO}_2$  gas adsorption from vehicle emissions is shown in Figure 2.

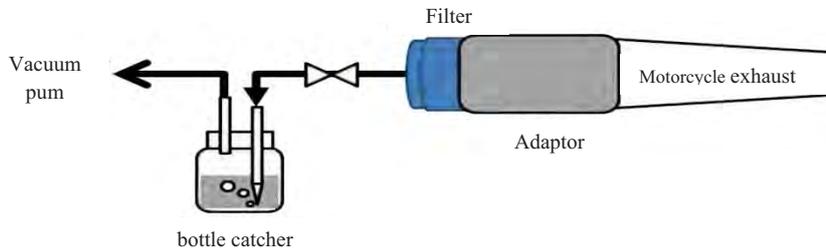


Figure 2: Equipment scheme for  $\text{NO}_2$  gas adsorption from vehicle emissions

### 3. RESULTS AND DISCUSSION

The experimental results are discussed include NZ characterization, and testing of the  $\text{NO}_2$  gas adsorption NZ/ $\text{TiO}_2$  artificial or from motor vehicles.

#### 3.1. Natural Zeolite Characterization

NZ who have and have not been through the stages of preparation and modified with  $\text{TiO}_2$  were characterized by EDAX and BET. Characterization results are presented in Table 1 and Table 2.

Table 1: The Si/Al ratio

Adsorbent	$\text{SiO}_2$ (wt%)	$\text{AlO}_2$ (wt%)	$\text{TiO}_2$ (wt%)	Si/Al
NZ	37,85	4,39	-	8,62
Activated NZ	54,20	2,26	-	23,98
NZ/ $\text{TiO}_2$ -20%	50,08	2,72	21,63	18,41

Table 2: Surface area

Adsorbent	Surface area ( $\text{m}^2/\text{g}$ )
NZ	23,35
Activated NZ	44,29

Characterization of the results shows that an increase in the ratio of Si/Al in NZ activated from 8.62 to 23.98. This is consistent with the expected results because zeolites are both used as adsorbent is a zeolite with Si / Al ratio ranged between 10-100, and the lower the zeolite Si/Al, the better the zeolite adsorption to  $\text{NO}_2$  gas [1]. On the other hand, on NZ/ $\text{TiO}_2$ -20% can be seen that there is  $\text{TiO}_2$  on zeolite surface of 21.63 wt%. The formation of  $\text{TiO}_2$  on the surface of the zeolite showed that the synthesis process NZ/ $\text{TiO}_2$  relatively successful.

It can be seen also that an increase in the surface area of 23,35  $\text{m}^2/\text{g}$  to 44.29  $\text{m}^2/\text{g}$ . This increase occurs because the NZ immersion in a solution of 2% HF, HCl 6 M, and 0.1 M  $\text{NH}_4\text{Cl}$  oxide impurities contained in NZ has been dissolved to form an empty space in the zeolite crystals.

#### 3.2. Adsorption Test of NZ/ $\text{TiO}_2$

The test is conducted to see the ability of zeolite on adsorbing  $\text{NO}_2$ . The adsorption test result can be seen in Figure 3. Based on Figure 3, it can be seen that there is an increase in the amount of  $\text{NO}_2$  adsorbed by zeolite modified with  $\text{TiO}_2$ .  $\text{TiO}_2$  zeolite loading of 10%, 20% and 30% by weight have a better adsorption power than the unmodified zeolite with  $\text{TiO}_2$ . This shows the increasing loading up to 20 wt% of  $\text{TiO}_2$  on zeolite, the adsorption of the zeolite increased to. However, there is a decrease in the adsorption power NZ/ $\text{TiO}_2$ -30% compared with NZ/ $\text{TiO}_2$ -20%.

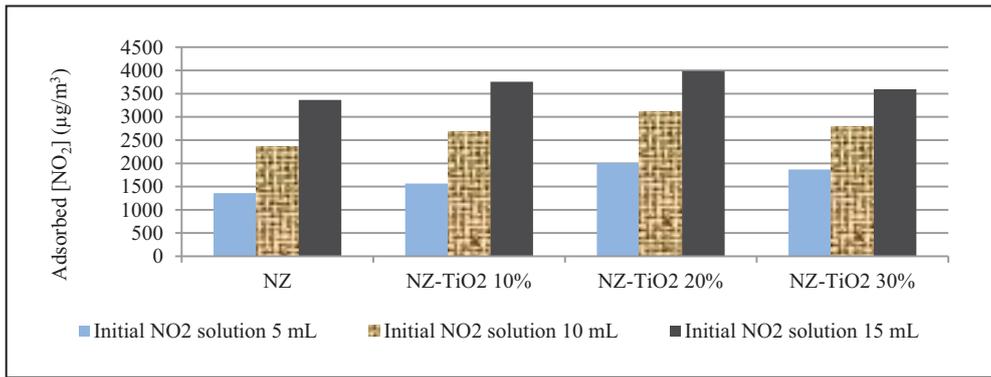


Figure 3: Loading effect of TiO<sub>2</sub> for 0%, 10%, 20% and 30% to NO<sub>2</sub> adsorption

### 3.3 Isotherm Pattern of NO<sub>2</sub> Gas Adsorption by NZ/TiO<sub>2</sub>

Isotherm patterns used in this study are Freundlich isotherm. The pattern of adsorption isotherms and the maximum adsorption of zeolite to NO<sub>2</sub> gas can be determined by the equation:

$$(x/m) = kc^{1/n} \quad (4)$$

where (x/m) is the amount of NO<sub>2</sub> adsorbed per unit mass of adsorbent (mg /g), c is the initial concentration of NO<sub>2</sub> (µg/m<sup>3</sup>), k and 1/n is the Freundlich isotherm equation constants. Figures 4-7 show the effect of initial concentration on the amount of gas adsorbed NO<sub>2</sub> and Freundlich equation.

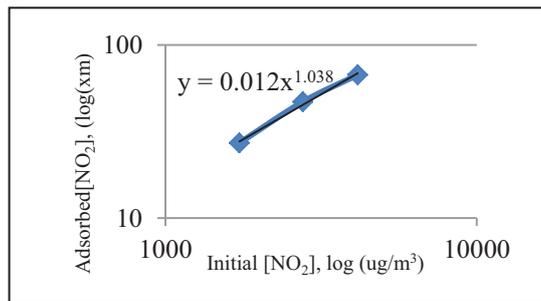


Figure 4: Effect of initial concentration of the amount of NO<sub>2</sub> adsorbed on zeolite without modification

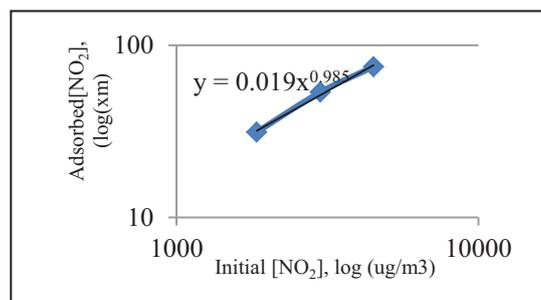


Figure 5: Effect of initial concentration of the amount of NO<sub>2</sub> adsorbed on NZ/TiO<sub>2</sub>-10%

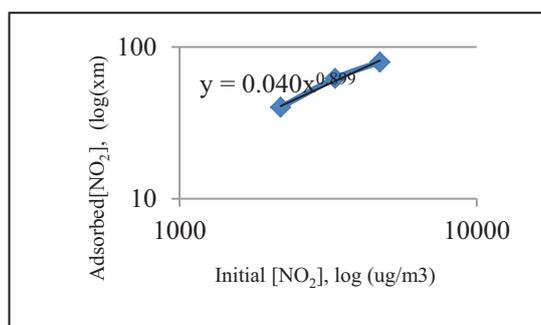


Figure 6: Effect of initial concentration of the amount of NO<sub>2</sub> adsorbed on NZ/TiO<sub>2</sub>-20%

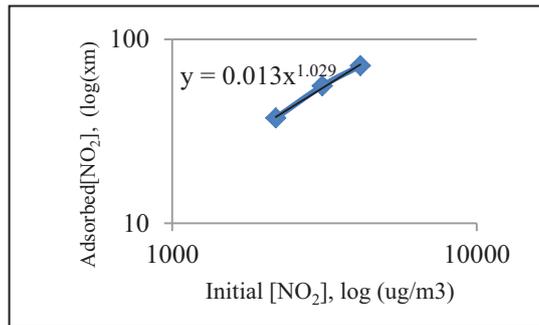


Figure 7: Effect of initial concentration of the amount of NO<sub>2</sub> adsorbed on NZ/TiO<sub>2</sub>-30%

Obtained from the equation for each graph, it is known the Freundlich isotherm adsorption constants  $k$  and  $1/n$  for each adsorbent, as shown in Table 3 below.

Table 3: The constant value of  $k$  and  $1/n$  for each adsorbent

Adsorbent	1/n	K
NZ	1,0380	0,0120
NZ/TiO <sub>2</sub> -10%	0,9850	0,0190
NZ/TiO <sub>2</sub> -20%	0,8990	0,0400
NZ/TiO <sub>2</sub> -30%	1,0290	0,0013

Based on the value of  $k$  and  $n$  are obtained, it is seen that the power NZ/TiO<sub>2</sub>-20% have the best for NO<sub>2</sub> gas with low initial concentrations, followed NZ/TiO<sub>2</sub>-10%, and NZ/TiO<sub>2</sub>-30%. While the natural zeolite without modification has the lowest adsorption capacity for NO<sub>2</sub> gas with low concentrations. This shows the influence of TiO<sub>2</sub> to NO<sub>2</sub> gas in the reduction process. It can be seen that, with the increasing number of TiO<sub>2</sub> on zeolites, the ability of zeolite to reduce NO<sub>2</sub> gas is increasing. TiO<sub>2</sub> zeolite loading of 20%, has a better capability than the reduction NZ/TiO<sub>2</sub>-10% and zeolite without modification. However, a decrease in the adsorption when loading TiO<sub>2</sub> on zeolite reached 30%. It is caused by too much content of TiO<sub>2</sub> on zeolite surface, can lead to seal the pores of adsorbent.

Experiment to create a model of the Langmuir isotherm can not see a match between the data obtained with the Langmuir isotherm models, as indicated by the low value of  $R$  obtained Langmuir isotherm equation ( $R < 95\%$ ). This suggests that the Langmuir isotherm models do not apply to the NO<sub>2</sub> gas adsorption process is done. It also means that the process of adsorption of NO<sub>2</sub> was not able to meet the assumptions used to develop the Langmuir isotherm equation. Langmuir isotherm is applicable if the adsorbent has a particle size and shape are uniform, while the adsorbent used still has a particle size distribution that is wide enough (35-40 mesh). Another assumption must apply the ideal gas. This assumption can be approximated by using the gas at low concentrations. However, as the ambient gas used to dilute sorbate gas in this experiment is a gas mixture that contains water (water vapor). The use of air as a diluent gas intended for NO<sub>2</sub> were tested in the air close to the real situation as one pollutant.

### 3.4 Adsorption Test of NO<sub>2</sub> Vehicle Emission

Adsorption ability of the adsorbent was applied to the motor vehicle as a motor vehicle exhaust emissions is one of the biggest sources of NO<sub>2</sub> gas. Adsorbents used in this experiment the adsorbent with the best adsorption capability in the earlier experiment, ie NZ/TiO<sub>2</sub>-20%. The experiments were performed several times with repetition three times. Results of experiments are presented as follows.

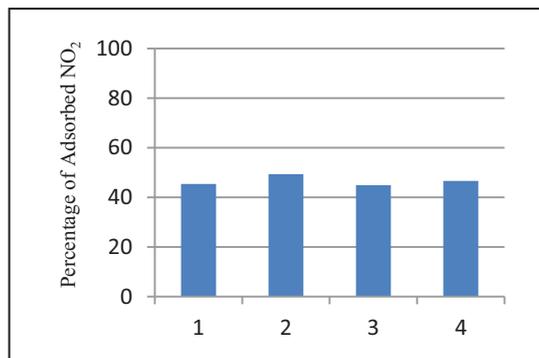


Figure 8: Percentage of NO<sub>2</sub> gas adsorbed from vehicle emission by NZ/TiO<sub>2</sub>-20%

From the above data it can be seen that NZ/TiO<sub>2</sub>-20% NO<sub>2</sub> gas can adsorb up to 45-49% of the initial concentration. These results are still far below the adsorption ability NZ/TiO<sub>2</sub>-20% of the NO<sub>2</sub> gas at the time of testing in the laboratory. NZ/TiO<sub>2</sub>-20% at the time of testing NO<sub>2</sub> gas adsorption is able to adsorb up to 70% of the initial concentration. The decrease is due to interference by carbon dioxide and water vapor gas emissions are high on the vehicle [1]. The mixture will be more dominant on the surface of zeolite fill sites are used, thus reducing the portion that can be occupied by molecules NO<sub>2</sub>. Hal It happens because of the nature of zeolite that has a high affinity for water, so it is very easy to adsorbed water (Suraputra, 2011). This causes problems not optimal zeolite used as an adsorbent for application on vehicles. Therefore, more research needs to be done in order to be more hydrophobic zeolite so as to reduce interference on the zeolite due to high moisture content.

#### 4. CONCLUSION

From the research that has been done, some conclusions can be drawn as follows:

1. The higher the initial concentration of the gas, the higher the amount of NO<sub>2</sub> are adsorbed by natural zeolite.
2. This is due to the increase of the BET surface area of 23.35 m<sup>2</sup> natural zeolite/g to 44.29 m<sup>2</sup>/g and Si/Al ratio of zeolite from 8.62 to 23.98.
3. Natural zeolite with the maximum adsorption to adsorb NO<sub>2</sub> gas is natural zeolite with 20% TiO<sub>2</sub> loading.
4. Natural zeolite with 20% TiO<sub>2</sub> loading can reduce motor vehicle emissions of NO<sub>2</sub> gas up to 45-49% initial concentration.

#### 5. REFERENCES

- [1] A. R. Ginanjar, "Adsorption of NO<sub>2</sub> gas by activated zeolite for respiratory mask application", University of Indonesia, 2011.
- [2] M. Anpo, and Matsuoka, M, "Local Structures, Excited States, And Photocatalytic Reactivities of Highly Dispersed Catalyst Constructed Within Zeolit", *J. of Photochem and Photobiology C: Photochem. Rev.*, vo. 3, pp. 225-52, 2003.
- [3] B. T. Kris, "Penurunan Konsentrasi CO Dan NO<sub>2</sub> Pada Emisi Gas Buang Dengan Menggunakan Media Penyisipan TiO<sub>2</sub> Lokal Pada Karbon Aktif", *JFN*, No. 1, vol. 1, pp. 45-64, 2007.
- [4] Hertanto, "Pertumbuhan Sepeda Motor Di DKI 890 Unit Per Hari", *Kompas*, 2010.
- [5] M. Huuhtanen, "Zeolite in The Reduction of NO<sub>x</sub> in Lean Automotive Exhaust Gas Conditions", University of Oulu, pp. 83-89, 2006.
- [6] S. Reza, "Adsorption of Carbon Monoxide (CO) gas and Clearing Fire Smoke Using Lampung Natural Zeolite Modified TiO<sub>2</sub>", University of Indonesia, 2011.
- [7] T. Maggos, Bartzis, J., Leva, P. and Kotzias, D., "Application of photocatalytic technology for NO<sub>x</sub> removal", Greece: Department of Energy Resources Engineering, University of West Macedonia, pp. 90-9, 2005.

## Octaarginin-Apoptin Induces Apoptosis in the Human Cervix Cancer HeLa Cell Line

Muhamad Sahlan<sup>1\*</sup>, Anom Bowolaksono<sup>2</sup>, Raditya Immamul Khalid<sup>1</sup> dan Amarila Malik<sup>3</sup>

<sup>1</sup>Department of Chemical Engineering, Faculty of Engineering, Universitas Indonesia, Kampus Depok 16424, Indonesia.

<sup>2</sup>Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Indonesia, Kampus Depok 16424, Indonesia.

<sup>3</sup>Faculty of Pharmacy, Universitas Indonesia, Kampus UI Depok 16424, Indonesia.

\*Address Corresponding Author : Department of Chemical Engineering, Faculty of Engineering, Universitas Indonesia  
Kampus UI Depok, West Java, Indonesia 16424.

Phone : +62-21-7863516, Fax.: +62-21-7863515; Email: sahlam@che.ui.ac.id

### ABSTRACT

Apoptin is a small protein encoded by chicken anemia virus (CAV). It has ability to induce apoptosis of human tumor cells selectively. This protein was expressed as a recombinant protein by employing *Bacillus subtilis* as hosts for expression in soluble fashion. To improve cell penetrating ability of the Apoptin, the C-terminal of the protein was fused with octaarginine. MTT assay were used to identify antitumor effect of Octaarginin-Apoptin. The viability of cell was analyzed when the cell incubated in the concentration protein of 0.1, 1 and 10 µg/mL for 72 h. The results of the MTT assay indicated that Octaarginin-Apoptin was able to induce apoptosis of HeLa cell lines in a dose-dependent manner. The recombinant apoptin without fusing with octaarginine, have no ability to induce apoptosis of HeLa cell lines. This octaarginine-apoptin may in the future allow the development of a therapeutic protein that is able to specifically kill tumor cells.

### Keywords

Apoptin, octaarginine, MTT assay, Cervix cancer.

## Removal of Heavy Metals from Aqueous Solution by Hydroxyapatite/Chitosan Composite

Eny Kusrini\*<sup>1,a</sup>, Nofrijon Sofyan<sup>2,b</sup>, Dwi M. Nurjaya<sup>2,c</sup>, Santoso<sup>1,d</sup>, Dewi Tristantini<sup>1,e</sup>

<sup>1</sup>Department of Chemical Engineering, Faculty of Engineering Universitas Indonesia, Kampus Baru UI, Depok, 16424, Indonesia. \*Corresponding author Tel.: +62-21-7863516 ext. 6207, Fax: +62-21-7863515

<sup>2</sup>Department of Metallurgical and Materials Engineering, Faculty of Engineering, Universitas Indonesia, Kampus Baru UI, 16424 Depok, Indonesia

<sup>a</sup>ekusrini@che.ui.ac.id, <sup>b</sup>nofrijon.sofyan@ui.ac.id, <sup>c</sup>jaya@metal.ui.ac.id, <sup>d</sup>pong.ping@rocketmail.com, <sup>e</sup>detris@che.ui.ac.id

### ABSTRACT

Hydroxyapatite/chitosan (HApC) composite has been prepared by precipitation method and used for removal of heavy metals ( $\text{Cr}^{6+}$ ,  $\text{Zn}^{2+}$  and  $\text{Cd}^{2+}$ ) from aqueous solution. The HAp and 3H7C composite with HAp:chitosan ratio of 3:7 (wt%) were characterized by Fourier transform infrared spectroscopy, X-ray diffraction and scanning electron microscopy-energy dispersive X-ray spectroscopy. The SEM results showed that HAp is spherical-shaped and crystalline, while chitosan has a flat structure. SEM micrograph of 3H7C composite reveals crystalline of HAp uniformly spread over the surface of chitosan. The crystal structure of HAp is maintained in 3H7C composite. Chitosan affects the adsorption capacity of HAp for heavy metal ions; it binds the metal ions as well as HAp. The kinetic data was best described by the pseudo-second order. Surface adsorption and intraparticle diffusion take place in the mechanism of adsorption process. The binding of HAp powder with chitosan made the capability of composite to removal of  $\text{Cr}^{6+}$ ,  $\text{Zn}^{2+}$  and  $\text{Cd}^{2+}$  from aqueous solution effective. The order of removal efficiency ( $\text{Cr}^{6+} > \text{Cd}^{2+} > \text{Zn}^{2+}$ ) was observed.

### Keywords

Adsorption, Chitosan, Composite, Heavy metals, Hydroxyapatite

This Paper is Published in Advanced Material Research Journal

## **Simulation of Gas Leakage in a City Gas Utilization System in Household Sector**

**Yuswan Muharam, Henry Septian**

*Department of Chemical Engineering, Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail: muharam@che.ui.ac.id*

### **ABSTRACT**

The government is setting up a program of city gas utilization for household sector. People are not convinced of the safety of city gas. One of the accidents people worry about is gas leakage in a city gas utilization system, such as kitchen. Leaking gas is not dangerous when fire can be prevented. Therefore, the information on potential fire caused by leaking gas and ways to prevent are needed. This research was intended to obtain the information on fire prevention caused by leaking gas in a kitchen through simulation. The system modelled in the research is a rectangular room of 3 m x 2 m x 3 m. The models consider mass and momentum balances, and were solved using COMSOL Multiphysics. The simulation results show that when leaking gas detected, the leakage hole must be closed. Even if there is an exhaust system, the safe limit is not reached.

### **Keywords**

*Modelling, simulation, city gas, fire prevention*

**This paper is published in International Journal of Technology (IJTech)**

# Synthesis of aligned carbon nanotubes By methane catalytic decomposition reaction On spherical substrate

Widodo Wahyu Purwanto, Ryan Januar Rusli Putra

Department of Chemical Engineering  
Faculty of Engineering, Universitas Indonesia, Depok 16424  
E-mail: widodo@che.ui.ac.id

## ABSTRACT

*This research was conducted to determine the impact of reaction time on the quality of carbon nanotubes (CNTs), CNT's yield and also methane conversion. CNTs were grown on alumina balls coated Fe/Mo/MgO catalyst prepared by sol-gel method. The decomposition reaction carried out in CVD reactor at 850°C with methane as carbon source. The reaction time of 15, 30, 45 and 60 min. were used to evaluate its impact. FE-SEM method was used to characterize CNT. The FE-SEM images show that CNT has been successfully grown on alumina balls with diameter approximately 50 until 130 nm. but it didn't form aligned CNT. The less evenly catalyst coating and less homogenous of catalyst composition are the causes of this result. The reaction performance shows that CNT's yield is increases when the reaction time increases, while the methane conversion decreases due to the catalyst deactivation.*

## Keywords

*Aligned CNT, methane decomposition, Fe/Mo/MgO, alumina ball*

## 1. INTRODUCTION

Carbon Nanotube (CNT) is a material that has a lot of advantages over other materials. The advantages are as follows: chemical reactivity, electrical conductivity, optical properties and also young's modulus [1]. Because of its advantages, CNT becomes one of the most applicative materials for devices, fuel cell, composites, etc. Bundles of CNT that oriented into certain direction is called aligned CNT. Aligned CNT can be use on some application such as the self-cleaning application, DNA biosensor, glucose sensor, pH, NO<sub>2</sub>, etc [9]. Therefore, the research on aligned CNT is very important to develop.

Various studies about CNT have been carried out in Chemical Engineering Department University of Indonesia, but haven't been able to generate aligned CNT. It is caused by the number of parameters that need to be considered such as substrate shape and type, catalyst, and also some reaction condition such as reaction time. In this research, reaction time is becoming our major concern. On the other hand, there are many other researches that has successfully generate aligned CNT by using some substrate, catalyst and method. Aligned CNT can be grown on porous silica substrate [5]. However, among the aligned CNT produced, there are several CNT that is not vertically aligned. This caused by the form of the pore in the substrate is not uniform [5]. On the other side, aligned CNT that growth on glass substrate without pores has better CNT quality [8] and the usage of spherical substrate make the reaction occured continuously [12]. Therefore alumina ball become the substrate of this research to grow aligned CNT.

Meanwhile, in the selection of the catalyst, Fe/Mo/MgO catalyst that has Fe active site was choosen. It is based on a variety studies that has been done such as ferrocene [3,12] and Fe catalyst [2,4]. Meanwhile, methane is the carbon source and CVD is the method used in this research.

This research was conducted to find out the influence of reaction time on the orientation of CNT, CNT's yield and also methane conversion, as there is a possibility that the orientation of the CNT is affected by the length of time reaction.

## 2. RESEARCH METHODS

The CNT were grown by chemical vapour deposition method on alumina ball with 2-4 mm of diameter, methane as the carbon source and hydrogen gas to reducing the catalyst. The Fe/Mo/MgO catalyst with 1/0.1/13 molar ratio and catalyst was prepared

using sol-gel method by mixing  $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ ,  $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$ ,  $\text{Mg}(\text{NO}_3)_2 \cdot \text{H}_2\text{O}$ , and citric acid, into deionized water. Two stages of calcination at  $550^\circ\text{C}$  and  $850^\circ\text{C}$  was conducted to the sol-gel, to get the catalyst powder. The CVD reactor made by quartz with 4.5 cm of inner diameter and 50 cm of length. The arrangement of reactor system can be seen in Fig. 1.

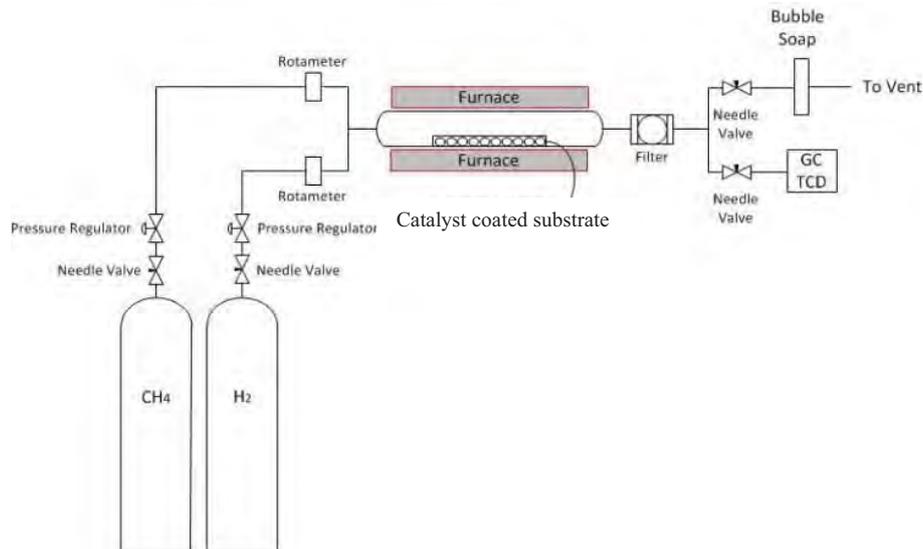


Figure 1: Equipment layout

At the beginning, the furnace was set at  $850^\circ\text{C}$ . Hydrogen was supplied into the reactor at a flow rate of 20 mL/min for 30 minutes to reducing the catalyst, and followed by methane gas at a flow rate of 80 mL/min. The 60, 45, 30 and 15 minutes of time reaction was used in this research. The output gas composition was analyzed using Shimadzu 8-APT Gas Chromatography (GC) with active carbon column & C-R6A TCD Detector, every 5 minutes during the reaction.

The catalyst properties were characterized by X-Ray Diffraction (XRD) and Scanning Electron Microscopy – Energy Dispersive X-ray (SEM-EDX) methods. The XRD characterization is done using a Shimadzu 7000 ( $\text{CuK}\alpha = 0,1541 \text{ nm}$ ), and the SEM-EDX characterization was performed by using Carl Zeiss Bruker MA-EVO10. The morphology of the catalyst coating and the growth of CNT were characterized by FE-SEM method using Inspect F50 by FEI.

### 3. RESULTS AND DISCUSSION

#### 3.1 Catalyst Characteristics

$\text{Fe}_3\text{O}_4$  and  $\text{MgO}$  are the desired crystal structure catalyst, which both of them are proved their existence through the result of XRD characterization before hydrogen reduction as shown in Fig. 2(a). The presence of  $\text{MgO}$  crystal in the catalyst helps the dispersion of Fe active site and prevent the sintering of Fe catalyst. Meanwhile, the presence of  $\text{Fe}_3\text{O}_4$  is the source of Fe active site [10].

The reduction of Fe/Mo/MgO catalyst is performed to produce Fe and Mo catalyst active site [10]. Fig. 2(b) shows the existence of  $\text{MgO}$ , but there are no Fe or Mo peak through the XRD result. This is happen due to its very small composition of Mo in the catalyst. In the other hand, Fig. 3 shows there are Fe, Mo, Mg and O in Fe/Mo/MgO catalyst.

FE-SEM images of alumina coated catalyst [Fig. 4] shows the less evenly catalyst coating, especially at 80.000 and 300.000 times of magnification [Fig 4.(c) and (d)]. This was caused by the spray coating method which is difficult to produce an uniform coating and may lead to irregular position of Fe particles.

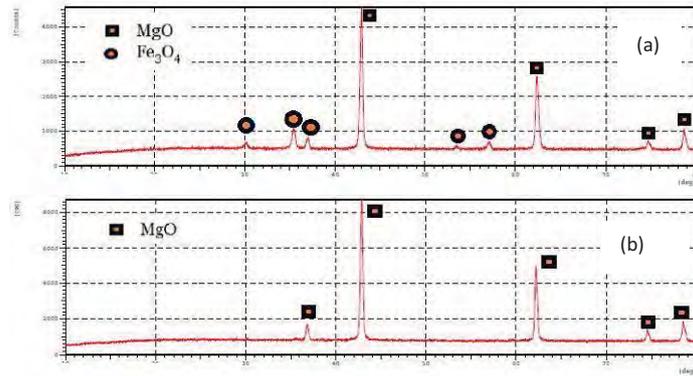


Figure 2 : XRD characterization result of Fe/Mo/MgO catalyst. before (a) and after (b) reduction

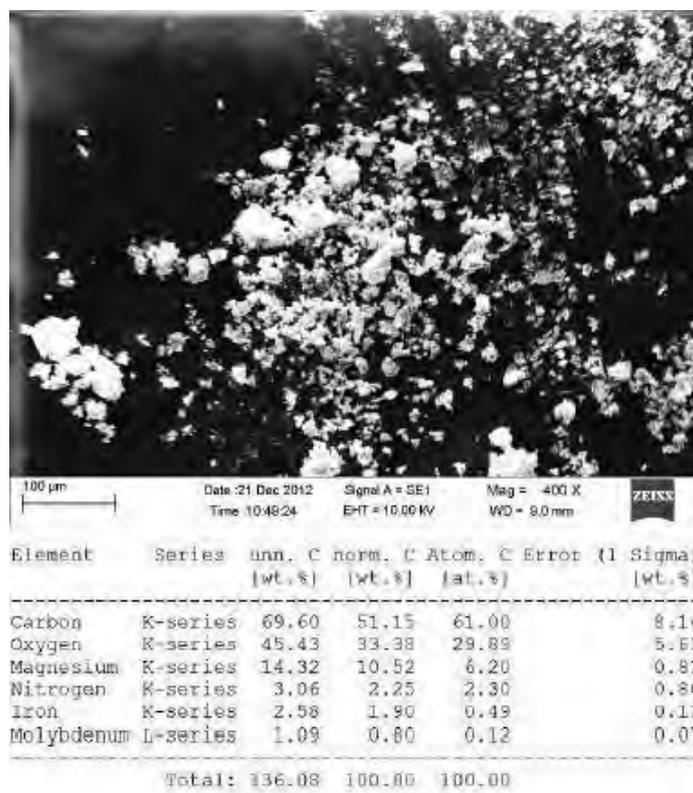


Figure 3 : SEM-EDX result of Fe/Mo/MgO reduced catalyst

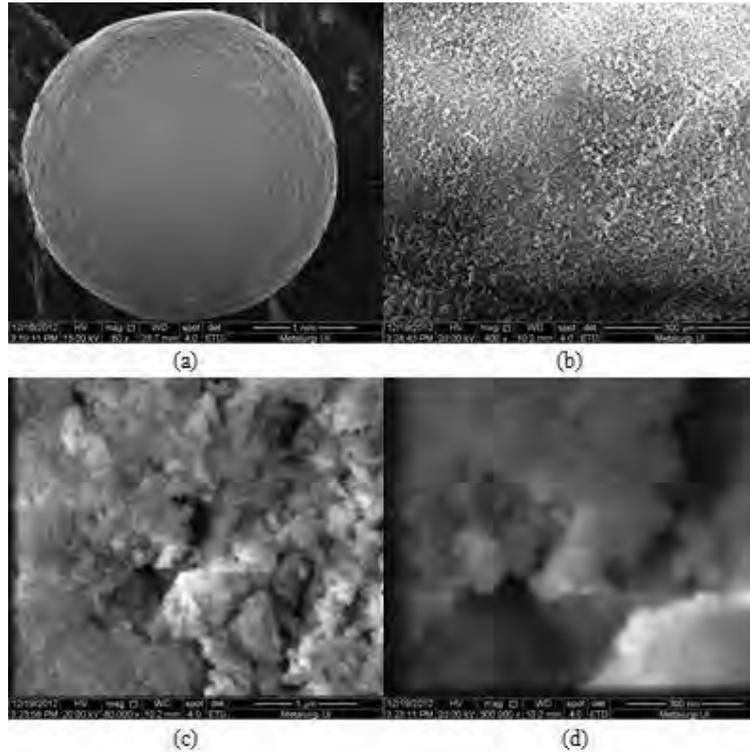


Figure 4 : FE-SEM images of alumina coated catalyst at : 80x (a), 400x (b), 80.000x (c) and 300.000x (d) magnification

### 3.2 CNT Characteristics

CNT has been successfully growth on alumina ball at all reaction time variation. FE-SEM images of alumina overgrown CNT [Fig. 5 and 6] shows that the decrease in reaction time produce a more tidy CNT bundles. The decrease in reaction time also impact the diameter of CNT:  $\pm 130$ ,  $\pm 100$ ,  $\pm 75$  and  $\pm 50$  nm in 60, 45, 30 and 15 minutes of reaction time respectively, which is caused by the growth. Unfortunately, there is no aligned CNT produced. It was caused by the less evenly catalyst coating and less homogenous of catalyst composition.

The less evenly catalyst coating caused the Fe catalyst can be placed in all sections so the CNT is grow unpredictable. Meanwhile, reference [14] shows that the difficulty of making a homogenous composition of the catalyst cause the existence of catalyst particle that rich in Fe composition and catalyst particle that rich in Mo composition. Based on volcano curve, we know that Fe particle has better reactivity than Mo particle. The difference in particle reactivity cause CNT will go higher on Fe particle than Mo particle and loss its orientation [14].

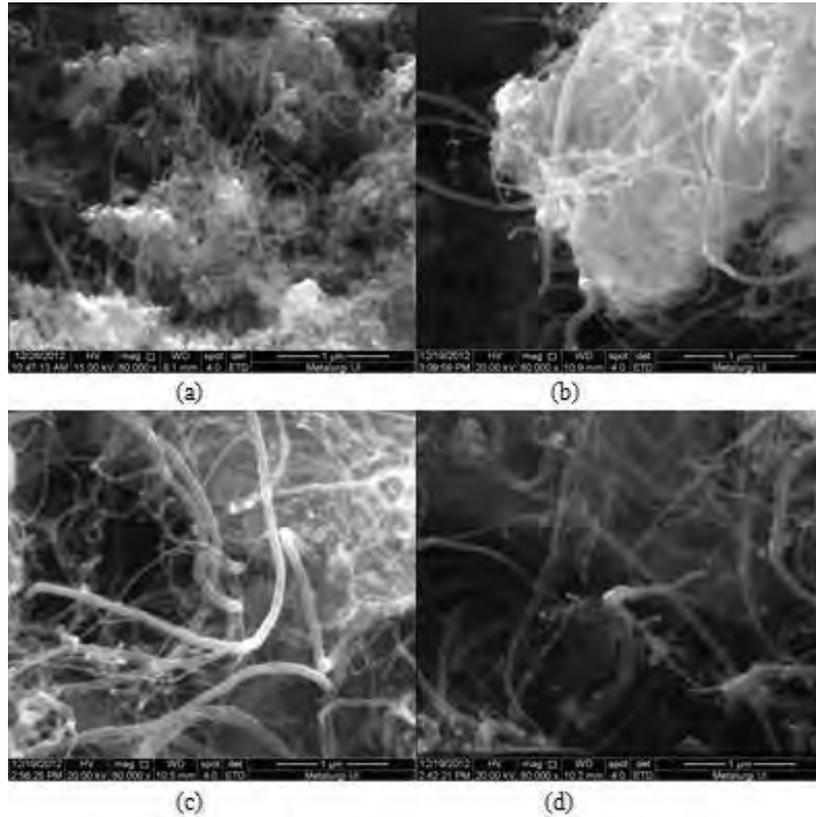


Figure 5 : FE-SEM images of alumina overgrown CNT on 80.000x magnification at : 15 (a), 30 (b), 45 (c) and 60 (d) minutes of variation times

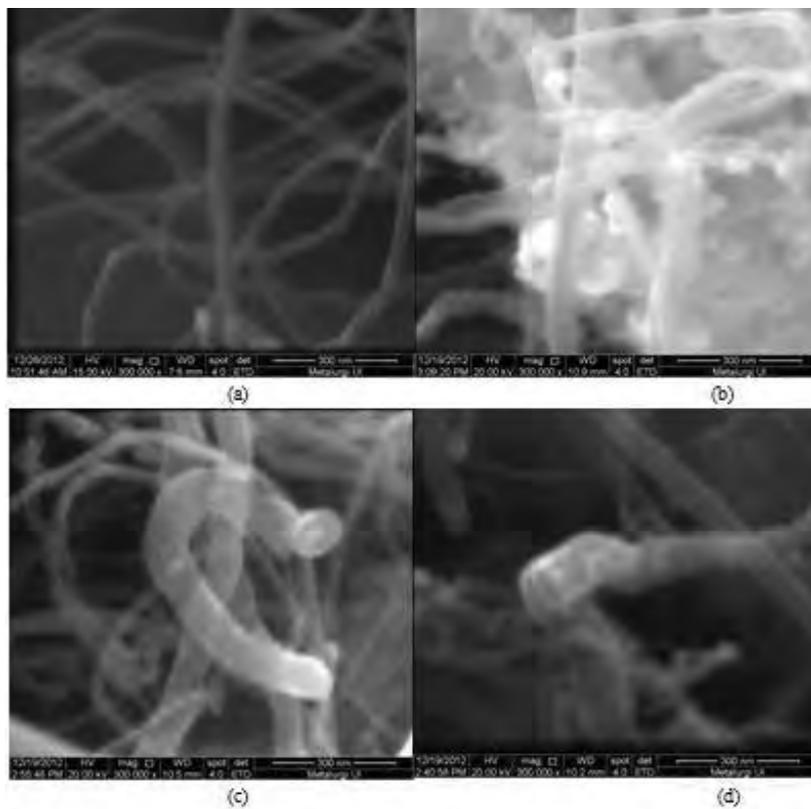


Figure 6 : FE-SEM images of alumina overgrown CNT on 300.000x magnification at : 15 (a), 30 (b), 45 (c) and 60 (d) minutes of variation times

### 3.3 Reaction Performance

Carbon loss was calculated by using the initial carbon mass balance and the modified carbon mass balance by identification of carbon loss. The initial carbon mass balance was calculated by using the raw data that we got during the research such as the feed rate that measured by flow meter and product rate that measured by a bubblesoap. In the other side, the modified carbon mass balance was calculated by using feed and product rate that have been corrected.

Table 1 shows that there are some carbon loss happend in this research. Carbon loss happend because of some error, such as decrease in methane flow rate due to the growth of CNTs, product flow sampling error, methane gas converted into another higher gases, some CNTs was carried away from the reactor by the gas flow, unstability of feed flow rate due to the unstable flowmeter [13]. Growth of CNT reduce the empty space in the reactor that makes a pressure drop and the resulting decline of methane flow rate [13]. By calculation, there is a bit decrease in carbon loss [Table 1]. The unidentified carbon loss caused by the other error as mentioned above. The TCD type of gas chromatography can not detect the presence of other gases such as  $C_2H_4$ ,  $C_2H_6$ ,  $C_2H_2$  and  $C_4H_{10}$  [13]. Therefore, we need FID type of gas chromatography to detect those gases. This error causes the calculated carbon mass balance si not accurate and causes huge amount of carbon loss.

Table 1: Carbon loss calculation

Time Variation (minutes)	Theoretical Carbon (g)	CNT Mass (g)	Carbon Loss	Carbon Loss (corrected)	
15	0.23	0.15	34.41%	33.33%	± 1.59%
30	0.65	0.30	53.79%	52.49%	± 1.72%
45	0.82	0.31	62.14%	60.35%	± 1.72%
60	0.95	0.43	54.96%	52.06%	± 1.71%

Methane conversion is decending when the reaction time increase [Fig. 7]. It is happened because the occurrence of catalyst deactivation [11] and CNT has grown on the catalyst [13]. Its cause the surface area of the catalyst that can be used to perform the reaction is getting smaller and results in decending methane conversion.

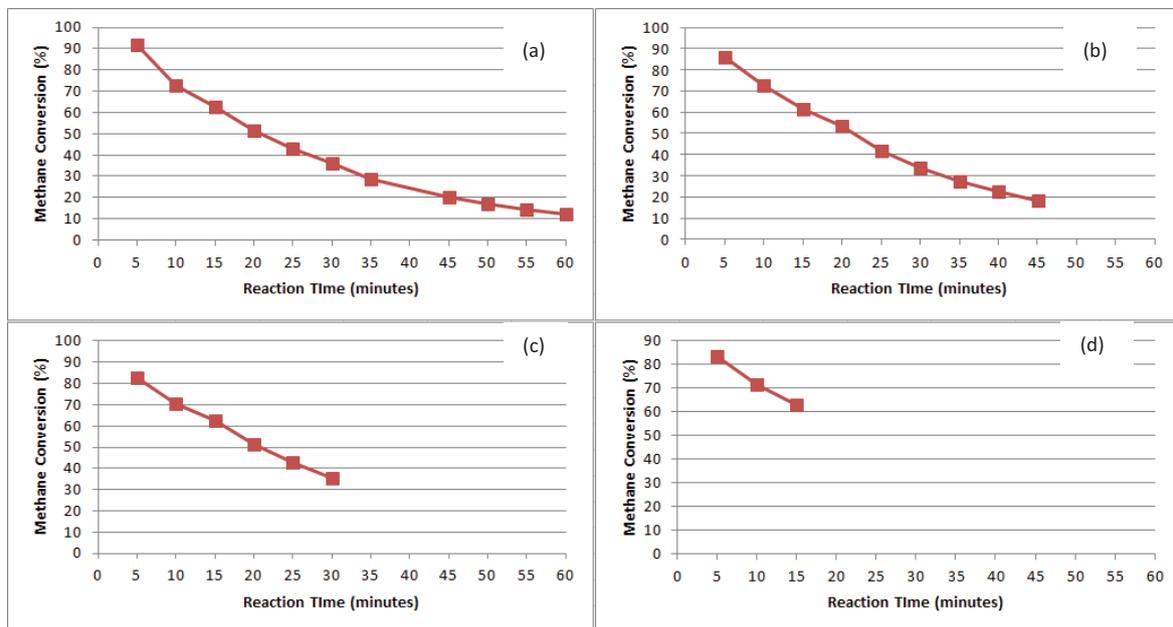


Figure 7 : Methane conversion : 60 (a), 45 (b), 30 (c) and 15 (d) minutes of reaction time

Yield is describe as the amount of CNT produced compared with the amount of catalyst used. The reaction time variation impact the CNT's yield as the CNT's yield was increasing when the reaction time increase. Fig. 8 shows the produced CNT's yield for 15, 30, 45 and 60 minutes of reaction time is 0.41, 0.52, 0.54 and 0.75 gCNT/gCat, respectively. This result indicates that CNT is still growing until the carbon source is no longer exist.

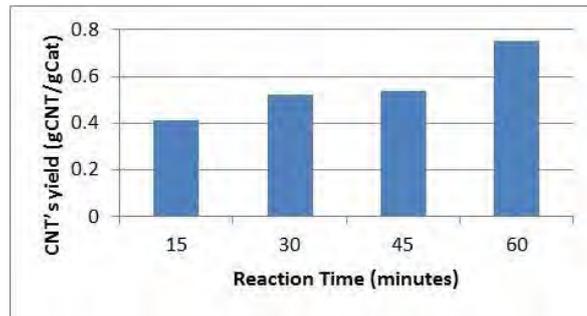


Figure 8 : CNT's yield at some reaction time variation

#### 4. CONCLUSION

Carbon nanotubes have grown on spherical substrate coated Fe/Mo/MgO catalyst and methane by CVD method. The variations in reaction time performed have shown that CNTs grown more tidy in a shorter reaction time. Unfortunately, there are no indication that aligned CNT have grown by using this combination of catalyst, substrate, carbon source and method. It is happened because of the less evenly catalyst coating and less homogenous of catalyst composition. The variation of reaction time impact the CNT's yield, where CNT's yield is increasing when the reaction time increase. It indicates that CNT is still grow until the carbon source is no longer exist. The methane conversion has decreased along the reaction time because the occurrence of catalyst deactivation.

#### REFERENCES

- [1] M. Daenen, R.D.de Fouw, B. Hammers, P.G.A. Janssen, K. Schouteden, M.A.J. Veld, "The wondrous world of carbon nanotubes," unpublished.
- [2] C.P. Deck, and K. Vecchio, "Prediction of carbon nanotube growth success by the analysis of carbon-catalyst binary phase diagram," *Carbon*, vol. 44, no. 2, pp. 267-275. 2006.
- [3] D.L. He, H. Li, W.L. Li, P.H. Ashtiani, P. Lejay and J.B. Bai, "Growth of carbon nanotubes in six orthogonal directions on spherical alumina microparticles," *Carbon*, vol. 49, no. 7, pp. 2273-2286. 2011.
- [4] Z.P. Huang, D.Z. Wang, J.G. Wen, M. Sennett, H. Gibson and Z.F. Ren, "Effect of nickel, iron and cobalt on growth of aligned carbon nanotubes," *Appl. Phys. A*, vol 74, no. 3, pp. 387-391. 2002.
- [5] W.Z. Li, S.S. Xie, L.X. Qian, B.H. Chang, B.S. Zou, W.Y. Zhou, R.A. Zhao and G. Wang, "Large-scale synthesis of aligned carbon nanotubes. *Science*, vol. 274, no. 5923, pp. 1701-1703. 1996.
- [6] A. Manggiasih, "Performance comparison of Fe and Ni with MgO support structured catalyst for carbon nanotube synthesizing by methane catalytic decomposition reaction" (in Indonesia), undergraduate thesis at University of Indonesia.
- [7] W.W. Purwanto, P.P.Wulan and Y. Muharam, "Intrinsic kinetic model for catalytic deposition of methane to produce carbon nanotubes on Ni-Cu-Al catalyst," unpublished.
- [8] Z.F. Ren, Z.P. Huang, J.W. Xu, J.H. Wang, P. Bush, M.P. Siegal and P.N. Provencio, "Synthesis of large arrays of well-aligned carbon nanotubes on glass," *Science*, vol. 282, no. 5391, pp. 1105-1107. 1998.
- [9] C.M. Seah, S.P. Chai and A.R. Mohamed, "Synthesis of aligned carbon nanotubes," *Carbon*, vol. 49, no. 14, pp. 4613-4635. 2011.
- [10] B. Valentine, "Synthesis of carbon nanotubes by methane catalytic decomposition reaction using Fe/Mo/MgO catalyst" (in Indonesia), undergraduate thesis at University of Indonesia.
- [11] P.P.Wulan, "Methane decomposition reaction using Ni-Cu-Al for carbon nanotube production : reaction kinetic and reactor modelling" (in Indonesia), dissertation at University of Indonesia.
- [12] R. Xiang, G.H. Luo, W.Z. Qian, Y. Wang, F. Wei and Q. Li, "Large area growth of aligned CNT arrays on spheres: towards the large scale and continuous production, unpublished.
- [13] N. Yeni, "Carbon loss identification on pilot scale carbon nanotube (CNT) production using gauze reactor" (In Indonesia), undergraduate thesis at University of Indonesia.
- [14] H. Yu, Z. Li, C. Zhang, F. Peng and H. Wang, "Growth of aligned carbon nanotubes on large scale by methane decomposition with deactivation inhibitor," *J. Natural Gas Chem.*, vol. 16, no. 4, pp. 382-388. 2007.

## Practical isolation of bullatacin from *Annona muricata* leaves extract using an open column chromatography technique

Kamarza Mulia\*, Silvester W. Winarcahyo, Elsa Krisanti, Dewi Kurniasuci

*Chemical Engineering Department, Faculty of Engineering, Universitas Indonesia  
Depok 16424, Indonesia*

*\*E-mail: kmulia@che.ui.ac.id*

### ABSTRACT

Annonaceous acetogenins are bioactive compounds present in the leaves of *Annona muricata* (soursop) with significant anti-cancer activities. In this study, acetogenin-rich ethanol fraction extracted from soursop leaves was further separated and isolated using a simple open column chromatography technique with silica gel as the stationary phase. The separation procedure consists of three steps, each step employing sequential elution with organic solvents having different polarity as the eluent. Eluted fractions rich in acetogenin compounds were identified using the Kedde reagent which formed a distinctive dark green complex with the unsaturated  $\gamma$ -lactone group present in all of the annonaceous acetogenin compounds. HPLC analysis showed that the initial methanol fraction, as well as isolates from the second and the third isolation steps, contain bullatacin, squamostatin-A, and squamostatin-D. Bullatacin produced from this study can be used further as a standard compound for quantitative analysis of other acetogenin compounds contained in soursop leaves extract.

### Keywords

*Annonaceous acetogenin, soursop, open column chromatography, bullatacin*

**This paper is published in Advanced Materials Research Journal**

# A Catalytic Conversion of Ethanol to High Quality Hydrocarbon Fuel Using the Catalyst Mixture $\text{Al}_2\text{O}_3$ -HZSM-5

Setiadi , Rezhi Ramadhia Putra,

*<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : setiadi@che.ui.ac.id*

## ABSTRACT

One of the aspect quality of the product refinery for the requirement of atoumotive is the hydrocarbon products with high octane number ( $> 88$ ) in order to be accepted well as primary quality fuel. In the conventional industrial refinery processing, the producing of the high octane number hydrocarbons usually employs the reactions of : catalytic reforming, hydrocracking, alkylation or catalytic cracking. This research is intended to give an overview of alternative route for recovery the high quality hydrocarbons from ethanol. Ethanol is one of the biomass derivative compound, could be generated renewably from fermentation process. The reaction of the ethanol conversion to hydrocarbons could be performed using the mixture catalyst of the  $\gamma$ -alumina and H-ZSM-5 with weight composition (5, 10, 15 %wt). The catalytic reaction test was carried out by fixed bed reactor at atmospheric pressure during 3 hours raction, with each of catalyst composition examined and reaction temperatures. The results showed that the reaction of ethanol to the containing hydrocarbons product such as aromatic, isoparaffin, olefin was obtained significantly. The calculation result of the high octane number up to 109.5 was achieved using catalyst composition 15% HZSM-5-75 %  $\text{Al}_2\text{O}_3$  at 450 °C. This such high octane number is due to isoalkane and aromatic hydrocarbons produced as the main comprising component in the product.

## Keywords

*Ethanol, hydrocarbons, mixture of H-ZSM-5 and Alumina, octane number, reaction catalytic conversion*

## 1. INTRODUCTION

Crude oil is one of the unrenewable source of energy. It is because of how the crude oil formed in the earth. Crude oil existed because of decomposition of a long dead organism which is buried in the earth for a very long time. The time it took for it to become crude oil could be a hundred's or even thousand years. This minimum quantity of crude oil means that an export and import to satisfy the demand must be done. In this case, Indonesia have to import the crude oil to satisfy the demands. Crude oil production in Indonesia until the end of 2009 was 900,000 barrel per day and 50 percent of that production was exported outside the nation. At that time, crude oil needs in indonesia was 1.4 million barrel per day, therefore Indonesia still have to imported 950,000 barrel per day of crude oil to satisfy that much demand [1]. To solve this problem, a new source of crude oil well need to be discovered and built, but even so, the demands would not be fulfilled until 2015 [2]. Because of those problems, the needs of alternative energy beside the crude oil is increasing to solve the problems of this limitation.

In the study of ethanol catalytic transformation over zeolite HZSM-5 catalyst showed that the mechanism of reaction is similar with those in MTG (methanol to gasoline) reaction [3]. Moreover, the range of product made from this reaction is also similar [4]. This showed us that the process in MTG reaction generally could also be used in ETG reaction. The study of hydrocarbon production with hybrid catalyst (physical mixed catalyst or bifunctional catalyst) have also been done before which used  $\text{B}_2\text{O}_3$ /Zeolit as the catalyst and the feed on that research use the mixture of palm oil and methanol with catalytic reaction [5].

One of the quality indicator of fuel like gasoline that really familiar with us all is octane number (RON). For example, a commercial gasoline produce by PT. Pertamina have an octane number of 88 for premium, and 92 for pertamax. The difference between that two kind of gasoline in octane number is very little. But, this little difference have a greater impact on the machine performance and the price of these gasoline. Basically, octane number of chemical compound is related to what kind of hydrocarbon compound involved. Generally, hydrocarbon compound that have an ability and capability to boost an octane number is for example an aromatic compound, cycloparaffins (naphta), and an iso-paraffins compound. Because of that, a hydrocarbon mixture which contain those kind of hydrocarbons will have a higher octane number than those whose not. Generally, those hydrocarbons were made from the processing of crude oil. In this research, those hydrocarbon compounds

will be synthesized from ethanol which is not the product of crude oil, thus made it renewable because ethanol can be obtain from renewable source like fermentation.

The purpose of this research is to get an optimum variable on this catalytic reaction of ethanol into high octane hydrocarbons with RON above 88. The variable consist of reaction temperature and ratio of mixture between  $\text{Al}_2\text{O}_3$ -ZSM-5 catalyst.

## 2. METHOLOGY

The first step on this research is the mixing of the catalyst to create a desired catalyst composition ratio. An  $\text{Al}_2\text{O}_3$ /HZSM-5 catalyst mixture is a combination of catalyst where the catalyst is supporting each other in the reaction. HZSM-5 composition in this research will be vary from 5%, 10%, 15%, and 20%.

Next step in this research is reaction test. This is the main step in this research. Ethanol will be used as the feed for conversion reaction. Ethanol will be fed into the fixed bed reactor containing the already prepared and mixed  $\text{Al}_2\text{O}_3$ /HZSM-5 catalyst. So that the ethanol will become a smaller molecule compound through the catalytic reaction. The general procedure to put this reaction into practical means is first, fed the ethanol into the reactor, then the output product of reactor which is in gas phase will be cooled in the condensation system to get the liquid phase product, while the remaining gas phase product will be flowed into the gaseous bag. At the end of the flow of liquid product, n-heptane will be putted on to do the bubbling of the uncondensed gas product so that the liquid product in this research will be greater.

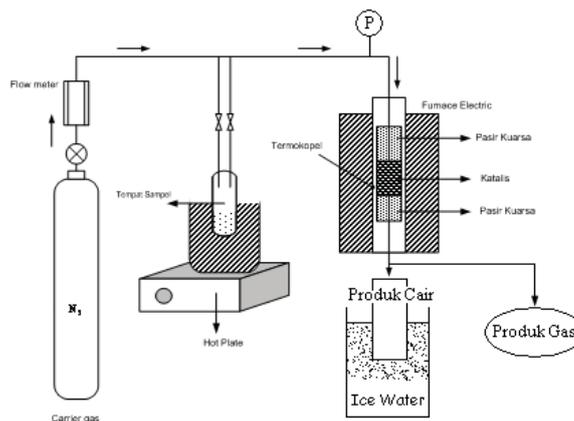


Figure 1: Schematic diagram of experimental set-up for ethanol catalytic reaction in a atmospheric fixed bed reactor

The last step is analyzing the liquid product from the experiment. On this step, the liquid product of catalytic reaction from the synthesis of hydrocarbon compound from ethanol reaction will be analyzed. The liquid product will be analyzed using GC/MS. From this analysis, all of the compound produce from the reaction in liquid product will be clear, and we also could quantify and identify this compound. This is very vital in order to calculate the octane number of the product later.

## 3. RESULT AND DISCUSSION

To identify the product from reaction, Gas chromatography-Mass Spectrometer (GC/MS) analysis will be used. The data from GC/MS instrumentation will be processed using the software which is connected with the computer and the instrumentation. The resulting data from GC/MS analysis will be on the form of peak spectrum (chromatogram) and the hydrocarbon product identification for each peak appeared based on  $m/z$ . From this peak, the characteristic of each compound could be analyzed qualitatively and quantitative based on the peak area or peak height, because each peak have a different peak characteristic. This peak characteristic will be analyzed based on the similarity with the peak that already in the library of the software and will be sort between the match quality to identify what is the compound of those peak based on match quality. Moreover, with GC/MS, the retention time of each compound could be identified along with the percent area of each compound which is the main point to get the quantification or composition of each compound in the analyzed product. Here are some typical chromatogram of the GC-MS for the sample resulted from the reaction using HZSM-5 with 5% at various temperature 350 °C, 400 °C, 450 °C depicted at figure 2, figure 3, figure 4, and figure 5 for 15 % HZSM-5 at 350 °C, irrespectively.

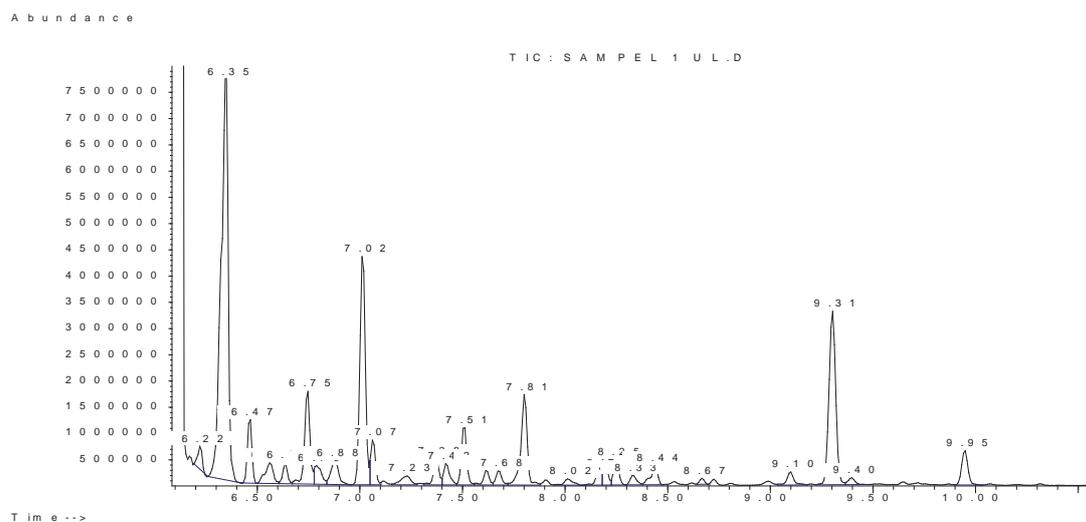


Figure 2: The chromatogram for the sample resulted from the acetone reaction using 5% HZSM-5-Al<sub>2</sub>O<sub>3</sub> at 350 °C

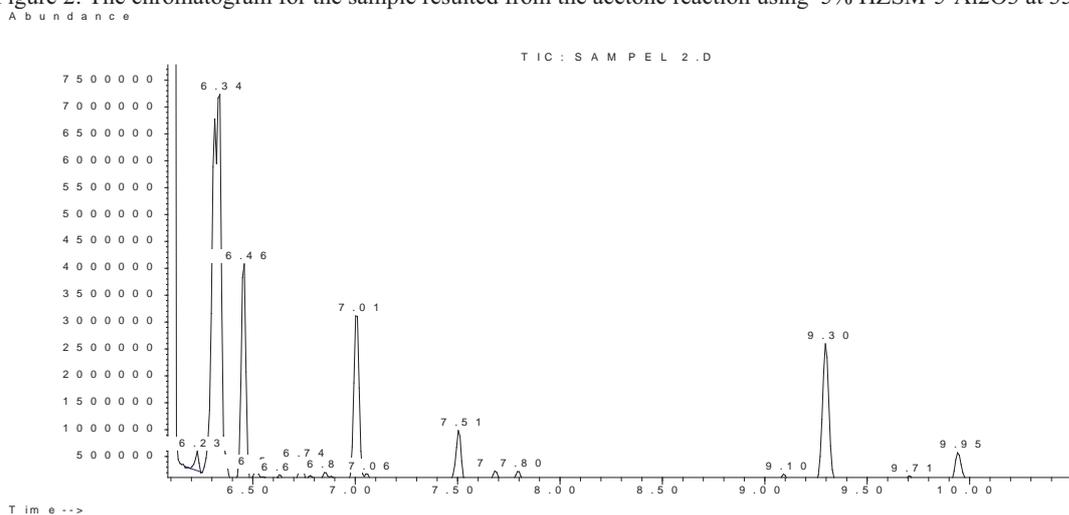


Figure 3: The chromatogram for the sample resulted from the acetone reaction using 5% HZSM-5-Al<sub>2</sub>O<sub>3</sub> at 400 °C

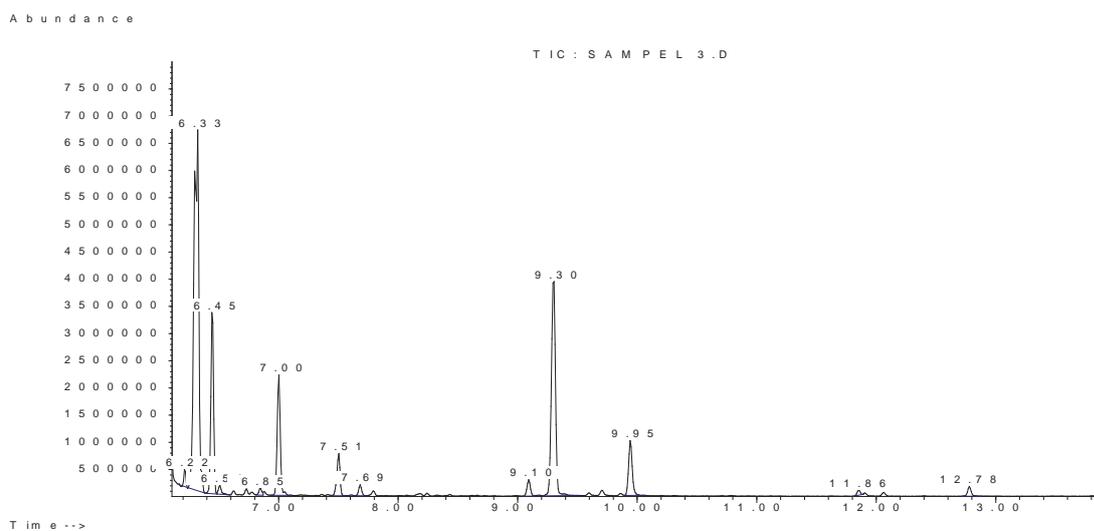


Figure 4: The chromatogram for the sample resulted from the acetone reaction using 5% HZSM-5-Al<sub>2</sub>O<sub>3</sub> at 450 °C

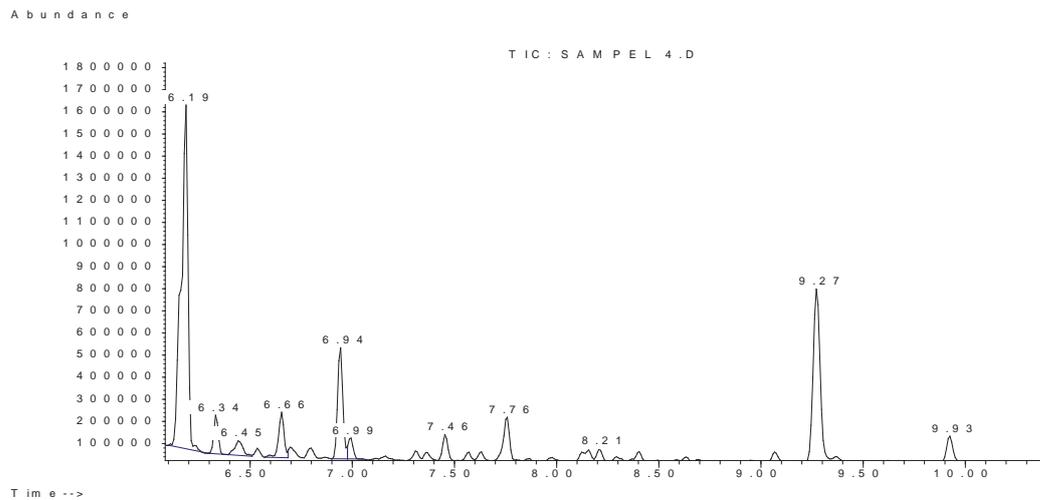


Figure 5 : The chromatogram for the sample resulted from the acetone reaction using 15% HZSM-5-Al2O3 at 350 °C

Table 1 : The Classified Hydrocarbon compositions from Catalytic Reaction of Ethanol

Catalyst mixture (%w) (H-ZSM-5-Al2O3)	5%	5%	5%	15%	15%	15%	20%	20%	20%
Temperature (°C)	350 °C	400 °C	450 °C	350 °C	400 °C	450 °C	350 °C	400 °C	450 °C
Hydrocarbon Compound (%w)									
Olefin	1.36	1.11	1.03	15.12	51.96	1.34	1.93	0	0
Cycloparafin	83.32	50.12	29.09	49.67	12.2	28.52	45.39	77.74	53.96
Aromatic	2.2	43.26	67.59	35.21	35.84	51.6	48.47	22.1	45.34
Isoparafin	0	0	2.29	0	0	17.21	0.61	0	0
n-parafin	0	0	0	0	0	0.53	0	0	0
The Others (Unknown)	13.12	5.51	0	0	0	0.8	3.6	0.16	0.7
	100	100	100	100	100	100	100	100	100

The product analyzed with GC/MS then will be calculated using the equation to calculate each octane number of the sample hydrocarbon product. Because of that, the quantification of composition from the analyzed product using GC/MS was very essential on this research. To calculate the octane number, first each of the compound have to be categorized based on each hydrocarbons chain structure i.e. Olefin, cycloparafin, aromatic, isoparafin and n-parafin hydrocarbon. Based on the amount of hydrocarbons in each category, will be calculated using the equation to get the product octane number as you can see below [6].

$$\begin{aligned}
 \text{RON} = & 69.0306 - 1.0729Y_{NP} + 0.7875Y_{IP1} + 0.0976Y_{IP2} \\
 & + 0.3395Y_{CP} + 0.4049Y_{AR} \dots\dots\dots (1)
 \end{aligned}$$

where:

- Y = Fraction of each category
- NP = N-Paraffin (without C5)
- IP1 = Iso paraffin from C5 to C7
- IP2 = Iso paraffin other than C5 to C7
- CP = Cycloparaffin
- AR = Aromatic

The octane number of liquid product from the calculation can be seen on figure 6.

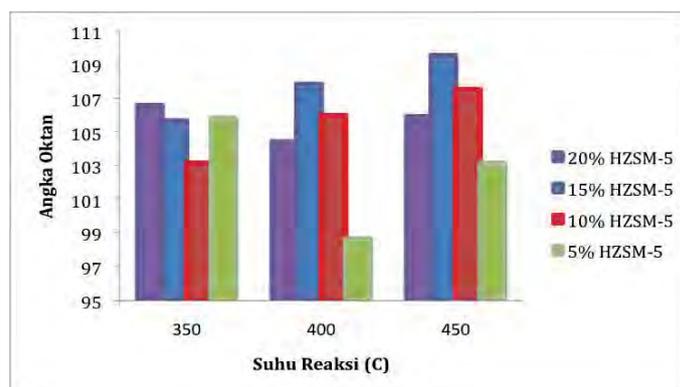


Figure 6: The Calculation results of the Octane Number for each hydrocarbon product

From figure 6 we may see the product octane number with various parameter, from catalyst  $Al_2O_3/HZSM-5$  ratio composition (5% to 20% HZSM-5) to reaction temperature (350 °C, 400 °C, and 450 °C). From this figure above, we can see that the optimum condition to get the highest possible octane number in this research is 15% HZSM-5 catalyst composition at reaction temperature of 450 °C. The resulting octane number of the product at this condition is 109.6. At this condition, the aromatic content of the product maybe not as high as the condition at 10% HZSM-5 but higher than at the lower temperature. We knew that aromatic hydrocarbon have a very high octane number. But, why did at 10% HZSM-5 at the same temperature the octane number is lower even though the aromatic content is higher.

This shows us that aromatic content which have a generally very high octane number isn't the only compound that affecting greatly on octane number. We can see that on 15% HZSM-5 at 450 °C reaction temperature, another compound that could

Table 2 : The composition of liquid hydrocarbon product using 15% HZSM-5 At 450 °C

no	name	RT	%w
1	Cyclopentane, methyl-	2.553	0.27
2	Benzene	3.008	2.14
3	Pentane, 2,3-dimethyl-	3.083	2.41
4	Hexane, 3-methyl-	3.224	9.09
5	Pentane, 2,3,4-trimethyl-	3.433	5.35
6	Cyclohexane, methyl	5.743	25.13
7	Cyclopentane, ethyl-	5.835	3.48
8	Cyclohexene, 4-methyl-	5.933	0.27
9	3,5-Dimethylcyclopentene	6.13	0.53
10	Cyclopentene, 3-ethyl-	6.208	0.27
11	Toluene	6.517	22.99
12	Cyclohexene, 1-methyl-	6.577	0.27
13	Ethyl ester of 1-Methyl-2-methylene	7.703	0.27
14	Cyclohexane, 1-methyl-4-methylene	8.414	0.27
15	3-Heptyne, 5-methyl-	8.603	0.27
16	Benzene, ethyl-	9.508	0.80
17	o-Xylene	9.898	21.93
18	p-Xylene	10.585	3.48
19	2,3-Dimethyl-3-phenylbutan-2-ol	12.809	0.00
20	Benzene, 1,2,3-trimethyl-	13.833	0.27
21	Hexadecane	23.918	0.00
22	Pentadecane	26.441	0.27
23	Hexadecane	28.232	0.27

affect the octane number even greater than aromatic compound also present. This compound is isoparaffin, which is present at 17% weight of the product. The presence of this isoparaffin considerably boost the octane number. And because of that, the octane number at this variable was higher than any other variable. But, the presence of isoparaffin compound throughout this

research was very minimum. And this is resulting in the majority of octane number was very dependant on aromatic and cycloparaffin content. Therefore, the trend of octane number rising along with the temperature rising is the effect of the aromatic content improvement. The identification of each compound present on the product with 15% HZSM-5 at 450 °C can be seen at the table below (table 2). And the product distribution using 15% HZSM-5-Al<sub>2</sub>O<sub>3</sub> catalyst at various reaction temperature can be seen at figure 7 below.

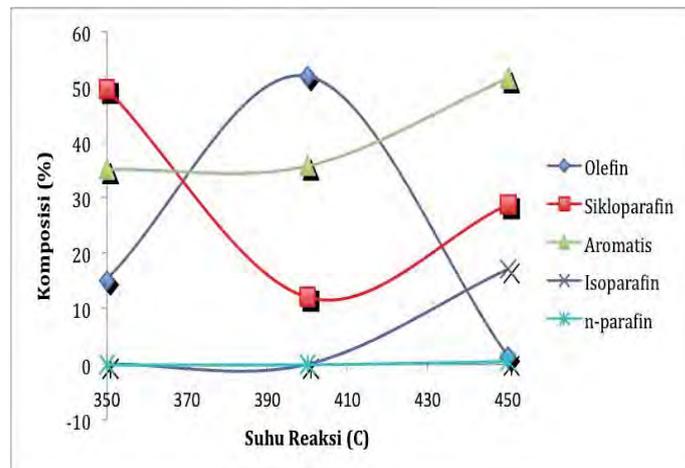


Figure 7 : Product distribution of hydrocarbon compound using 15% HZSM-5 Catalyst at various reaction temperature

From figure 7 we can see that at temperature 400 °C there is a change of product selectivity distribution from cycloparaffin into olefin. This is could happen because of the reaction chain on this ethanol reaction to hydrocarbons. Based on the previous research of ethanol to gasoline (ETG) reaction, the reaction starts from ethilen and end with aromatic or paraffin. The first reaction is the forming of ethylene from dehydration of ethanol, then the oligomers formation. From there, the reaction chain split into two possible route, either directly into a cyclic compound, or becoming an olefin first than into cyclic compound (might become a paraffin compound too). And the last part is from cyclic to aromatic compound [7].

This significant change on product distribution might be caused by the conversion of oligomer compound to olefin was greater than the one directly change into cyclic compound, and because of that the cycloparaffin conversion was dropped resulting the rise of the olefin compound, including the cyclo olefin compound.

#### 4. CONCLUSION

The synthesis of high quality hydrocarbon for possible fuel from ethanol over HZSM-5 - Al<sub>2</sub>O<sub>3</sub> catalyst has been successfully investigated with resulting a high octane number above 88. The containing hydrocarbons product such as aromatic, isoparafin, olefin was confirmly established and hence, the calculation result for the high octane number attained 109.5. This high octane number was achieved using catalyst composition 15% HZSM-5-Al<sub>2</sub>O<sub>3</sub> at 450 °C. And this is due to isoalkane and aromatic hydrocarbons produced as the main comprising component in the product.

#### REFERENCES

- [1] Anonim (2010). *Cadangan Minyak Indonesia Tinggal 10 Tahun*. <http://www.kompas.com/lipsus052009/antasariread/2010/02/01/2001197/Cadangan.Minyak.Indonesia.Tinggal.10.Tahun> [diakses 12 Maret 2011].
- [2] Anonim (2009). *Produksi Minyak Baru Cukupi Kebutuhan Tahun 2015*. <http://sains.kompas.com/read/2009/03/04/22153496/Produksi.Minyak.Baru.Cukupi.Kebutuhan.Tahun.2015> [diakses 26 Februari 2011].
- [3] R.G. Shah, M.C. Payne, "Methanol Adsorption in Zeolites. A First-Principles Study. *J. Phys. Chem*, vol. 100 (28), 11688– 11697, 1996.
- [4] J. B. F. Schulz, "Conversion of Ethanol over Zeolite H-ZSM-5. *Chemical Engineering & Technology*, vol. 17, 179-186, 1994.
- [5] Mailisa, R. F. (2006). *Konversi Katalitik Dalam Sintesa Senyawa Hidrokarbon Setaraf Fraksi Gasolin dengan Katalis B<sub>2</sub>O<sub>3</sub>/Zeolit* Skripsi.. Departemen Teknik Gas dan Petrokimia Fakultas Teknik Universitas Indonesia, Depok.
- [6] G. Losavic, N. Jambrec, D.V. Deur-Siftar, & M. Prostenik, M., "Determination of catalytic reformed gasoline octane number by high resolution gas chromatography," *Fuel* (69), 525-528, 2000.
- [7] N. Viswanadham, S.K. Saxena, J. Kumar, J., P. Sreenivasulu, & D. Nandan, "Catalytic performance of nano crystalline HZSM-5 in ethanol to gasoline (ETG) reaction," *Fuel*, vol. 95, pp. 298-304, 2012.



## Preparation of the Edible Biocomposite Film Gelatin / Bacterial Cellulose Microcrystal (BCMC): Variation of Matrix Concentration, Filler, and Sonication Time

Heri Hermansyah<sup>1,a</sup>, Rena Carissa, Fitri Anisa, Mondya Purna Septa, Tania Surya Utami<sup>2,b</sup>, Rita Arbianti<sup>3,c</sup>

<sup>1,2,3</sup>Department of Chemical Engineering, Faculty of Engineering, Universitas Indonesia,  
Kampus UI, Depok 16424, Indonesia  
Phone: 62-21-7863516, Fax: 62-21-7863515  
<sup>a</sup>heri@che.ui.ac.id, <sup>b</sup>nana@che.ui.ac.id, <sup>c</sup>arbianti@che.ui.ac.id

### ABSTRACT

Several biodegradable polymers have been explored to develop biodegradable edible films in order to reduce the use of conventional plastics. In this study, edible biocomposite film is made from gelatin filled with Bacterial Cellulose Microcrystal (BCMC). BCMC is produced from nata de coco paste, which is hydrolyzed with cellulase enzyme. In making biocomposite, gelatin matrix is first dissolved in distilled water and then mixed with BCMC filler solution in ultrasonic bath. The solution resulted is then casted and dried in room temperature. The addition of BCMC is proven to improve physical properties, mechanical, and thermal properties of the resulting material. BCMC distribution of SEM showed increasing the tensile strength test results, DSC, and WVTR. When the BCMC concentration was varied from 1-4 wt% of the gelatin mass, tensile strength and glass transition temperature (T<sub>g</sub>) increased from 37.07 MPa to 74.04 MPa and 27.520°C to 39.60°C, respectively. Water Vapour Transmission Rate (WVTR) decreased from 37.77 gr.m<sup>-2</sup>.h<sup>-1</sup> to 19.73 gr.m<sup>-2</sup>.h<sup>-1</sup>. Tensile test and DSC results also increased when varying the sonication time from 3-6 minutes, from 48.57 MPa to 57.23 MPa and 25.890°C to 37.290°C. WVTR decreased from 36.09 gr.m<sup>-2</sup>.h<sup>-1</sup> to 20.54 gr.m<sup>-2</sup>.h<sup>-1</sup>.

### Keywords:

*Biodegradable, Biocomposite, Edible film, Gelatin, Bacterial Cellulose Microcrystal (BCMC)*

**This paper is published in Advanced Materials Research Journal**

## Process Making of a Calcium Sulfonate Complex Biogrease and Its Antiwear Performance

Sukirno\*), Rizky Aulia Prasasti Dewi

Departemen Teknik Kimia, Fakultas Teknik Universitas Indonesia

\*)E-mail : [sukirno@che.ui.ac.id](mailto:sukirno@che.ui.ac.id)

### ABSTRACT

Sulfonate grease is most newly type of grease among many types of lubricating greases, nevertheless this type of grease has already get popularity due to its antiwear superiority. In this research, calcium sulfonate complex biogreases have been produced using base oil of epoxidized palm oil. The thickening agent is an overbased detergent, a mixture of calcium sulfonate and calcium carbonate as the main thickening agent, and calcium hydroxy stearate and calcium acetate as the complexing agent. The biogrease is manufactured via saponification process in a closed batch reactor, follow by cooling step and homogenization step. Product quality test conducted for the biogrease are, penetration test and dropping point test to measure the stability of the matrix of the thickening agent, and four ball wear test to measure antiwear performance of the product. The best quality of the calcium sulfonate komplek biogrease has composition 56.03% thickening agent which consist of calcium sulfonate, calcium carbonate, calcium hydroxystearate, and calcium acetate. This biogrease has a dropping point 301 °C at NLGI 2. The calcium sulfonate complex biogrease show an excellent antiwear performance and outperform that of calcium stearate-acetate complex biogrease. The calcium sulfonate complex biogrease produced the amount of wear 0.02 mg, while the calcium stearate-acetate complex biogrease produced the amount of wear 0.4 mg, from four ball wear test at the same test condition. The antiwear superiority of this biogrease is considered as the contribution boundary layer of calcite crystal which is formed by series process adsorbing, packing and crystallization of CaCO<sub>3</sub> amorf on friction surface.

### Keyword

*Calcium sulfonate comple, biogrease, overbased detergent, epoxidized palm oil, antiwear performance.*

## Plenary 4

# Intelligent transport systems – technological, economic, system performance and market views

**Pekka Leviäkangas**

*Department of Industrial Engineering & Management, Faculty of Technology  
University of Oulu, PO Box 4610, FIN-90014, Finland  
Tel: +358 40 561 65 29  
pekka.leviakangas@oulu.fi*

This paper introduces a holistic view to intelligent transport systems (ITS) by providing four different perspectives to it: the technological, economic, system performance and market views. These perspectives are essential in understanding the full picture of ITS, which is much more than just advanced transportation engineering. ITS requires management tools coming from systems engineering. These tools are ITS architectures. ITS has unique features related to transport economics and it differs from the traditional transport engineering solutions. ITS can improve transport system performance in numerous ways, but it is furthermore an important business segment for many technology companies and it has become an industry by its own right. Each of these perspectives call for different types of expertise and management of ITS, which as a meta-system is almost as demanding management object as the entire transport system.

### **Keywords**

*ITS, transport, system architecture, management, benefits, impacts*

**This paper is published in (IJTech)**

## **Quality in Color Laser Printing and Data Mining**

**Chao-Lung Yang**

*Department of Industrial Management  
National Taiwan University of Science and Technology*

### **ABSTRACT**

Maintaining color consistency throughout the cartridge or printer life is an important engineering challenge for color laser printer manufacturers. Since color reproduction is susceptible to variations in operating, performing calibrations at specific intervals to compensate for operating conditions is a common approach to ensure consistent tone reproduction. This research focused on utilizing operating information to improve the sensor mapping which predicts colorimetric tone reproduction (CTR) values on printing media obtained from densitometer readings measured on substitute media in calibration. Time-series sensor data and color measurements have been collected from off-the-shelf color printers under a variety of operating conditions. The data analysis shows that the sensor mapping has distinctive behaviors under different levels of relative humidity and cartridge toner consumption. In addition, the sensor mapping has been found to be sensitive to tone level and the variation of cartridges. A new sensor mapping model including a cartridge classification module was proposed to not only compensate for environmental and consumable conditions, but also to consider cartridge variation. The experimental results show that the accuracy of the sensor mapping can be improved by the compensations of environmental and consumable conditions. The data-driven study also shows that the cartridge classification by selected operating parameters is feasible, and the accuracy of cartridge classification is acceptable. The overall accuracy of the sensor mapping can be improved by ~ 40% on average after considering the operating information.

# Analysis on Consumer Adoption Process in Marketing Strategy Implementation using A System Dynamics Model (Study Case of Fast-Moving Consumer Goods Product)

Akhmad Hidayatno, Rama Raditya, Edelina Melisa

*Systems Engineering Modeling and Simulation Laboratory  
 Industrial Engineering Department, Faculty of Engineering, University of Indonesia, Depok 16424  
 E-mail : rama.raditya90@gmail.com*

## ABSTRACT

Marketing strategies have different implications on diffusion factors in the consumer adoption process. A system dynamics model could give a better understanding between the interaction of variables in the diffusion factors and its influence in the consumer adoption process. The basis for the model is Bass Diffusion Mode. In addition, the model tested three different scenarios, namely business as usual, word of mouth marketing, and social media marketing in order to understand how different parameters of diffusion factors affect the adoption process. This research will produce behavior over time analysis of customer number, potential customer, and adoption rate on each scenario. Based on analysis, promotion is the important factor for increasing awareness of product, while word of mouth marketing is important for product adoption.

## Keywords

*Bass diffusion model, system dynamics, consumer adoption, marketing strategy, word of mouth, marketing modeling*

## 1. INTRODUCTION

With Indonesia's economic growth, there has been a substantial increase in the purchasing power of consumers. This power has been influencing the marketplace by expanding market potential and creating higher and more competitiveness pressure. Therefore, in order to maintain its position in the marketplace, a business must select and execute the right marketing strategy. Marketing strategies discuss about advertisement, customer satisfaction, customer needs identification, high quality product development, distribution, and promotion [1]. All of which will affect the consumer adoption process.

The example of the consumer adoption process is consumer response toward a product may vary when a product is launched on the market. Some consumers, who will immediately adopt the product without interference from trends and social systems, are categorized as innovators. While the rest, who will adopt as a result of the pressure of the social system and trends, are categorized as imitators. Variables that influence the adoption process are the diffusion factors [2].

Word of mouth is one of the most influential diffusion factors in the consumer adoption process. A research study in Jordan found that negative word of mouth has a bigger role in consumer adoption decision than the positive word of mouth. The source of word of mouth also plays an important role in the decision-making process [3]. There is evidence that word of mouth can enhance and increase the promotion effectiveness and has a great effect in the product sales.

This research developed a system dynamic model in order to understand how various diffusion factors can affect the adoption process, based on the Bass diffusion model. The Bass diffusion model is a model framework that represents a product adoption process. System dynamics has the advantage of showing the dynamic complexity of a system, such as the interaction of variables influencing the consumer adoption process, and captures how a change in a variable can affect the other variables. The model could help strategy planners and policy makers in marketing organizations to make a better marketing strategy decision.

## 2. METHODOLOGY

### 2.1 Model Conceptualization

This research uses a system dynamic approach for modeling, consisting of four major steps: model conceptualization, development, validation and usage through scenarios. Model conceptualization is represented in the building of a system diagram. A system diagram represents the interaction and feedback from the variables. It provides a comprehensive understanding about the model. **Error! Reference source not found.** shows the system diagram for the consumer adoption process developed in this research. External variables are variables used as the input for the process in an endogenous model structure, however their values do not

influenced by the variables' interaction and feedback. Promotion strategy scenarios are variables determined by the user of model for understanding the effect of each scenario. The goal indicator is shown as the output of the model.

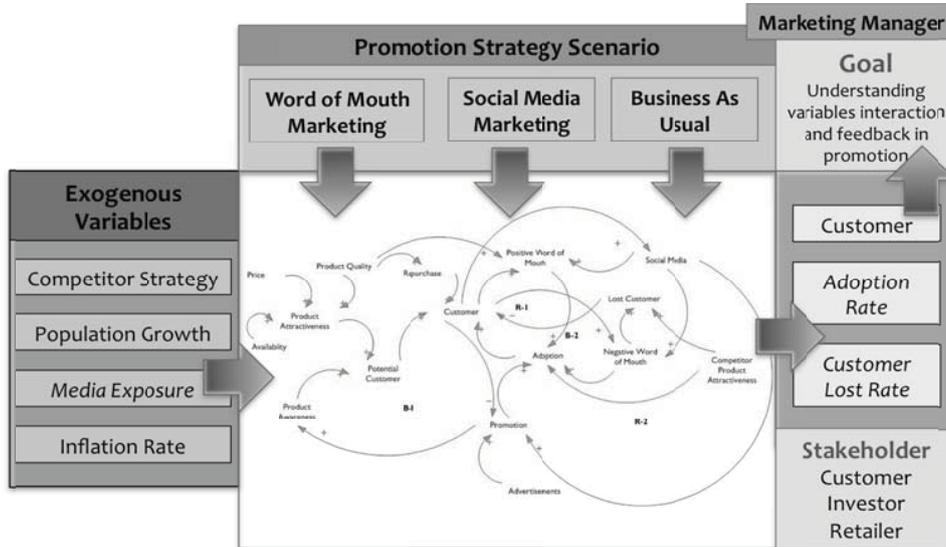


Figure 1: System Diagram

## 2.2 Model Development

Using bass diffusion model as the base, the developed model showed the basic process of transformation from potential customer into customer, that were expanded by inserting the variables that affect industry market potential and variables that affect customer change into lost customer (Figure 2). There are two groups of diffusion factors: promotion and word of mouth.

The model incorporated primary data from Focus Group Discussion (FGD) and market research secondary data from a well-known FMCG company. In FGD, there were 16 participants from age group of market target of the consumer goods. The discussion were focused on the relationship and weight the effect of various promotion methods, factors which influence world of mouth and buying, how the effect of WOM is, etc. The secondary data consist of as target market, population growth target, etc.

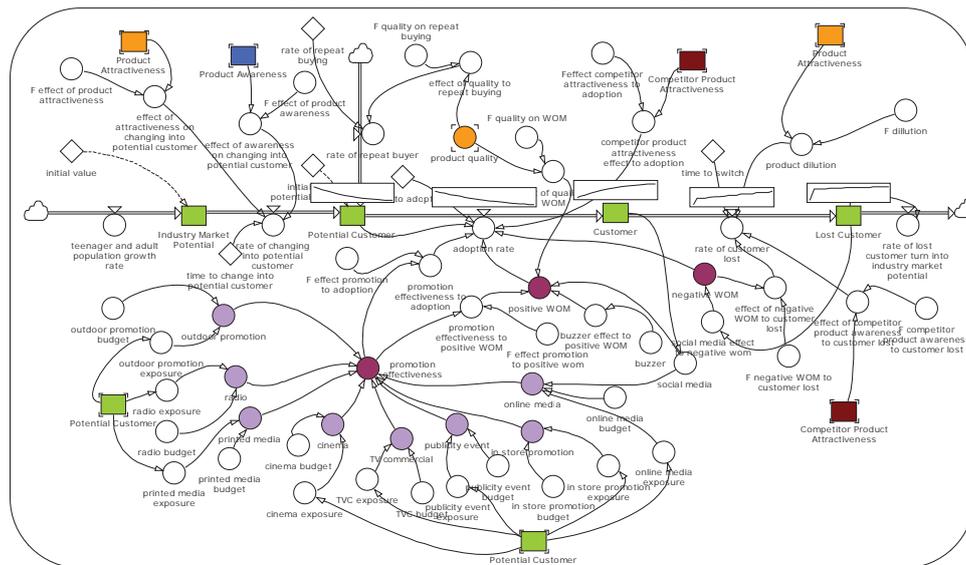


Figure 2: Model Stock and Flow Diagram

### 2.3 Model Validation

Reference mode is graphical representation of behavior over time (BOT) from system acquired from expert judgment or literature study. Behavior-reproduction-test validation test uses reference mode in order to check the validity of model by comparing BOT of model with BOT of reference mode. A valid model has marginal different between BOTs. This research use BOT from customer-adoption-rate, number of customer, and number of potential customer for validation.

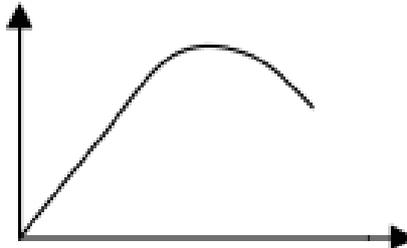


Figure 3: Reference Modes for Adoption from Word of Mouth

The horizon line shows the time and the vertical line indicates the number of people who adopt a product influenced the effect of word of mouth. The starting rate of the product adoption is low and expected to increase gradually until one point and then it decreases. [6]

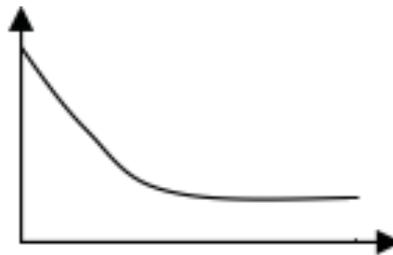


Figure 4: Reference Mode for Adoption from Advertisement

The adoption of the products is high at the time that the product enters the market, then people gradually purchase the goods because of word of mouth instead of company's advertisements, therefore it will decrease over time [6]. The horizon line shows the time and the vertical line indicates the number of people who adopt a product because of the advertisements.

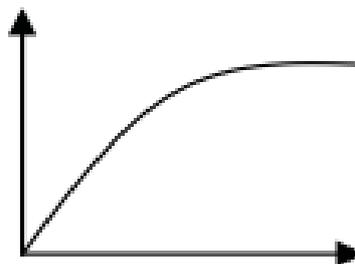


Figure 5: Reference Mode for Customer

Bass states that the number of customers increases at first at the time of launching the new product to the market, after that it reaches to a constant rate [6]. The horizon line shows the time and the vertical line indicates the number of people who adopts the product.

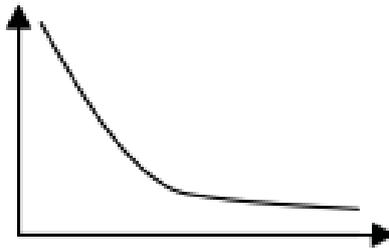


Figure 6: Reference Mode for Potential Customer

The number of potential customer is high at the first time the product enter the market, and it will decreases gradually over time [6]. The horizontal line shows the time and the vertical line indicates the number of potential customer.

We run developed model in order to see the output of model created through interaction between endogenous and exogenous variables inside structure of model. Developed model runs for five years according to common long term planning of company. The output of the model (Figure 7 and Figure 8) indicated that the model have similar Behavior Over Time (BOT) output graph with reference model on Figure 4 for Adoption Rate, Figure 5 for Customer, and Figure 6 for Potential Customer.

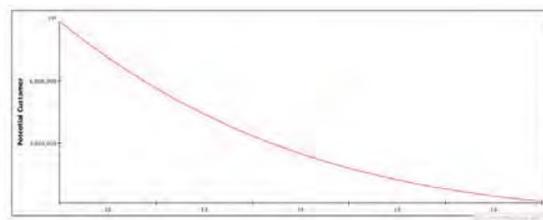


Figure 7: Behavior Over Time Potential Customer

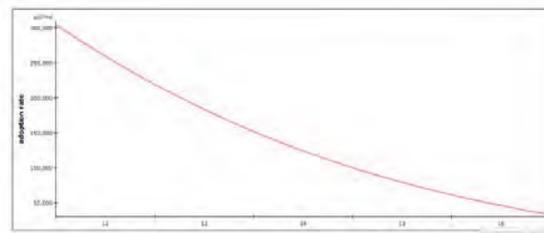


Figure 8: Behavior Over Time Adoption Rate

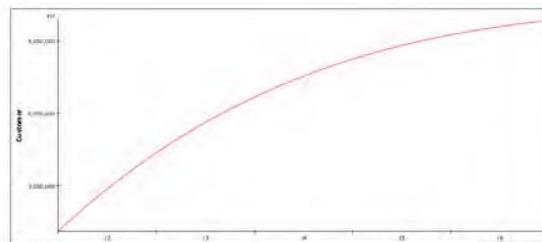


Figure 9: Behavior Over Time Customer

### 3. RESULTS AND DISCUSSION

There are three scenarios implemented: business as usual, word of mouth marketing, and social media marketing. The business-as-usual scenario results are the one that used to validate the model.

Table 1: Scenario Effect on Variables

	Business as Usual	Word of Mouth Marketing	Social Media Marketing
--	-------------------	-------------------------	------------------------

<b>Product Quality</b>	90 quality	200 quality	90 quality
<b>Budget for Online Media</b>	Min: Rp 2.200.000.000 Max: Rp 2.899.924.585	Min: Rp4.400.000.000 Max:Rp 5.799.849.170	Min: Rp 4.400.000.000 Max: Rp 5.799.849.170
<b>Buzzer</b>	10 people	50 people	10 people
<b>Promotion</b>	Linked to “adoption process” variable	Unlinked to “adoption process” variable	Linked to “adoption process” variable
<b>Multiplier of Social Media on WoM</b>	0.68	0.68	1
<b>Budget for Publicity Event</b>	Min: Rp 1.225.000.000 Max: 1.614.730.734	Min: 1.225.000.000 Max: 1.614.730.734	Min: 2.450.000.000 Max: 3.229.461.469

The second scenario is word of mouth marketing (WOM). In this scenario, we would like to see the effect of word of mouth marketing strategy and disregard the promotion effect in the adoption process. The model cut the promotion feedback to adoption rate hence promotion only influences product awareness. The variables intervened are the ones that directly influence the word of mouth, they are product quality, online media, and buzzer (Table 1).

The last scenario is social media marketing (SMM). It focuses on customer engagement through various kinds of promotional effort. Variables intervened in this scenario are social media, online media, and publicity event (Table 1).

The results of the three scenarios are Figure 10 for the Business as Usual Scenario, Figure 11 for Word of Mouth Marketing Scenario and Figure 12 for Social Media Marketing Scenario.

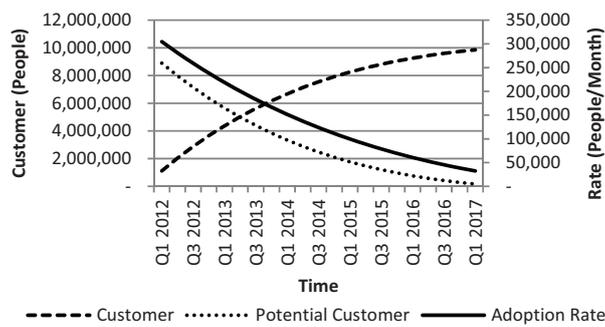


Figure 10: Behavior Over Time for Business as Usual Scenario

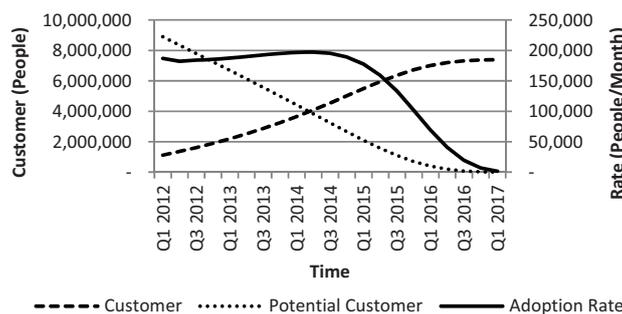


Figure 11: Behavior Over Time for Word of Mouth Marketing Scenario

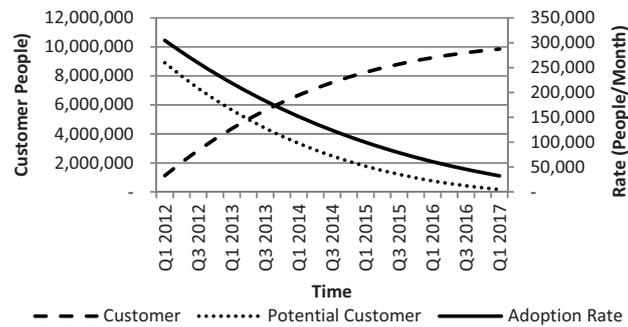


Figure 12: Behavior Over Time for Social Media Marketing Scenario

The result of adoption rate variable in word of mouth marketing scenario shows a significant difference from the other scenarios, because it only captures the behavior of adoption from word of mouth, which is not very high at the beginning and then increases up to eighteen percent and then declines (Figure 11). While the other two scenarios capture the behavior of adoption from advertisements, which is high at the beginning then decreases over time. The balancing structure of promotion, word of mouth, and competitor's attractiveness influences the adoption rate.

Customer variable shows an exponential growth curve behavior, as the result of business as usual and social media marketing scenarios, meaning that the growth rate is higher at the beginning and then slowing down at the end of the simulation period. Meanwhile, the word of mouth scenario indicates rather an S-shaped growth curve behavior, which means that the growth rate is almost the same during the time simulation period. The customer variable is the result of balancing structure of lost customer, potential customer, and repeats buying variables.

The third variable observed in this research is potential customer. All of the scenarios implemented show similar result for potential customer variable, which is an exponential decline curve behavior. It means that the number of potential customer is high at the beginning and then it decreases as higher numbers of potential customer already turn into customer. This variable is also a result of balancing structure of promotion, product awareness, product attractiveness, and customer.

From all scenarios, we acquire the expected behavior result for adoption rate from the word of mouth marketing strategy. Because it shows an increase for half of the time period then starting to decline rather than the other two scenario which only decline without any increase at all during the simulation period. For the customer and potential customer variable, though all scenario show similar behavior over time result, the business as usual and social media marketing have a higher number of people compared to word of mouth marketing scenario.

#### 4. CONCLUSION

Managing and using word of mouth as part of promotion strategy have significant difference in consumer adoption process. Promotion itself is most suitable for raising product awareness and attractiveness, however when it comes to adoption or buying decision, word of mouth has the bigger impact. The combination of each diffusion factor matched with the stages of the product introduction is the most effective and efficient promotion strategy.

#### REFERENCES

- [1] P. Kotler, G. Armstrong, J. Saunders and V. Wong, Principles of Marketing, New Jersey: Prentice Hall Inc., 1999.
- [2] F. M. Bass, "A new product growth for model consumer durables," *Management Science*, p. 215, 1969.
- [3] A. M. Zamil, "The Impact of Word of Mouth (WOM) on the Purchasing Decision of the Jordanian Consumer," *Research Journal of International Studies*, no. 20, pp. 24-29, September 2011.
- [4] S. Radas, "Diffusion Models in Marketing: How to Incorporate the Effect of External Influence?," *Privredna kretanja i ekonomska politika*, p. 31, 2005.
- [5] M.-A. A. Kazemi, A. T. Eshlaghy and S. Tavasoli, "Developing the Product Strategy via Product Life Cycle Simulation according to the System Dynamics Approach," *Applied Mathematical Science*, vol. 5, pp. 845-862, 2011.
- [6] J. Sterman, Business Dynamics: System Thinking and Modeling for A Complex World, Boston: The McGraw Hill Companies, Inc, 2000.

# The Model Development of Revenue Management in Fashion Retailer Using Game Theory

Alina Hasna Rasyanti<sup>a</sup>, Hilya Mudrika Arini<sup>b</sup>, Nur Aini Masruroh<sup>c</sup>

<sup>a</sup>Mechanical and Industrial Engineering, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta 55281  
E-mail : alina.rasyanti@gmail.com

<sup>b</sup>Mechanical and Industrial Engineering, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta 55281  
E-mail : hilya.mudrika.a@mail.ugm.ac.id

<sup>c</sup>Mechanical and Industrial Engineering, Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta 55281  
E-mail : aini@ugm.ac.id

## ABSTRACT

Fashion can be categorized as a perishable product which has the high uncertainty. Thus, many retailers usually conduct the strategy to provide the discount price to prevent the perishable characteristic and to minimize the inventory. This study developed the dynamic pricing in revenue management which is more parsimony, simpler, and more applicative in Indonesia considering on the consumer strategy. The model was developed under two conditions, namely monopoly and duopoly. In the duopoly model, two-person game is used where the customer valuation is considered as competitor. In addition, the development model stages were divided into four scenarios that are the deterministic and stochastic of demand model, the revenue model, and the pricing model developed from the best reaction of function. Based on the case study among four scenarios of model development, two-person game with considering the stochastic of demand model is strongly representing the actual system. This model can be generated to the products observed, easy to use and disregard the composition of myopic and consumer strategy in system.

## Keywords

*Perishable, fashion retailer, revenue management, game theory, consumer strategy*

## 1. INTRODUCTION

Fashion can be categorized as a perishable product which has the high uncertainty [1]. The perishable and uncertainty of product is commonly caused by the changing of customer value towards the product during the particular period, such as the different customer value between selling season and discount season. Furthermore, fashion also has the short product life cycle in which has the long of distribution time and waiting time. For instance, most of the fashion product produced in the US and Europe, must distribute their product to retailer in other countries. Thus, the retailer must consider the distribution time, reorder point, and demand forecast in order to maximize profit and handle the uncertainty of the fashion product. One method developed to manage the problem of such a fashion product is known as Revenue Management (RM).

Actually, RM has been used for managing several businesses, such as restaurant, aviation industry, hotel management, car rental, retailing and so forth. There are unique characteristics in business implementing RM. Firstly, the product must have the exact and limit capacity. Therefore, the first characteristic can affect the perishable of product in which the product cannot be sold in another selling season. For instance, the fashion product must be sold in the end of selling season. Hence, to eliminate the perishable characteristics, retailer usually provides the discount season. Secondly, the product has the high fixed cost yet the low variable cost. Thirdly, the product also has the different demand in each period yet it can predict the pattern of demand itself. Ultimately, the product can provide the different customer segment with the different value in the same product [2].

Customer segment in fashion retailing is commonly divided into two types, namely myopic customer and strategic customer [2]. Myopic customer is the type of customer who will buy directly when the price provided is less or equal with their own value to the product. Meanwhile, strategic customer is the type of customer who will optimize their buying behavior as the response towards the price strategy provided by the company. Hence, second type of customer will seek and wait to buy the product until the end of selling season to get the product with the cheapest price.

Regarding to the strategic customer who always maximizes their value, the competition between fashion retailer and customer itself is occurred. It is caused by the rationality between the players in which the strategic customers want to optimize their value of product while the companies want to maximize the profit obtained. The condition of the competition between strategic customer and company is sufficient to be depicted by the game theory. The game theory is usually used for two or more player

which has the interdependent relationship among the others [3]. On the other hand, game theory also had been used for several companies, such as to simulate and increase the ability of decision maker with providing valuable insight of player interaction who has the different needs [4].

Basically, there are many methods and studies explaining the competition of player in game theory, such as the study of [5] and [6]. However, the study of [5] and [6] is strongly complex to be adopted in Indonesia. Whereas, the complexity of system needs the uniformity of data and the adequate of data, in which in Indonesia the data are difficult and confidential to be obtained.

The other approaches to simulate the strategic customers had been conducted by [1]. Nevertheless, this model only considered the arrival demand from myopic customer. Therefore this study extends the study of [1] by developing mathematical model which considers the strategic customer behavior. On the other hand, this study also utilizes the price as the main consideration in the decision variable in RM that is combined with game theory in order to find the equilibrium point of price. Briefly, this model is not only used for deciding the optimal selling value in monopoly market without considering strategic customer but it also enables to decide the optimal selling value in the competitive market with considering strategic customer behavior. In addition, it also measures the revenue model developed in order to represent the real phenomena occurred in fashion retailer industry.

## 2. METHOD

This study is started by the collecting of data. The data is obtained from two inputs, namely the revenue of retailer in selling women dress and the quantity of product which is sold during the particular selling season. The data is collected from the fashion retailer in the biggest shopping centre in Yogyakarta. Nevertheless, in term of collecting data, many data is difficult and sensitive to obtain, such as the revenue of the retailer. Therefore, in this study, the revenue of the retailer can be assumed as the multiplication between the quantity of product sold and the selling price in the particular period, in which the quantity of product sold, is collected from the quantity of demand from myopic and strategic customer.

Having collected data, the model can be started to develop by using spreadsheets. In this stage, all data must be assessed and reduced which are sorted by the significance of the product towards the revenue and demand. Subsequently, the significant products selected are utilized by the game theory in terms of revenue management. Furthermore, they are modeled in demand and revenue by using monopoly and two-person game. In order to develop model, this study refers to model from [1] and [7]. Different with the previous model from [1] and [7], this model considers strategic and find the equilibrium point between two types of customer.

For demand modeling, the data collected are divided into two types, namely deterministic and stochastic demands. The deterministic demand is modeled by linear regression analysis in order to find intercept and coefficient value in each variable. Subsequently, the developed model is tested by using statistical test. On the other hand, the stochastic demand is utilized by distribution fitting whether the distribution is appropriate or not. If the distribution is appropriate, the CDF value can be found. Meanwhile, if the distribution is inappropriate, thus the CDF value can be found by empirical approach in order to obtain coefficient value. Subsequently, both the deterministic and stochastic demands are validated by using statistical test using SPSS 16.0. By using statistical test, the result of the model can be assessed whether it is significantly different or not compared to the actual data. Therefore, if the data have not significantly different with the actual data, the model can be stated as valid and sufficient to predict the expected value which can be accomplished of the retailer in the equilibrium point.

## 3. RESULT AND DISCUSSION

This study collects the data from the biggest shopping centre in Yogyakarta. However, the shopping centre consists of 40 different products of women formal attire obtained from January 2010 to April 2012. Therefore, the variability of product is high in which several products have the routine demand in each month yet the others do not have the demand in each month. This phenomena can affect the bias whether all products is considered to count in the model. Hence, to reduce bias, the product must be assessed and reduced sorted by the significance of the product towards the revenue and demand. By using the plotting data and pareto analysis, the product can contribute significantly towards the revenue and demand only four, namely long sleeve shirt, long blouse, short blouse and trouser. Hence, for developing model, only four products will be used both on monopoly and two-person game.

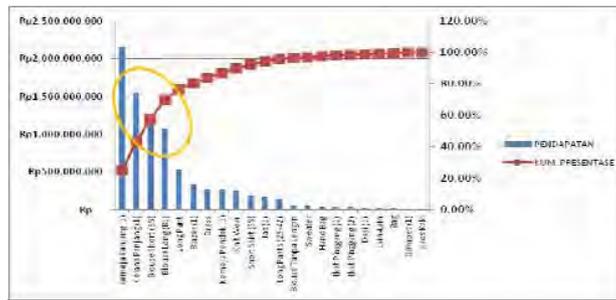


Figure 1: Pareto Diagram of Retailer's Revenue

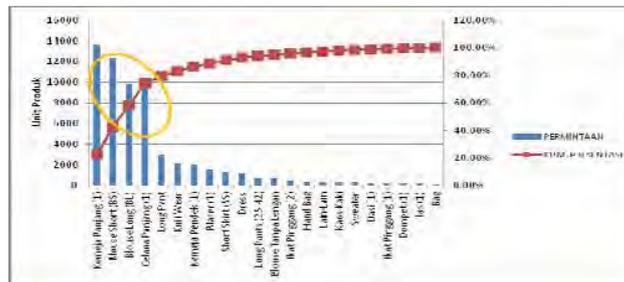


Figure 2: Pareto Diagram of Demand

### 3.1. Monopoly Model

Actually, there are two criteria in monopoly model, namely deterministic and stochastic model. In the deterministic model, the demand is assumed as certain and comes from the myopic customer. Therefore, the retailer can be stated as monopoly because they can control in terms of deciding the price to their customer completely.

The first step to build the deterministic monopoly model is by deciding the demand model for each product. The demand deterministic is built with assumptions the linear function from price [1].

$$d_{mono, det}(p) = a - bp$$

$$d_{mono, det}(p) \geq 0 \quad (1)$$

With  $d_{mono, det}$  = demand in deterministic monopoly

- $a$  = intercept
- $b$  = coefficient of price
- $p$  = price in each product

From this linear equation, the deterministic demand model can be achieved for four types of product depicted in Table 1. Having the deterministic demand model for each product, the revenue model of retailer must be built in order to obtain the best reaction function, in which  $\pi_{mono, det}$  depicted revenue of retailer obtained by multiplying between the price value and demand.

Table 1: The Deterministic Monopoly of Demand Model

Product Type	The Demand Model
Trouser	$d_{CP, mono, det}(p) = 1028,747 - 0,004 p$ (2)
Long Sleeve Shirt	$d_{KP, mono, det}(p) = 1669,486 - 0,007 p$ (3)
Long Blouse	$d_{BL, mono, det}(p) = 1073,876 - 0,006 p$ (4)
Short Blouse	$d_{BS, mono, det}(p) = 1515,714 - 0,009 p$ (5)

$$\pi_{mono, det}(p) = p[d_{mono, det}(p)] \quad (6)$$

Almost similar with deterministic model, in stochastic model, the customer is categorized as myopic customer without considering strategic customer. However, in this model, demand is considered as uncertain and probabilistic. Therefore,

customer demand always follows the particular distribution by conducting fitting distribution. In this model, the stochastic demand model conducted follows the model proposed by [1] in which  $d_{mono,sto}$  is demand in stochastic monopoly,  $N$  is market size of retailer assumed as random and probabilistic and  $F(p)$  is cumulative distribution function from price. On the other hand, in order to get CDF, finding the sufficient distribution with the data is required by using Stat::Fit.

$$d_{mono,sto}(p) = N(1 - F(p)) \tag{10}$$

The sufficient distribution of fashion product is Weibull because the fashion product can be categorized as perishable and the value of product is related towards time. CDF value from Weibull distribution can be obtained as following in which  $p$  is price,  $\alpha$  is form parameter,  $\beta$  is scale parameter and  $e$  refers to exponential. After CDF value is stated as appropriate, the demand model in stochastic monopoly can be developed which is depicted in equation 12.

$$F_w(p|\alpha,\beta) = 1 - e^{-\left(\frac{p}{\beta}\right)^\alpha} \tag{11}$$

Tabel 2: The Parameter Value of Product

Jenis Produk	Paramater Skala $\alpha$	Parameter Bentuk $\beta$
Trouser	4.395	195661
Long sleeve	5.160	195834
Long blouse	4.349	141268
Short Blouse	4.287	128187

$$\begin{aligned} \pi_{mono,sto}(p) &= p[d_{mono,sto}(p)] \\ &= pN(1 - F_w(p|\alpha,\beta)) \\ &= pN\left(1 - e^{-\left(\frac{p}{\beta}\right)^\alpha}\right) \end{aligned} \tag{12}$$

### 3.2. Two-Person Game Model

This model is divided into two types, namely deterministic two-person game model and stochastic two-person game model. The competition of two-person game in this study is competition between retailer and strategic customer in one-shot game. Strategic customer will maximize surplus from valuation affecting competition for retailer. The customer valuation is assumed to follow uniform distribution [8].

On the other hand, in the two-person game model, retailer is assumed as myopic customer and the strategic customer act as opponent who must be competed. Therefore, this model adopts model in [7] by using multiple linear regression in order to predict demand in myopic and strategic customer.

Different with monopoly model, the number of deterministic demand achieved by retailer in two-person game has the particular composition which is portion between the number of myopic and strategic customer in the system. However, in this study, information about composition of myopic and strategic customer is unavailable. Hence, building several scenarios of demand model is required. Scenario conducted in order to build deterministic two-person game uses myopic customer composition as much as 50%, 60%, 70%,80% and 90% from total of demand. Afterwards, demand model will be used for building general revenue model in myopic customer depicted in equation 13.

$$\begin{aligned} \pi_{1,sto} &= p_{1r}[d_{1,sto}(p_{1r},p_{2r})] \\ &= p_{1r}(h_{1r} + g_{1r}p_{1r} + h_{1r}p_{2r}) \\ &= p_{1r}h_{1r} + g_{1r}p_{1r}^2 + h_{1r}p_{1r}p_{2r} \end{aligned} \tag{13}$$

Almost similar with deterministic two person game, stochastic two-person game also considers behavior of strategic customer. Nevertheless, the number of demand from each customer will provide the different valuation price with probabilistic factor. In line with deterministic model, stochastic model also adopts model developed by [7] which is added strategic customer.

$$d_{1,sto}(p_{1r},p_{2r}) = N[1 - F(p_{1r}) + 1 - F(p_{2r})] \tag{14}$$

$F(p_M)$  is CDF value from price provided by retailer when only myopic customer is appeared in the system, while  $F(p_s)$  is CDF value from valuation price provided by strategic customer. Therefore, for achieving CDF value from sufficient theoretical distribution, fitting distribution must be conducted by using Stat::Fit. By conducting fitting distribution, three products, namely long sleeve, long blouse and short blouse fulfill assumption of Beta distribution. Meanwhile, trouser does not fulfill any distribution hence the approach conducted for this product is by using empirical distribution. Nevertheless, even though Beta distribution is continue distribution which is closest to three products, yet CDF in Beta distribution is difficult to define due to the characteristic of no closed form [9]. Consequently, for finding CDF  $F(p_M)$  and  $F(p_s)$  from four products, empirical distribution is required. The general CDF value from retailer price is depicted in equation 15, while strategic customer is showed in equation 16 in which i, j, k, and m are constant.

$$F(p_M) = i + j/p_M \tag{15}$$

$$F(p_s) = k + mp_s \tag{16}$$

Table 3: The Comparison between CDF Value of Retailer Price and Strategic Customer

Product Type	CDF Value $F(p_M)$ of Retailer Price	CDF Value $F(p_M)$ of Strategic Customer
Trouser	$F_{TP}(p_M) = -0,688 + 0,66 \times 10^{-6} p_{Mf}$ (17)	$F_{TP}(p_s) = -1,882 + 1,72 \times 10^{-4} p_s$ (21)
Long sleeve	$F_{LSP}(p_M) = -0,884 + 7,42 \times 10^{-6} p_{Mf}$ (18)	$F_{LSP}(p_s) = -1,475 + 1,91 \times 10^{-4} p_s$ (22)
Long blouse	$F_{LBP}(p_M) = -0,610 + 8,66 \times 10^{-6} p_{Mf}$ (19)	$F_{LBP}(p_s) = -2,733 + 8,48 \times 10^{-4} p_s$ (23)
Short blouse	$F_{SBP}(p_M) = -0,587 + 9,86 \times 10^{-6} p_{Mf}$ (20)	$F_{SBP}(p_s) = -2,472 + 8,54 \times 10^{-4} p_s$ (24)

After CDF value is obtained for each product, the demand model of two-persons game stochastic can be conducted by substituting equation 15 and 16 to general equation two-person game stochastic demand in equation 25.

$$d_{M,sto}(p_M, p_s) = N[1 - F(p_M) + 1 - F(p_s)]$$

$$= N[1 - (i + j/p_M) + 1 - (k + mp_s)]$$

$$= N(2 - i - j/p_M - k - mp_s) \tag{25}$$

#### 4. VALIDATION

Model validation is required in order to confirm whether model represents the actual system or not. Validation is conducted by using statistical test for comparing the difference between mean in output and actual system. Output model compared are output demand model from deterministic monopoly, stochastic monopoly, deterministic two-person game, and stochastic two-person game.

Nevertheless, before conducting statistical test, normality test must be conducted to define the model can be assessed by using parametric or non parametric method. From normality test, Ho cannot be rejected thus the data are distributed normally. In other words, the parametric test, t-test can be used for assessing this model.

The result of t-test with significant level 95% provides information that the demand for each product can be modeled both deterministic and stochastic. On the other hand, significant p-value provides the result, as following:

1. The sufficient model applied in trouser is deterministic two-person game with composition myopic customer as much as 60%
2. The sufficient model applied in long sleeve is deterministic two person game with composition myopic customer as much as 80%
3. The sufficient model applied in long blouse is deterministic two person game with composition myopic customer as much as 50%

4. The sufficient model applied in short blouse is deterministic monopoly.

Even though deterministic two-person game is sufficient model applied for three products, yet this model has limitation because it is strongly related to the number of myopic customer composition in the system. Hence, alternative model, stochastic two-person game must be conducted which has the best significant value for three products. In order to find the significant differences between revenue output stochastic and deterministic two-person game, t-test is conducted.

According to Table 4, there are no significant differences between output in deterministic and stochastic two-person game. Therefore, revenue prediction can be conducted by using stochastic two-person game without considering the number of particular customer in the system. On the other hand, even though sufficient model applied in short blouse is deterministic monopoly, yet there are no significant differences when using stochastic two-person game.

Table 4: The Result of t-test in Two-Person Game Model

Model	Trouser		Long Sleeve		Long Blouse		Short Blouse	
	Sig.	Decision	Sig.	Decision	Sig.	Decision	Sig.	Decision
Deterministic Two-persons Game	0,469	do not reject	0,884	do not reject	0,479	do not reject	0,381 do not reject	
Stochastic Two-persons Game								
Deterministic Monopoly								

## 5. CONCLUSION

According to result explained in the previous chapter, there are two points that can be summarized. Firstly, the best mathematical model applied for all fashion products is stochastic two-person game. This model not only can be generalized for all products, but it is also easier to be used without considering myopic and strategic customer composition in the system. In addition, by selecting stochastic two-person game as the representative model, it depicts that behavior of strategic customer is required in revenue management.

Secondly, modeling process considering valuation from strategic customer in Indonesian fashion retailer can be conducted. Ultimately, stochastic and deterministic results are comparably no different.

## REFERENCES

- [1] K.T. Talluri, and G.J. van Ryzin, "The Theory and Practice of Revenue Management", Kluwer Academic Publishers, Boston, 2004.
- [2] A. Dietz and K. McGuire, "Optimizing Revenues in the Hospitality and Retail Industries: Comparing and Contrasting Different Industry Problems and How SAS® Analytics Is Used to Solve Them", *SAS Global Forum 2010*, vol. 346, 2010.
- [3] T.L. Turocy and B. Stengel, "Game Theory", CDAM Research Report, 2001.
- [4] F. Erhun and P. Keskinocak, "Game Theory in Business Application", Lecture Course of Management Science and Engineering, Stanford University, 2003.
- [5] Y. Aviv and A. Pazgal, "Optimal Pricing of Seasonal Products in The Presence of Forward-Looking Consumers", *Manufacturing & Service Operations Management*, Forthcoming, 2007.
- [6] G.P. Cachon, and R. Swinney, "The Impact of Strategic Consumer Behavior on The Value of Operational Flexibility", *Operations Management Models with Consumer-Driven Demand*, Serguei Netessine and Christopher Tang, Editors, 2008.
- [7] M.I.A. Azmi, "The Development of Pricing Model Under Competition for Airline Revenue Management", Undergraduate Thesis, Industrial Engineering, Universitas Gadjah Mada, Yogyakarta, 2011.
- [8] B. Mantin, "On The Effect of Competition and Strategic Consumer Behavior in Revenue Management", A Thesis Submitted in Partial Fulfilment of The Requirements for The Degree of Doctor of Philosophy, The University of British Columbia, 2008.
- [9] A.M. Law and W.D. Kelton, "Simulation Modeling & Analysis", Second Edition, McGraw-Hill International Editions, 1991.

# The Public Policy Model in Coal Mine Management

Indah Martati<sup>a</sup>, Priyo Suroso<sup>b</sup>, Suminto<sup>c</sup>

<sup>a</sup> Business Administration Department, Samarinda State Polytechnic, Samarinda 75131  
E-mail : iin\_polsam@yahoo.com

<sup>b</sup> Civil Engineering Department, Samarinda State Polytechnic, Samarinda 75131  
E-mail : priyo\_be01@yahoo.co.id

<sup>c</sup> Business Administration Department, Samarinda State Polytechnic, Samarinda 75131  
E-mail : mints\_polnes@yahoo.com

## ABSTRACT

This research is aimed at accelerating and expanding economic development to strengthen national and global competitiveness and realizing good governance in coal mining. A target outcome to be achieved is an academic paper as the basis for the preparation of local legal products on managing the special port of coal. The object of research is community around coal mining operations in East Kalimantan. The research sample is five regencies and analyzed by the SWOT method. The result shows that the Mahakam River has a high economic potency as a means of transportation to distribute coal from the stockpile to the ship through the construction of special port. The regional government need to issue regional regulation on special port construction. The strategy developed to achieve the acceleration and expansion of economic development is by utilizing the support of local governments and taking advantage of river transport facilities.

## Keywords

*Regulation, river transport, coal special port*

## 1. INTRODUCTION

Coal mining as the main sector replacing the timber, evidenced by the 913 mining business license permission issued by local government are scattered throughout the regencies and cities in East Kalimantan, from those numbers 560 companies are exploration and 353 companies are exploitation. (Department of Mine and Energy East Kalimantan, 2012). The data is beyond mining business license permission issued by the central government. Various problems caused by coal mining activities concerning some aspects such as environmental, socio-cultural, economic, health, infrastructure. All happened because of weak governance system in mining activities from the planning, implementation, outputs and outcomes are not integrated and sustained planned in accordance with sustainable environmental concepts.

The emerging problem is the destruction of many public roads crossed by vehicles transporting coal to the stockpile or port. Transporting coal passing the public road contributes 15 times accelerating of road destruction before the times. Most companies holds the local license do not have a special road to transport coal. The local government responded by forbidding coal transport vehicle on a public road starting in September 2013. The government plan is successful to encourage mining companies to build a special road transport mine or transfer using transport modes Mahakam River. Utilization of river transport is preferred by coal mining entrepreneurs evidenced by the emergence conveyor belt located along the Mahakam river by 29 locations, majority in Kutai Kartanegara Regency and in the last three years there are 92 locations of special ports listed on the Department of Transportation East Kalimantan.

Furthermore, to maintain the security the development and management of special facilities and infrastructure of coal mining is necessary to be regulated in the form of regional regulations. Because until now East Kalimantan province has not had legislation that regulates the hauling road, special port and the environmental impact of coal mining. The benefit by issuing special port regulations is expected to provide multiplier effect on the acceleration and expansion of the economy. The results of this study in the form of an academic paper to be used as the input of public policy decisions of local government in the coal mining sector.

Optimizing the benefits of coal mining operations is expected to drive the acceleration and expansion of the national economy when creating a good governance of coal mined either by regulating the management of facilities and infrastructure to be owned and its impact by the coal companies. Regulations can be made by the Government in accordance with their responsibility to provide guidance, supervision and control under the local regulations and its derivatives laws products on transport infrastructure of coal mining and environmental impact management.

## 2. METHODS

Population are society around coal mining companies operating in East Kalimantan . Samples taken from 5 regencies /cities that has been widely exploited their coal they are Samarinda, Kutai Kartanegara, Paser, East Kutai and Berau. Data collection method is by distributing of questionnaires, conducting focus group discussion (FGD), as well as literature study. A questionnaire was compiled based on research that is directed to the object of the public, companies, and local governments. Questionnaires were prepared using a range of categories linkers scale values: 5=Strongly Agree (SST), 4=Agree (ST), 3=Undecided (RG), 2=Disagree (D), 1=Strongly Disagree (STS). The number of instruments in question to the community around coal mine as many as 24 items, the instrument for the company is 30 items. FGD was conducted to the communities around the mining area which actually obtain a direct impact on mining operations. Interview is emphasized as a method to obtain information related to mine operations to the stakeholders at the local level such as regional development agency, department of transportation, the department of mines, environment agency and the regional council. Other secondary data obtained through the study of literature. The data collected were analysis with SWOT matrix method.

## 3. RESULT

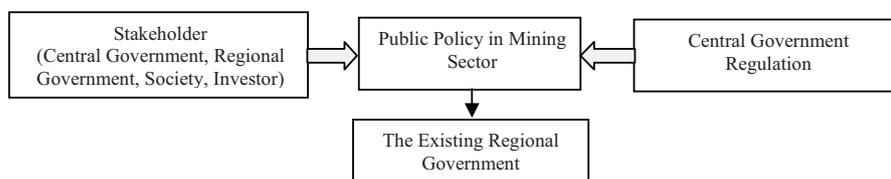
FGD is conducted at 4 (four) locations in Kutai Kertanegara, Berau, Pasir Regency and Samarinda City. The participants are societies around the coal mining area consisting of local community and company employees. Each FGD followed by 10-15 members of the public. The information obtained directly from the public related to mining activity in the positive sides are: raising the price of land surrounding the mining area, employing the local skill or unskilled people, opening of business opportunities, the implementation of community development program. Whereas the negative sides are: air pollution, mud flood, public health problems, the decline in soil fertility, the death of a plant that grows in the garden, the damage of ex-mine environment, the damage to public roads, noise pollution, the degradation of local wisdom, the erosion of cultural values, the shifting of agricultural land and residential area into land mine, communities conflicts.

From the data collected indicate an imbalance between mining companies operating in East Kalimantan as many as 913 companies but only 21 (twenty-one) firms reporting reclamation guarantees. This means that only a few companies executed post-mining reclamation (The Department of Mining and Energy East Kalimantan, 2012). It is also found that there is only a few special ports in East Kalimantan. The length of road in the southern part of East Kalimantan which extends from Paser District to the border of South Kalimantan reach to 240 km, and 225 km is damage. Road improvements have only done to the suffered severe damage road. In general, road damage in East Kalimantan, including in the Southern District caused by a mismatch between load tonnages passing vehicles. Load roads in East Kalimantan only class III B the maximum of 8 tons, while passing vehicles with a payload to 16 tons. The vehicles are owned by coal mining companies palm plantation companies and heavy equipment transport vehicles (Department of Highways East Kalimantan, 2012).

The perception of the people and employee who live around the area of the coal mining operations of 4 (four) regencies/cities averagely found that they very much agree with the average percentage of 85.6% (public) and 86.4% (employee) which means the majority absolutely agree method that: the construction of special port regulated by local regulation, every coal mining company must obey the regulation and should be met with the government requirement in administrative, feasibility study, and environmental impact studies, special port in the river is absolutely supporting the coal mining business and the right choice for the transportation of coal, development of special ports or terminals should pay attention to the social-economic, increase employment absorption, improving and expanding economy, expanding the business opportunities for the surrounding communities of the port, and eventually increase regional revenue.

## 4. DISCUSSION

From the result of the SWOT analysis, the strategies that should be develop by the regional government in coal mine management is strength-opportunity strategy. The strength are the potential of the Mahakam River to transport coal, the mining location close to river, the availability of Mahakam River bank as the location of special port, The huge deposit of coal. Whereas the opportunities are catching the coal business opportunities, Fulfilling domestic coal demand, increasing regional revenue, expanding the public access to get opportunities for employment. In optimizing the strengths to catch the opportunities, the regional government needs to issue regulation on the management of special port. Therefore, the model of the public policy is as follow figure 1.



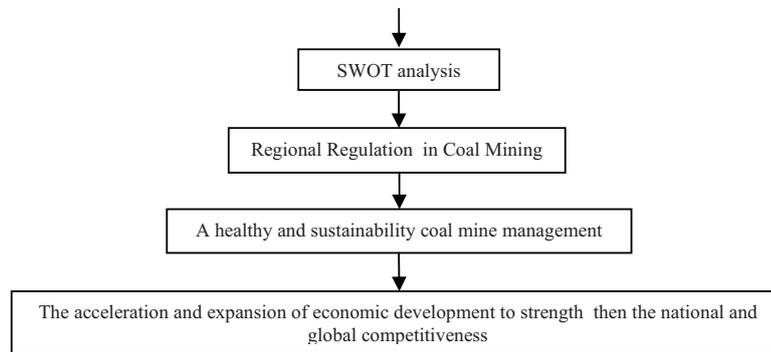


Figure 1: Public Policy Model in Mine Coal Management

The potential for coal resources in Indonesia come from East Kalimantan, and the potential is already excavated by mining investors, but its management is still not optimal. The number of companies operating in the mining activities that have not made clear and clean indicates that the problem of mining relating with the regulation does not function properly. A large number of licenses issued by the government of district/City so far indicate that issuance of permit of coal mining is uncontrolled. Besides, it also shows how easy people go into the coal mining business. How difficult to obtain data on how much production of coal in East Kalimantan indicates that monitoring does not work optimally

Coal mining activities conducted by many companies concession or license of central or local government with an obscure or unclear mining license must take the consequences of environmental capacity issues. If mining operations are not managed properly, the benefits can not be enjoyed by people rather unfortunate consequences. Therefore it is necessary to create healthy, transparent, accountable and sustainable as well as environmentally sustainable operational governance of coal mine.

In the issue of local license exploration and exploitation checking the documents must be done and field checking and cross-sector coordination should be done, the results of verification of all the parties is then used to submit to the regent /mayor to set permissions. At the time of permit issued, there is already a commitment to run the company's corporate social responsibility program with primary emphasis is empowering community. Checking the environmental impact analysis document should be done regularly before starting mining activities will vary with the condition after exploitation activities carried out. Checking on the waste management such as solid waste, liquid and air waste also needs to be done regularly.

Referring to the data processing both primary and secondary research analysis reinforces that any well-run business in the mining sector should have sustainable development. Wishes and desires of the community at large public companies that coal mining operations carried out in an orderly manner according to the rules in force, and performed in a sustainable manner by considering environmental sustainability. Society also expects that the exploitation of coal carried out in an environmentally friendly and provide maximum benefit for the community, local government, and the state.

The existence of a coal mine in East Kalimantan has not been able to keep a balance between the interests of corporate interests - local government - the public. Strategies and policies coal companies should refer to the triple bottom line that are economy, social and planet. Means there should not be harmed by operating coal mines, if the company is able to run consistently rules issued by the central government and local governments related to mining, environmental protection and other relevant laws and regulations derivatives. There was also a commitment of local government to carry out development and supervision of mining operations.

Establishment of good governance is indicated with a number of conditions including: 1) there is the efficiency and effectiveness of the company's coal mining operations, 2) there is transparency related to the status of the mine permitting, land concessions, reclamation guarantees, treatment and disposal of waste products, the implementation of reclamation , the amount of production, corporate social responsibility, land rent, non-tax state revenue, 3) there is a public accountability associated

with the production, which in reclamation deposit insurance, implementation of reclamation, and budget as well as the implementation of corporate social responsibility programs, payment of taxes.

Patterns of public policy in the field of regional economic development through the optimization of the management of coal mining as a stimulus to the acceleration and expansion of economic growth that can provide a multiplier effect on various other related fields. Multiplier effect on public policy will involve opening up opportunities for employment and business potency community, growing and opening new areas of economic growth, rising incomes, minimize traffic accidents due to road hauling.

## 5. CONCLUSION

Based on the analysis and discussion, it can be concluded that:

- a. The coal industry in East Kalimantan has positive and negative impact, the negative impact is greater than the positive one.
- b. The utilization of the river in East Kalimantan as a means of coal transportation is effective
- c. The regional government has an authority to regulate and supervise the special port construction along river in East Kalimantan.

## 6. ADVICE

In order to realize a good, clean, healthy, efficient, effective, accountable and environmentally sustainable governance of coal mine, then:

- a. Need to be issued legal products on special port and other related regulation ..
- b. The coal mining company need to be audited.
- c. Need public participation in supervising coal mining operation.
- d. Need cross-sector coordination to implement the local or central legal product ( regulation ).

## REFERENCES

- [1] Anonim, *The Seventh Announcement Clean and Clear Local License of East Kalimantan*, Department of Mine and Energy. Prov. Kaltim. 2012
- [2] Anonim, *The Data of Coal Port in East Kalimantan*, Department of Transportation . Prov. Kaltim. 2012
- [3] Anonim, *The data of Length and Class of Road, Department of Public Works*. Prov. Kaltim. 2012
- [4] Raden, I., Sholeh, M.P., Tamrin., D., *Coal Mining Impacts Assessment Of Socio-Economic Development and the Environment in Kutai Kartanegara Regency*, Jakarta, 2010.

# Understanding the Dynamics of 6P Branding Strategy with Brand Equity for a Mature Customer-Goods Brand using a System Dynamics Model

Akhmad Hidayatno<sup>a</sup>, Daisy Nadia Putri<sup>b</sup>, Irvanu Rahman<sup>c</sup>

<sup>a,b,c</sup> System Engineering, Modeling, and Simulation Laboratory  
Industrial Engineering Department, Faculty of Engineering,  
University of Indonesia, Depok 16424  
E-mail : akhmad@eng.ui.ac.id

## ABSTRACT

With high economic growth, the Indonesia's Fast-Moving Consumer Goods (FMCG) companies also experiencing a rapid market growth that has attracted more new players in the market. For both new and established FMCG companies, success in building and sustaining a brand is the key driving factor in winning the competition. A major concern in brand equity, as measurement of the intrinsic value of the brand competitiveness, is how to understand the behavior of brand equity overtime in relationship to the brand management strategy the major concern. This is especially true for an established mature brand to stay ahead. Therefore, this research develops a system dynamic model simulating the impact of brand strategy implementation to brand equity as a medium for understanding these relationships. Brand equity consists of brand-loyalty, brand-awareness, brand association and perceived product quality. Brand strategy consists of 6P factors: product, price, place, promotion, proposition and pack. The research investigates three plausible scenarios: aggressive competitor, business-as-usual, and passive competitor. The model shows how mature brand would have a different behavior than new brand that requires a different 6P branding strategy than a new or growing brand.

## Keywords

*Simulation, System Dynamics, Brand Strategy, Brand Equity, Brand Awareness, Brand Loyalty*

## 1. INTRODUCTION

With the increased market-size of Fast-Moving Consumer Goods (FMCG), due to Indonesia's high economic growth, has lured new companies to enter the market or old companies to expand its current product portfolio. Any mature product must be able to defend itself with the wave of new or rebranding old product. Which means brand strategy represents a key important aspect in marketing for FMCG companies. However, the process of building and sustaining a brand is highly complex and unstructured. Many dynamic variables, which are mostly tacit knowledge, affects this process and makes it difficult for brand managers to predict how branding strategy implementations could affect the brand as a whole.

This research developed a model that would help brand managers, who are responsible for a brand specifically in FMCG companies. The purpose of the model is to produce a brand equity model as a learning tool for brand managers to simulate interactions amongst indicators of brand equity in the system in order to evaluate the implementation of 6Ps branding strategies. It is suggested that the development of a system dynamic model will enhance the decision making process of brand managers.

## 2. LITERATURE REVIEW

Competition among brands is one of the most important key that determines business competitiveness to win the market. Companies with strong brands portfolio will have better options to compete rather than competing in price and specification alone [1]. Brand is a set of attributes that sticks to certain product or service, such as character, value, association, and quality that consumers have in mind and could interfere with consumers buying process [2]. Brand management roles are very crucial in managing brands to grab market potential through the application of branding strategy. According to Martins (2000) and Sampaio (2002), branding is an effort that aims to generate and develop brand value. Branding is also perceived as brand management process to generate brand equity and in turn will make the brand become more valuable and maximize its effect among the competitions [3]. The concepts that endorse brand equity are the most popular common practices in modern businesses since it considered as key business performance in maximizing its profit.

Brand equity is an example of a complex system that is affected by dynamic interaction among factors, both among elements that structure it and the interactions among those elements to the application of branding strategy. Aaker (1991) defines brand equity as a set of added values that is given by a brand to a product or service [4]. Brand equity give an added-value in increasing marketing efficiency and affectivity, build brand-loyalty, increase profit margin, and increase bargaining position toward seller [5]. Brand concept that aligns with brand equity will enable companies to evaluate their brand more effectively therefore will be able to develop a better branding [6].

For the model, brand equity consists of four elements: brand-awareness, brand-loyalty, perceived-quality, and desire-to-buy brand [7]. Oliver (1997) describe brand-loyalty as consumer commitment to repeat purchase of a product, although it is rather situational and very much affected by marketing effort to change this tendency [6]. Brand awareness is the ability of potential consumers to recall or remember a brand and link it to its product or service. Perceived-quality is defined as consumer's perspective toward overall quality of a product or service. It is rather subjective and cumulative over time [6]. Otto & Bois (2001), defined desire-to-buy brand as consumer's aspiration to buy certain brand [7].

There is a need of a learning medium, in a form of a model, to solve this brand complexity to highlight the interactions among brand equity elements and with branding strategy. With a more understanding of these interactions, brand managers will be able to evaluate their branding strategy to survive and grow as competition is getting crowded. It should be able to accommodate the concept of brand equity as the accumulation of relevant consumers and their expectations [8]. System dynamics methodology could accommodate understanding these complexities understanding through behavior changes over time when there is a change in the structure [9]. System dynamics is also accommodates scenario implementation test needed in this research. It could also show how it affects toward the whole system behavior [10].

### 3. RESEARCH METHODS

The research methodology follows the four steps of systems dynamics modeling methodology of conceptualization, development, validation, and model usage and analysis.

#### 3.1. Model Conceptualization

Interaction amongst variables and feedback from each variable are the focus in system dynamics modeling. System diagram is a perfect tool to represent interaction and feedback from variables. Figure 1 shows the system diagram for Brand Equity Model. The primary users are brand managers, which have to manage the brand to achieve desired key outputs from the system: brand-awareness, desire-to-buy brand, brand-loyalty and product perceived-quality. Other stakeholders of the system would also influence the output definition from the system. Brand managers would like to exercise certain branding scenarios to the interaction in the model and see how the results changes. The model must also account input from exogenous variables such as price, availability media exposure, shown on the left side of the diagram.

Based on the systems diagram, the construction of the model was starting by examining Otto's Brand Equity Model (Figure 2). In this linear model, desire-to-buy brand approached to be the effect pool from three other brand equity indicators. Considering the definition of brand equity as value added generated by the brand, desire-to-buy brand becomes the closest indicator for assessing Brand Equity success in adopting consumers. Otto also stated that desire-to-buy brand indicator is able to summarize the effects produced by other elements such as brand-awareness, brand-loyalty, and perceived-quality [7].

However, Otto's model does not explain about how each variable affecting the adoption process of a product. Therefore, a new concept, shown in Figure 3, was developed on explaining how each stage in the adoption process influence bay the variables Otto's model.

Figure 4 illustrates the translation of the Otto's model into CLD. It shows how product attractiveness and customer satisfaction can build perceived-quality. Increased in perceived-quality is the result of the interaction amongst four factors: product, price, packaging, and availability, and balanced by the brand negative image. Perceived-quality is considered as 'moment of truth' to consumers, whether the product is good or not. If consumer perceived it acceptable and preferable, consumers will tend to buy more and increase brand-loyalty. In turn, brand-loyalty will affect customer satisfaction.

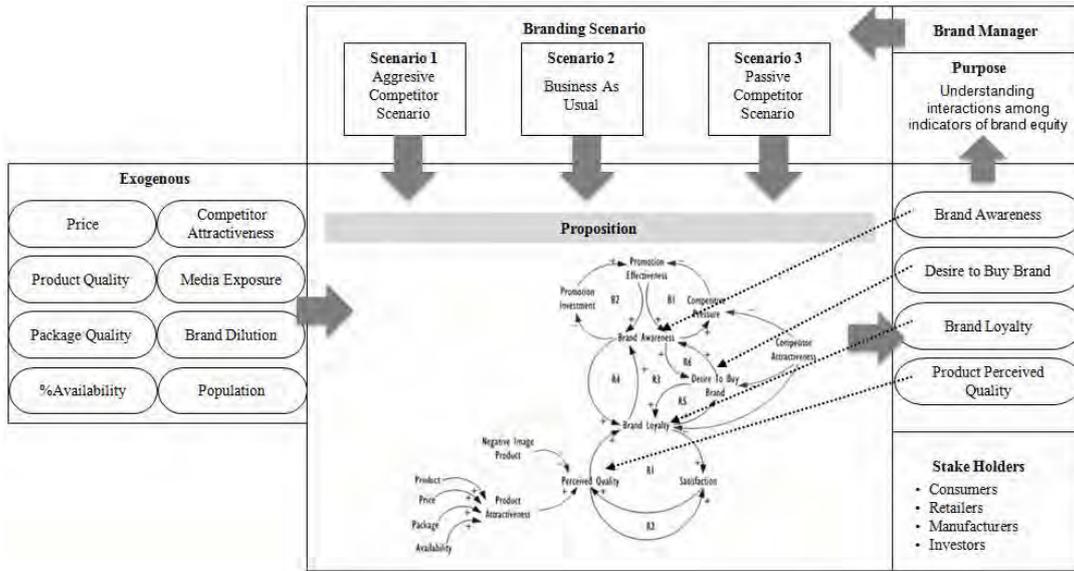


Figure 1: Model Conceptualization of Brand Equity Model as a System Diagram

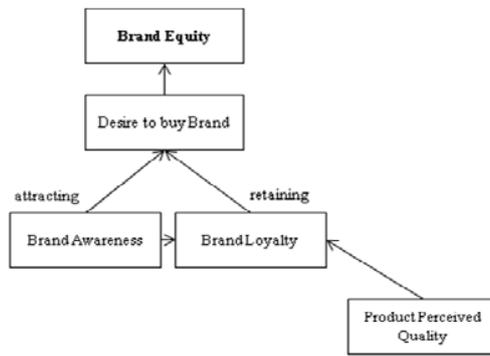


Figure 2: Model Assumptions based on Otto's Brand Equity Model

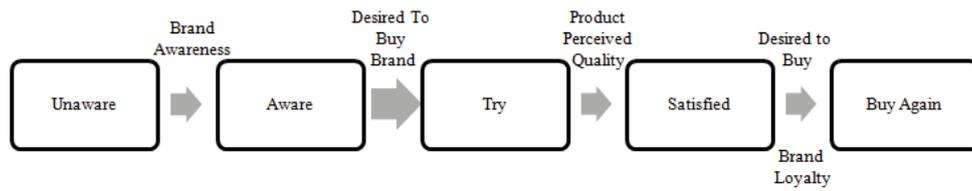


Figure 3: How Each Brand Variables affecting the Adoption Process

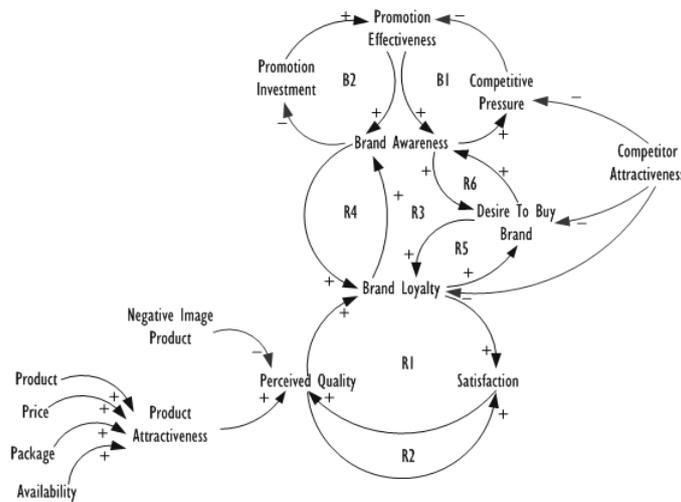


Figure 4: Causal Loop Diagram of Brand Equity Model

In brand-awareness, promotion effectiveness will affect brand-awareness but can be distracted by the distortion of competitor attractiveness. Promotion investment is likely to improve the effectiveness of promotional campaigns and the effectiveness of this campaign will ultimately increase brand-awareness. The more consumers know the brand; it will increase brand-loyalty. Likewise, the more loyal consumers know the brand better. Desire-to-buy brand can influence brand-awareness and brand-loyalty. In turn, they can also affect the desire-to-buy brand. Besides distorting promotion effectiveness, attractiveness competitors will also distract the desire-to-buy brand and brand-loyalty.

### 3.2. Model Development (SFD)

In order to complement the secondary data obtained through company reports, a Focus Group Discussion (FGD) was conducted to gain insight on the relationships of the model. The model was shown and discussed in the FGD, and the complete model is illustrated in Figure 5

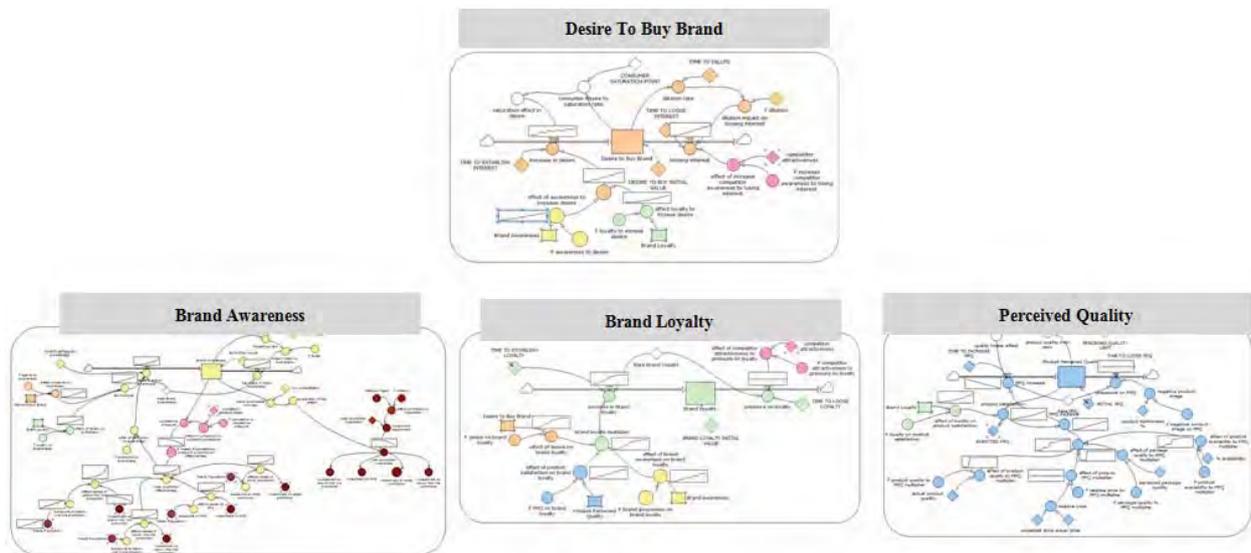


Figure 5: Brand Equity Model Birds-Eye View

### 3.3. Model Validation

The model underwent four validation methods in SD: dimensional consistency test, structure assessment test, behavior validation test, and sensitivity analysis test. For the behavior validation test, output from our model validate the reference mode from Otto's desire-to-buy brand variable (Figure 6) [7].

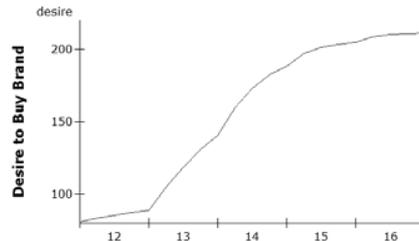


Figure 6: Desire-to-buy Brand Indicator Model Simulation Validation

Sensitivity analysis validation aims to determine how sensitive a variable affect other variables and sees whether the response of the model is appropriate with the response in real behavior condition. The model used two exogenous variables: brand-loyalty and competitor attractiveness.

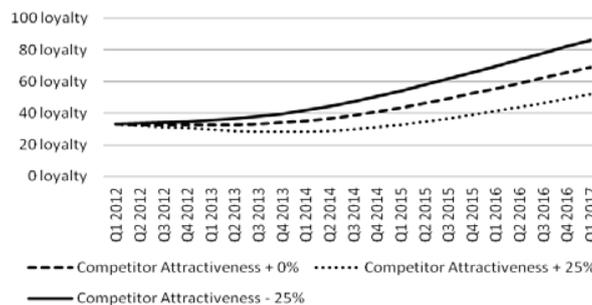


Figure 7: Brand-loyalty toward Competitor Attractiveness Change

Based on Figure 7, we can see that level of competitor attractiveness is strongly influence the brand-loyalty. Competitor Attractiveness will give pressure to brand-loyalty. A higher increase of Competitor Attractiveness will result a higher pressure on brand-loyalty that may caused decline in brand-loyalty value. These behaviors correspond with the real live perceptions.

### 3.4. Scenario Development

From the results of simulation scenarios, conducted summary on each indicator of each scenarios to get an idea of how the effect of these scenarios running on each indicator. Since brand strategy links with competitor brand strategy, the scenarios were developed based on the brand manager's plausible responds to any changes in the competitor brand strategy. Any competitor strategy would affect their products attractiveness. Business-as-usual scenario illustrates the currently implemented 6Ps branding strategy. Aggressive-competitor scenario is when the brand manager responds if competitor aggressively increases its product competitiveness. Passive-competitor scenario is when the competitor actually loosens the product brand positioning. The model runs for five years, a long term planning perspectives for a FMCG company.

## 4. RESULTS AND DISCUSSION

### 4.1.1 Desire-to-buy Brand

Figure 9 shows the behavior over time of desire-to-buy brand which rose slowly at first, but then accelerated and slowed down again at the end of the period because of the balancing effect of the variable representing the dilution effect of consumer boredom.

On passive-competitor-scenario, desire-to-buy brand experienced faster movement behavior over time curve resulting greater value than business-as-usual scenario as much as 3% by the end of the simulation period. Meanwhile, on aggressive-competitor-scenario, desire-to-buy Brand experience slower movement behavior over time curve resulting decline value than on business-as-usual scenario as much as 3% by the end of the simulation period.

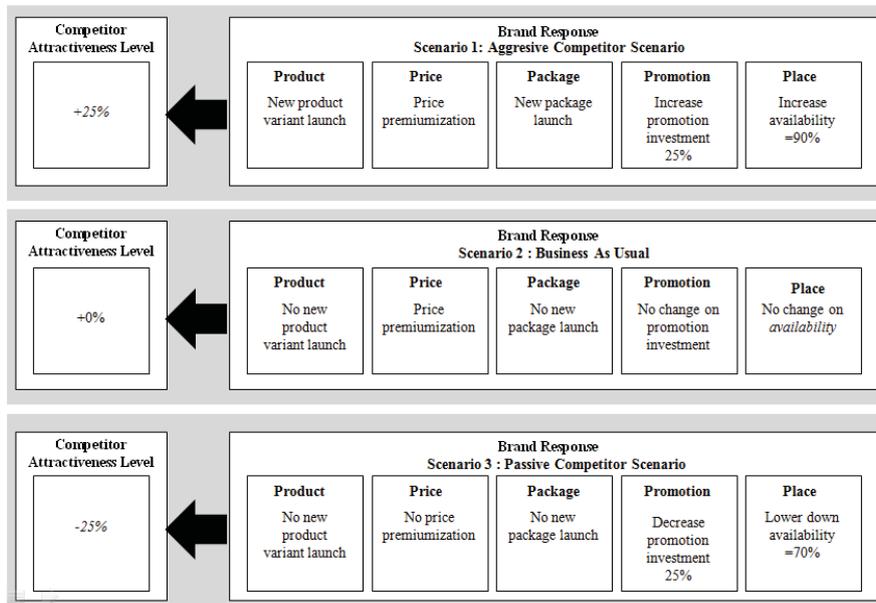


Figure 8: Scenarios for 6P Branding Strategies

#### 4.1.2 Brand Awareness

Figure 10 shows how brand-awareness creates an exponential curve behavior over time, as the effect of the interaction between promotion investment and promotion exposure. Two balancing-loop structures on the CLD between brand-awareness, investment promotion and brand-awareness, and with the competitive pressure on promotion effectiveness is not significantly influence the brand-awareness to create a limit to growth behavior. Both loops just reduce the growth level of the brand-awareness. These behaviors show loyalty in mature brand is very strong comparing to any attack from competitors promotion.

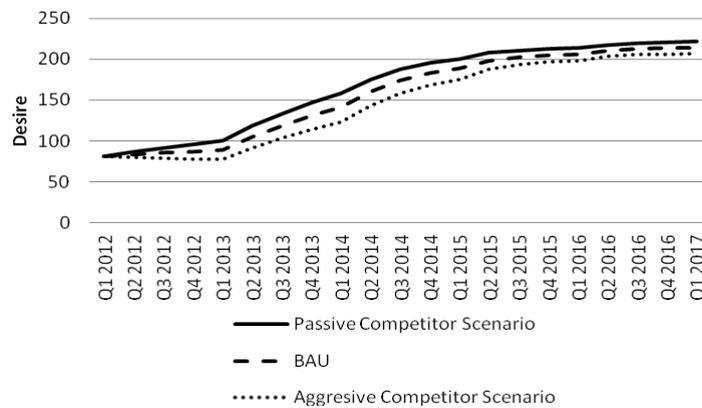


Figure 9: Desire-to-buy Brand Behavior Over Time in Each Scenarios

Between the scenarios, on aggressive-competitor-scenario, brand-awareness indicator performance decreased compare to its simulation result on business-as-usual scenario implementation. Promotion effectiveness is one of the most influencing variable to brand-awareness, which itself is influenced by the promotion investment, promotion exposure, as well as competitive pressure caused by competitors attractiveness.

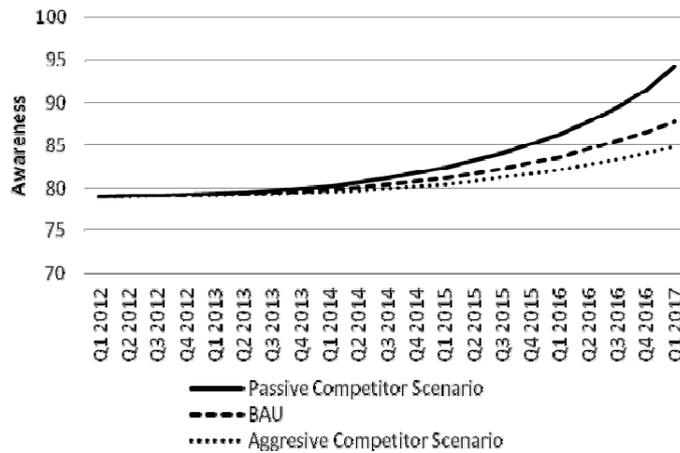


Figure 10: Brand-awareness Behavior Over Time in Each Scenarios

In the case of a mature brand, the distortion from competitor attractiveness plays a bigger dominating effect to promotion effectiveness. Therefore, when it reaches to a saturation point, increase in consumer awareness level is slowing down. Consumers are uninterested with the same marketing messages. This would affect on the brand-awareness performance. It shows in the aggressive-competitor-scenario by experiencing slower movement on behavior over time curve and declining brand-awareness value as much as 3% by the end of the simulation period.

From the model, brand-awareness indicator performance on passive-competitor-scenario increased by 7% compared to the scenario. This happens due to a decline in attractiveness competitors that has an effect of investment promotion become even stronger in promotion effectiveness, although the investment amount is reduced.

#### 4.1.3 Brand Loyalty

Brand-loyalty also increased exponentially due to the reinforcing loop structure between brand-awareness, brand-loyalty, desire-to-buy brand, and perceived-quality (Figure 11).

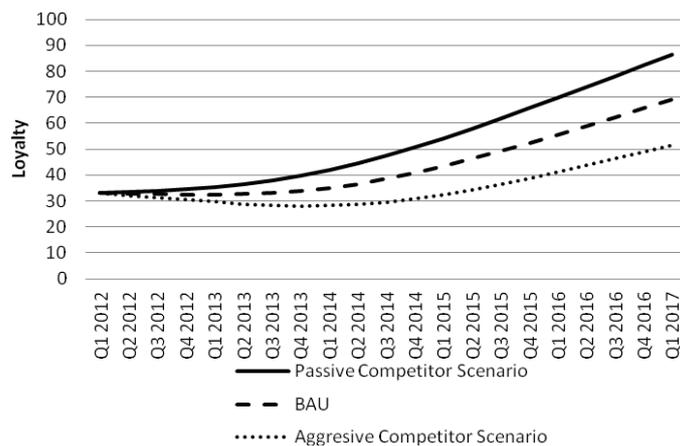


Figure 11: Brand-loyalty Behavior Over Time in Each Scenarios

Brand-loyalty on aggressive-competitor-scenario shows lower performance than business-as-usual, as the competitor awareness increased. Since competitor awareness influenced brand-loyalty in reverse, brand-loyalty went down by 25% as competitor awareness increased. On the contrary, brand-loyalty indicator on passive-competitor-scenario experience faster movement on behavior over time curve than business-as-usual scenario much as 25% at the end of the simulation period

#### 4.1.4 Perceived Quality

Figure 12 shows that perceived-quality is remained constant due to the fact that the brand has reached a mature stage in its brand life cycle. The launch of new products, new packaging, premium price, and improved distribution availability do not show significant effect on perceived-quality.

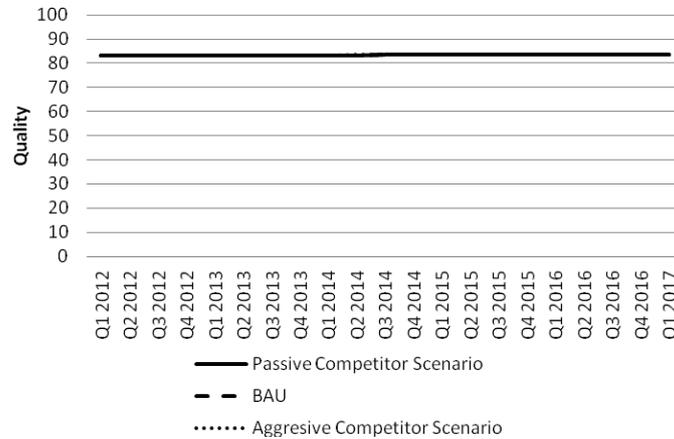


Figure 12: Brand-awareness Behavior Over Time in Each Scenarios

The lack of significant change in the perceived-quality also leads to lack of changes in satisfaction level, which in turn resulted to lack of change in the perceived-quality in total.

Perceived-quality on passive-competitor-scenario changes in two variables of the 6Ps branding strategy: distribution availability level (reduced to 70%) and price premium level. The simulation results of perceived-quality on passive-competitor-scenario showed similar results with the business-as-usual scenario; whereas on aggressive-competitor-scenario, a launch of new products and packaging and increases availability has caused slightly better result than business-as-usual scenario.

## 5. CONCLUSION

Based on the model, mature brands performance depend on competitor attractiveness. In a passive-competitor environment, when the competitor attractiveness declined, performance of all brand equity indicators moves up even when all branding strategy elements declined. On the contrary, when the competitor attractiveness increased and all the company branding strategy elements rose, the performance of all brand equity indicators declines. Therefore, mature brand should be very careful on maintaining its competitiveness against competitors, because it would need higher effort just to reach back its prior position on all indicators once the brand lost its prime position.

## REFERENCES

- [1] Aaker, D. A. (1992). Managing The Most Important Asset: Brand Equity. *Planning Review* , 56-58.
- [2] Keler, K. L., & Machado, M. (2006). *Marketing Management*. Sao Paolo: Prentice Hall.
- [3] Crescitelli, E., & Figueiredo, J. B. (2009). Brand Equity Evolution: a System Dynamics Model. *Brazilian Administrative Review* , 101-117.
- [4] Aaker, D. A. (1991). *Managing Brand Equity*. New York: Free Press.
- [5] Bagozzi, R., Rosa, J., Celly, K., & Coronel, F. (1998). *Marketing management*. Upper Saddle River: Prentice Hall.
- [6] Tuominen, P. (1999). Managing Brand Equity. *LTA* , 65-100.
- [7] Otto, P. A., & Bois, J. R. (2001). Brand Management Facilitation: A System Dynamics Approach for Decision Making. *PAD* , 824-843.
- [8] Ahmad, N. (1998). *Brand Equity form A System Dynamics & Decision-Making Perspective*. New York: Strategic Decisions Group.
- [9] Lyneis, J. M. (2000). System Dynamics for Market Forecasting and Structural Analysis. *Sys Dyn Rev 16(1)* , 3-25.
- [10] Fahey, L., & Randal, R. M. (1998). *Learning from the future*. New York: John Wiley & Sons.

# The Simulation of Booking Limit Models for Entertainment Event Ticketing Using Revenue Management Approach

Gayatri Pangriptadewi<sup>a</sup>, Nur Aini Masruroh<sup>b</sup>, Yun Prihantina Mulyani<sup>c</sup>

<sup>a</sup>Faculty of Engineering, University of Gadjah Mada, Yogyakarta 55281  
E-mail : pangriptadewi@gmail.com

<sup>b</sup>Faculty of Engineering, University of Gadjah Mada, Yogyakarta 55281  
E-mail : aini@ugm.ac.id

<sup>c</sup>Faculty of Engineering, University of Gadjah Mada, Yogyakarta 55281  
E-mail : yun.prihantina.m@gmail.com

## ABSTRACT

Entertainment event ticket is characterized as perishable product with fixed capacity as it cannot be saved as inventory for other events in the future. Moreover, ratio of fixed and variable cost is too high so remaining ticket indicates that event organizer lose revenue. To anticipate it, nowadays, event organizers tend to sell ticket in different price rates: the longer time from the D-day of the event the cheaper the price is. They offer part of capacity with discount fare and the rest with full fare. Based on that condition, there are two basic decisions for managing entertainment ticketing to gain optimal profit: capacity allocation and price rate. This research proposes to develop capacity allocation and optimal pricing model for each class of customers using revenue management approach. In this paper, capacity allocation model is developed into two model types. Firstly, using Littlewood model, two-class booking limit shows how to allocate capacity to two customer types. Secondly, heuristic EMSR-b (Expected Marginal Seat Revenue Version B) approach is used to develop n-class booking limit offering more than two price rates. Capacity allocation and optimal pricing models are then investigated by simulating models and evaluating the decision due to revenue performance in deterministic and stochastic condition. Based on case studies used, stochastic condition is more representative to actual system than the deterministic one. Optimal price rate and booking limit for both two class and n-class in stochastic condition are further recommended.

## Keywords

*Entertainment event ticketing, revenue management, booking limit, Littlewood two class model, n-class model*

## 1. INTRODUCTION

Nowadays, entertainment ticketing strategy has been varying developed. Due to business objective, to gain profit as much as possible, the most widely used is pre-sale method. The method, like airline ticketing, allows event organizer sells the same product (ticket) in different price rates, but airline ticketing offers wider level fare with more fluctuate changes in price based on time-frame. For entertainment event, event organizer which applies pre-sale method determines some classes, the higher the price rates, the closer the payment to the D-day of entertainment event. Certainly, event organizers have their own way to maintain capacity for each given class.

Actually, in several cases, pre-sale methods can increase revenues. For instance, Northwest Ballet Organizer, in Palm Beach Opera Sandiego, increased price about 5 dollars when sold tickets reached 80% of capacity, and 10 dollars each ticket when sold tickets reached 90% of capacity. Applied method increased successfully revenue about 1.5-2%<sup>[1]</sup>. The method can increase revenue smoothly in the end of the event<sup>[1]</sup> and give significant impact in business performance. If event organizer provides less lower class, the remaining capacity/ticket possibly cannot be sold, namely deadwood. The other way, if the event organizer provides more lower class, revenue will be not optimal. Deadwood loss its value when the event ends. That condition indicates that entertainment ticketing is similar to perishable product. Therefore, revenue management (RM) can be applied for entertainment ticketing. Thus, in this research, simulation using revenue management approach in entertainment ticketing is developed. The model includes capacity allocation and pricing model that can be simple decision support for practitioners.

## 2. LITERATURE REVIEW

Originally, revenue management has been examined since 1972 by Littlewood and it focused on airline ticketing. Nowadays revenue management is widely used in the other domains, like hotel, retailer, electric power supply, car rental, etc. Revenue management can model these domains properly because the domains have same basic property which is perishable product. Other characteristics of perishable product are the limited sale period, having price sensitivity, and having stochastic demand [2].

Theoretically, revenue management is defined as how to deliver product to the right consumer with the right price in the right time [2]. To achieve that condition, there are two perspectives in revenue management, pricing-based revenue management and quantity-based revenue management [3]. Pricing-based RM explores which level of price rate appropriate for each class of consumer is. On the other hand, quantity-based RM determines capacity allocation for each class. Therefore, perishable product can be delivered exactly to the right customer in the right time.

Revenue management is ever applied for pricing modeling of tour site in China [4] where previously, government increased the price based on cost-oriented method before RM was finally applied. The model is used to predict when the management should increase the price based on the remaining capacity namely backward induction. Revenue management is also applied for S&E (Sport and Entertainment) ticketing [5] to predict the best switching time of price changes to get optimal profit.

This research applies revenue management for S&E ticketing with live concert/entertainment concert as case study. Not only capacity allocation model with backward induction to predict optimal booking limit but also pricing model to decide the best offered price for each type of costumers are successfully developed. Hopefully, it can improve previous research done by Dake [5] which is only focused on capacity allocation. Booking limit model is then developed into two kinds: two class according to Talurri model and n-class using EMSR-b (*Expected Marginal Seat Revenue Version B*) and pricing model is also developed in both deterministic and stochastic conditions.

## 3. BOOKING LIMIT MODELS

Ticketing business with pre-sale/discount fare and normal fare are confined to limited capacity. Discount fare happen priory and then remaining tickets are sold with the normal fare with value greater than discount price. In practice, capacity allocation is decided by intuitive approach. Theoretically, it can be evaluated by revenue management approach. The following subchapter explains two models of booking limit. These models are represented the existing model and can be used to evaluate optimal capacity allocation.

### 3.1. Two-class booking limit

Littlewood two-class booking limit is applied to model capacity allocation for two levels of prices, high fare and low fare. In this model, demand of discount fare is assumed that happen previously and then followed by demand of high fare. Thus, there are rooms which are offered for discount fare called booking limit and the remaining room is protected for high fare called protection level. Booking limit is symbolized as  $b$  while protection level is symbolized as  $y$ .

This model shows optimal booking limit ( $b^*$ ) and optimal protection level ( $y^*$ ). Both parameters have relation as shown in equation (1) below where  $C$  is the capacity.

$$b_2^* = C - y_1^* \quad (1)$$

Protection level is defined as the function of cumulative distribution function of arrival customer which is one of the continuous distribution types as shown in equation (2). This model can explain demand uncertainty.

$$y_1^* = F_1^{-1} \left( 1 - \frac{P_2}{P_1} \right) \quad (2)$$

Which  $P_2$  is the high fare and  $P_1$  is the low fare.

Based on equation (1) and (2), optimal booking limit and protection level can be calculated manually and simulated for each ratio of price ( $P_1$  and  $P_2$ ). Calculation result of booking limit and protection can be easily determined. The result of the

simulation is then formed as linear regression. Equation (3) shows that the higher the ratio of price is, the more the room protected and vice versa. It is logically explain real condition in the system. Ratio itself is symbolized as  $r$ .

$$b = m + nr \quad (3)$$

Which  $m$  and  $n$  are parameter or intercept.

### 3.2. N-class booking limit

Littlewood booking limit is one alternative to determine capacity allocation. In this section, more advance method to find optimal decision for allocating all resources (capacity) is explored. This method called  $n$ -class booking limit is applied for several classes of costumers. The method is currently and widely used in the context of revenue management because it is easily notated, directly used, and close to real optimal solution.

Two of most familiar heuristic method is EMSR-a (Expected marginal seat revenue-version a) and EMSR-b (expected marginal seat revenue version b) [7]. Index and notation used in this model are same as the model of two-class booking limit. It also assumes that the model fit with certain continuous distribution.

Actually, EMSR-a is indicated resulting the higher protection level than the real optimal protection level because it does not use average statistic model to aggregate demand, so it causes pooling effect resulting higher protection level. Due to that reason, EMSR-b is preferably applied in this research. The basic idea is aggregation of demand for the previous class so  $n$ -class is changed into two-class form. For instance, forth class will be evaluated instead of three previous classes. First, second, and third classes are considered as only one class. Revenues of those classes are next accumulated and average revenue is used as divisor.

For  $(n+1)^{th}$  class, protection level will be determined as  $y_n$ . Cumulated demand for  $n^{th}$ ,  $(n-1)^{th}$ , 1st class is defined by the following equation (4). The weighted revenue for 1<sup>st</sup>,  $(n)^{th}$  is obtained by calculating  $\bar{p}_n$  as shown in the equation (5).

$$S_n = \sum_{k=1}^n d_k \quad (4)$$

$$\bar{p}_n = \frac{\sum_{k=1}^n p_k E[d_k]}{\sum_{k=1}^n E[d_k]} \quad (5)$$

EMSR-b equation is assumed that it is distributed normally. Equation (6) explains how  $y_n$  can be calculated.

$$y_j = \mu + z_\alpha \sigma \quad (6)$$

Which  $\mu = \sum_{k=1}^n \mu_k$  is mean and  $\sigma^2 = \sum_{k=1}^n \sigma_k^2$  is variance of the aggregation of demand from  $(n+1)^{th}$  stage where  $z_\alpha = \Phi^{-1}\left(1 - \frac{p_{n+1}}{p_n}\right)$  and  $\Phi^{-1}$  reflects the inverse of cumulative function of normal distribution.

## 4. REVENUE MODEL

To evaluate booking limit model, revenue becomes indicator whether booking limit model optimizes business performance itself. Firstly, demand model is developed in two conditions: deterministic demand model and stochastic demand model. Deterministic model provides simple form but it has limitation because it only can be applied in certain range. If the point exceeds the range, the calculated demand results zero or negative value. Therefore, stochastic model is also evaluated in this case and may represent the system better. Secondly, revenue model which consists of demand model and booking limit model is created by accommodating both pricing-based and quantity-based perspectives.

Revenue management assumed that the only factor affecting demand is price. Based on that statement, demand model is developed as function of price. Price itself consists of several stages depending on level of customers. Here, equation (7) is

deterministic demand model and equation (8) is the stochastic demand model. The equations show that if the price declines, then the demand increases and vice versa. So, the demand and price are negatively correlated.

If demand model is successfully modeled and checked by statistic tool that there is no significant different between model and real system, it can be used for further analysis. Revenue model with both demand and booking limit model is next logically developed into three conditions: when the demand exceeds the capacity, when the demand ranges from booking limit to capacity, and when the demand is less than booking limit. It is mathematically explained by equation (9) – equation (11). The model as shown in equation (9) counts single class revenue up into accumulated revenue.

$$d_{det(p)} = a - bp \quad (7)$$

$$d_{stoc}(p_n) = N(f(p_n)) \text{ Which } f(p_n) = e^{-p_n \lambda} \quad (8)$$

$$R_{acc} = \sum_{i=1}^n R_n \quad (9)$$

$$R_n = \begin{cases} p_n d_n & \text{if } d_n < b < C \\ p_n b_n & \text{if } C > d_n \geq b \\ p_n C & \text{if } d_n \geq C \end{cases} \quad (10)$$

$$R_n = \begin{cases} p_n(a - bp_n) & \text{if } d_{det_n} < b < C \\ p_n(C - \gamma_{n-1}) & \text{if } C > d_{det_n} \geq b \\ p_n C & \text{if } d_{det_n} \geq C \end{cases} \quad (11)$$

## 5. SIMULATION AND ALTERNATIVE SOLUTIONS

In this section, simulation using study case is needed to prove developed model: booking limit model, pricing model, and revenue model as shown in equation (1)-(11). The case is an entertainment event in Yogyakarta in 2011. This entertainment event is an annual event so result in this study can be considered in future time. It offered two price rates, high price (Rp150.000) and low price (Rp100.000) with fixed capacity (700 seats). The event organizer initially allocated 30% for high price and 70% for low price without logical consideration. By doing that strategy, they obtained Rp72.250.000. They got actually 210 seats sold out with high price and 420 seats sold out with low price. It means that there were remaining seats or they allocated too many rooms for high price. By applying the developed model above, we can evaluate whether their decision had been optimal or not yet. Three scenarios for two conditions (deterministic and stochastic) have been developed to evaluate and to find the best strategy.

1. One-class pricing strategy in deterministic and stochastic condition
2. Two-class pricing strategy in deterministic and stochastic condition
3. n-class pricing strategy in deterministic and stochastic condition

Before running simulation, basic parameter should be determined to classify better or worse business which is revenue model containing both quantity-based RM and pricing-based RM. As shown in equation (8)-(11), equation (12) is deterministic demand model and equation (13) is stochastic demand model. Both model can be substituted as the input for revenue model as mentioned by equation (11).

$$d_{det(p)} = 1857,813 - (0,012p) \quad (12)$$

$$d_{stoc} = N(e^{-p_n \lambda}) = N(e^{-8581 \times 10^{-6} p_n}) \quad (13)$$

The simulation uses random prices in range of Rp100.000-Rp250.000 based on historical data of entertainment events in Yogyakarta.

### 5.1. One-class pricing strategy

Two class or n-class model have a risk because of the fluctuate prices. It can influences costumer and organizers may loss their demand. So, in this case, one-class model is also evaluated. If the output of one-class model results higher revenue, it can be used as recommendation.

In range of Rp100.000-Rp250.000, by applying Rp120.000 for both deterministic and stochastic condition, we got the greatest revenue (Rp70.128.912). It can be explored detail in Figure 1. Unfortunately, the result of this model cannot be recommended because the expected revenue is less than actual revenue. It may be concluded that one-class model cannot offer better result in this case.

### 5.2. Two class model

Firstly, booking limit model is basically developed by arrival costumer rate so it can adapt or adjust uncertain demand. Figure 2 shows the correlation between protection level and ratio of high and low prices called discount rate. Based on figure 2, the greater the discount rate offered to the customer, the more the capacity protected for high price. It can be logically explained that if number of rooms with discount rate offered to costumer is more, the revenue should decreases. Therefore, the more rooms should be offered in high price. The correlation between booking limit and discount rate can be explained mathematically by equation (14).

$$h = 78,063 + 620,7 \frac{P_2}{P_1} \tag{14}$$

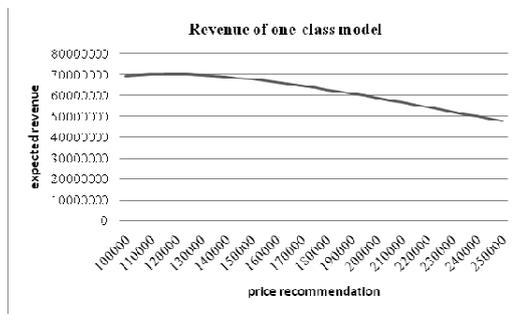


Figure 1: Revenue Output for One-Class Model

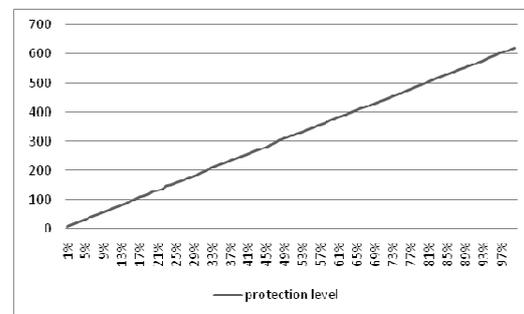


Figure 2: Protection Level for each discount rate

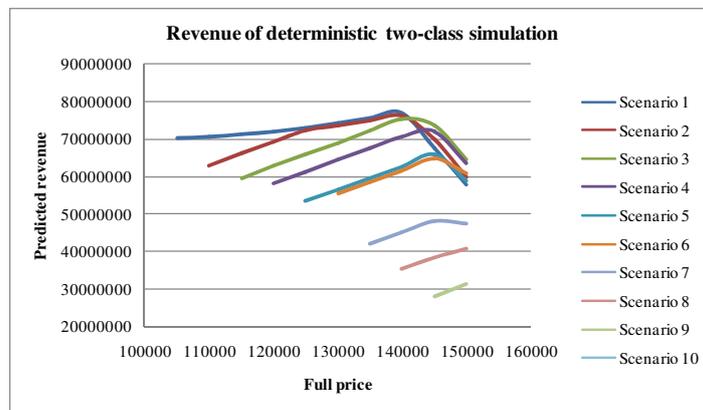


Figure 3: The result of two-class deterministic simulation

The two-class model simulation uses price in range of Rp100.000-Rp250.000 based on the historical data of entertainment event in Jogjakarta for both discount and full prices in deterministic and stochastic condition. However, because of restrictiveness of deterministic model, the simulation uses only price in range of Rp100.000-Rp150.000 because the price excess Rp150.000 values negative result. Meanwhile, stochastic simulation applies price in range of Rp100.000-Rp250.000.

In the simulation, full price is varied in the range of price with a given discount price on each scenarios. For example, in the 1<sup>st</sup> scenario, discount price is fixed which is Rp100.000 and full price is varied from Rp105.000-Rp150.000. Thus, local optimal revenue can be defined for each scenario by applying the model of equation (7)-equation (11). The results for both deterministic and stochastic conditions are depicted in the figure 3 and 4. The following table, Table 1 and Table 2, explains optimal combination of discount and full fare in each scenario.

According to Figure 3 and Table 1, best pricing strategy for deterministic simulation is Rp100.000 as discount price and Rp140.000 as full price with predicted revenue greater than actual revenue (Rp77.035.834) which rises about 6% from the actual revenue. Stochastic simulation as shown in Figure 4 and Table 2 predicts the best pricing for both discount and full price which are Rp145.000 and Rp230.000 respectively.

Table 1: Simulation result of two-class deterministic model

No	Discount price	Full price	Expected revenue	No	Discount price	Full price	Expected revenue
1	Rp100.000,00	Rp140.000,00	Rp77.035.834,00	6	Rp125.000,00	Rp145.000,00	Rp64.819.990,00
2	Rp105.000,00	Rp140.000,00	Rp76.256.480,00	7	Rp130.000,00	Rp145.000,00	Rp48.205.555,00
3	Rp110.000,00	Rp140.000,00	Rp75.264.545,00	8	Rp135.000,00	Rp150.000,00	Rp40.776.705,00
4	Rp115.000,00	Rp145.000,00	Rp72.031.380,00	9	Rp140.000,00	Rp150.000,00	Rp31.286.370,00
5	Rp120.000,00	Rp145.000,00	Rp65.834.425,00	10	Rp145.000,00	Rp150.000,00	Rp20.371.935,00

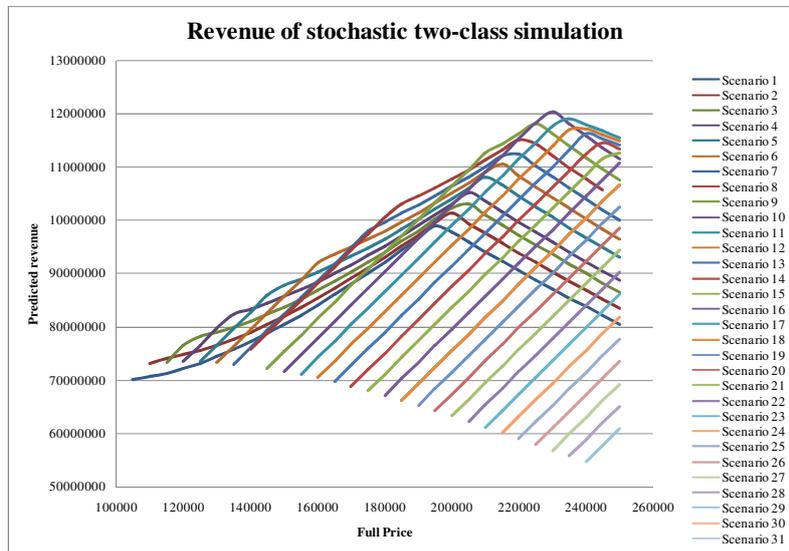


Figure 4: The result of two-class stochastic simulation

Table 2: Simulation result of two-class stochastic model

No	Discount price	Full price	Expected revenue	No	Discount price	Full price	Expected revenue
1	Rp100.000,00	Rp195.000,00	Rp98.844.784,23	16	Rp175.000,00	Rp250.000,00	Rp110.633.487,63
2	Rp105.000,00	Rp200.000,00	Rp101.222.509,63	17	Rp180.000,00	Rp250.000,00	Rp106.597.156,44
3	Rp110.000,00	Rp205.000,00	Rp102.971.712,65	18	Rp185.000,00	Rp250.000,00	Rp102.526.692,82
4	Rp115.000,00	Rp205.000,00	Rp105.136.549,51	19	Rp190.000,00	Rp250.000,00	Rp98.426.609,28
5	Rp120.000,00	Rp210.000,00	Rp108.052.615,71	20	Rp195.000,00	Rp250.000,00	Rp94.301.099,50
6	Rp125.000,00	Rp215.000,00	Rp110.451.674,66	21	Rp200.000,00	Rp250.000,00	Rp90.154.057,13
7	Rp130.000,00	Rp220.000,00	Rp112.317.890,25	22	Rp205.000,00	Rp250.000,00	Rp85.989.093,62
8	Rp135.000,00	Rp220.000,00	Rp114.989.497,27	23	Rp210.000,00	Rp250.000,00	Rp81.809.555,05
9	Rp140.000,00	Rp225.000,00	Rp118.036.511,67	24	Rp215.000,00	Rp250.000,00	Rp77.618.538,04
10	Rp145.000,00	Rp230.000,00	Rp120.340.112,20	25	Rp220.000,00	Rp250.000,00	Rp73.418.904,80
11	Rp150.000,00	Rp235.000,00	Rp118.915.004,08	26	Rp225.000,00	Rp230.000,00	Rp69.213.297,39
12	Rp155.000,00	Rp240.000,00	Rp117.126.957,55	27	Rp230.000,00	Rp250.000,00	Rp65.004.151,12

No	Discount price	Full price	Expected revenue	No	Discount price	Full price	Expected revenue
13	Rp160.000,00	Rp240.000,00	Rp116.267.983,24	28	Rp235.000,00	Rp250.000,00	Rp60.793.707,28
14	Rp165.000,00	Rp245.000,00	Rp114.479.481,33	29	Rp240.000,00	Rp250.000,00	Rp56.584.025,15
15	Rp170.000,00	Rp250.000,00	Rp112.530.675,52	30	Rp245.000,00	Rp250.000,00	Rp52.376.993,31

### 5.2.2. N-class model

In this case, it is assumed that there are three classes of customer. Optimal pricing in first and second class are set which are Rp100.000 and Rp125.000 respectively. Thus, n-class model searches optimal price for the third class. As explained before in subchapter 2.1, class is in order and notated as  $p_{n-1} > p_n$ . Customer arrival of the  $n^{\text{th}}$  class happens previously than the  $(n-1)^{\text{th}}$  class. Thus, arrival demand of discount price happens previously and followed by the arrival demand of higher price.

Figure 5-Figure 6 shows the simulation result which is calculated from some alternative  $n^{\text{th}}$  price and Table 3-Table 4 shows specific results and predicted revenues for both deterministic and stochastic conditions. The best pricing strategies are Rp150.000 for deterministic condition and Rp205.000 for stochastic condition.

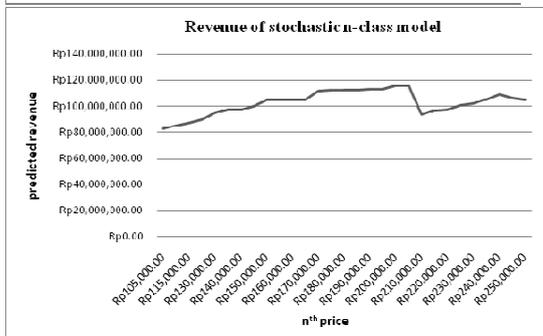
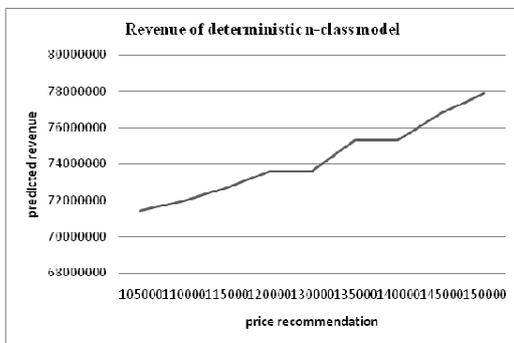


Figure 5. The result of deterministic n-class simulation

Figure 6. The result of stochastic n-class simulation

Table 3.  $n^{\text{th}}$  price recommendation for deterministic simulation

No	Alternative price	Expected revenue	No	Alternative price	Expected revenue
1	Rp105.000,00	Rp71.429.857,13	6	Rp135.000,00	Rp75.306.200,00
2	Rp110.000,00	Rp71.982.100,00	7	Rp140.000,00	Rp75.306.200,00
3	Rp115.000,00	Rp72.706.000,00	8	Rp145.000,00	Rp76.792.300,00
4	Rp120.000,00	Rp73.601.300,00	9	Rp150.000,00	Rp77.859.000,00
5	Rp130.000,00	Rp73.601.300,00			

Table 4.  $n^{\text{th}}$  price recommendation for stochastic simulation

No	Alternative price	Expected revenue	No	Alternative price	Expected revenue
1	Rp105.000,00	Rp82.607.221,82	16	Rp185.000,00	Rp112.355.193,41
2	Rp110.000,00	Rp84.870.893,41	17	Rp190.000,00	Rp112.564.893,41
3	Rp115.000,00	Rp87.308.793,41	18	Rp195.000,00	Rp112.774.593,41
4	Rp120.000,00	Rp89.918.093,41	19	Rp200.000,00	Rp115.126.793,41
5	Rp130.000,00	Rp95.050.993,41	20	Rp205.000,00	Rp115.336.493,41
6	Rp135.000,00	Rp97.403.193,41	21	Rp210.000,00	Rp93.401.800,00
7	Rp140.000,00	Rp97.403.193,41	22	Rp215.000,00	Rp96.525.300,00
8	Rp145.000,00	Rp99.965.093,41	23	Rp220.000,00	Rp97.334.900,00
9	Rp150.000,00	Rp104.459.793,41	24	Rp225.000,00	Rp100.715.500,00
10	Rp155.000,00	Rp104.669.493,41	25	Rp230.000,00	Rp101.610.800,00
11	Rp160.000,00	Rp104.879.193,41	26	Rp235.000,00	Rp104.820.000,00
12	Rp165.000,00	Rp105.088.893,41	27	Rp240.000,00	Rp108.629.100,00
13	Rp170.000,00	Rp111.726.093,41	28	Rp245.000,00	Rp106.391.743,31
14	Rp175.000,00	Rp111.935.793,41	29	Rp250.000,00	Rp105.292.590,37
15	Rp180.000,00	Rp112.145.493,41			

## 7. CONCLUSION

According to the research objective, booking limit model is successfully developed with three conditions: one-class, two-class, and n-class specifically for three-class in the case. It is generated into revenue model which combines both pricing-based RM and booking limit itself as quantity-based RM. Revenue model is developed in two conditions: stochastic demand and deterministic demand. From both conditions, stochastic is more representative because it can apply wider price range while deterministic has price range limitation. Based on case study, the simulation recommends two-class with optimal discount fare and high fare which are Rp145.000 and Rp230.000 respectively. For further research, developing customer valuation and switching time as consideration for revenue management model is suggested.

## REFERENCES

- [1] K. Larson, *Can You Use Dynamic Pricing*. Portland, Art Knowledge, Ilc, 2010.
- [2] G. Britain and R. Caldenetey, *An Overview of Pricing Models for Revenue Management*. Massachusetts, Sloam School of Business, MIT, Cambridge, 2002.
- [3] K.T. Talurri and G.J. Van Ryzin, *The Theory and Practice of Revenue Management*. Boston, Kluwer Academic Publishers, 2004.
- [4] D. Zhipping and M.Huaifu, *An Engineering Pricing Model for Scenic Spots Based On Revenue Management*. System Engineering Proceedia, 1, 279-285, 2011.
- [5] M.J. Drake, *Optimal Timing of Switches between Product Sales for Sports and Entertainment Tickets*. School of Business Duquesne University Atlanta, 2007.

# Customer Perception Towards Green Bag and Its Distribution System in A Retailer A Case Study in P.T. Carrefour Indonesia

Ketut Gita Ayu<sup>a</sup>, Farida Suhendra<sup>b</sup>, Merry Aulia Purwanti<sup>c</sup>, Christiani Purnomo<sup>d</sup>

<sup>a</sup> Industrial Engineering, BINUS University, Jakarta 11480  
E-mail : kgayu@binus.edu

<sup>b</sup> Industrial Engineering, BINUS University, Jakarta 11480  
E-mail : farida\_suhendra@gmail.com

<sup>c</sup> Industrial Engineering, BINUS University, Jakarta 11480  
E-mail : merry\_aulia@yahoo.com

<sup>d</sup> Industrial Engineering, BINUS University, Jakarta 11480  
E-mail : nina\_christiani@yahoo.com

## ABSTRACT

Case study is conducted in one of the leading retailers in Jakarta to determine its customer favorable green bag with aim to increase its usage through fitted distribution system for sustainability of Go Green program. Questionnaire with a sample of 357 is conducted in five Carrefour stores within Jakarta regions to uncover the favorable type of green bag by the retailer customers. Cloth bag (39%) is found to be favorable and customers are fully aware of its eco-friendly property (42%). A follow-up questionnaire and face to face interview with 350 customers is carried out in the stores located in North and East Jakarta. 95.43% of the respondents claim to support the replacement of plastic to cloth bag and 55.14% of the respondents prefer big cloth bag made from spun-bond nonwoven (51.71%) with a tote type (59.43%) and standout design (66.86%). Cloth bag distribution system is later designed based on customers' preference of having one free cloth bag for a minimum amount spent (58%).

## Keywords

Cloth bag, retailer, distribution system

## 1. INTRODUCTION

### 1.1. Go Green Program

Awareness on the environment issues arises worldwide as can be seen with the various "go green" programs proposed by multinational companies such as General Electric, McDonalds, Starbucks, Body Shop, Wal-Mart, Whole Foods, Honda, Hewlett-Packard, and many more. At first, it appears that going green will cost more in the short-term; however these companies aware that going green will pay off in the long-term with reputation points and invaluable word of mouth endorsement by the customers. In its simplest form, going green means elimination of wastes which save money leading to sustainability. For example, Wal-Mart, the multinational consumer goods retail company, introduced innovative ways to reduce waste and forced thousands of Wal-Mart suppliers to embrace sustainability from reducing packaging size which save approximately \$3.4 billion a year to reduction in overall carbon emission rate by 16 percent from 2005 to 2008. Wal-Mart's green course is triggered by its awareness on their customer trend and behavior towards sustainability issues. Wal-Mart's 2010 progress report on sustainability shows sharp reduction in plastic bags usage and reduction of printouts of store reports which worth \$20 million saving [2].

### 1.2. Plastic Bags in Retail Industries

The use of plastic bags in retailing became widespread in supermarkets in developing countries such as Indonesia since 1990s with rate of 500 billion to 1 trillion plastic bags annually. The plastic shopping bags in corporate retailing or traditional market are increasingly seen as more of an environmental hazard instead of convenience. This triggered various regulatory policies to control the use of plastic bags and researches on the public costs of plastic bag usage. It takes hundreds of years for a plastic bag to degrade and their existences quickly fill up landfills [7]. In 2009, a research is conducted by Greeneration Indonesia in over five major cities in Indonesia and it showed that 700 plastic bags are used per person per year. In other words, over 41 billion plastic bags are used in 2010 [13] and Jakarta alone generates 13.25% plastic waste of 6000 ton of waste every day.

### 1.3. Green Bag Distribution Program

P.T. Carrefour Indonesia started “Go green” program over four years ago. Carrefour customers are able to purchase a green bag located near the cashier for IDR 2,000 or IDR 10,000. Shall the bag torn or unusable, customers may exchange it with a new one in any Carrefour store as long as it is still within the six-month warranty period. Unfortunately, the response from its customers is not as expected. Based on a brief random observation conducted in several Carrefour stores in Jakarta vicinity on March and April 2012, none of the Carrefour customers purchase nor use a green bag when they do shopping in Carrefour. This fact triggers the need to examine their customers’ awareness of its “go green” program and their preference on the attributes of green bags which later on can be used to plan a more effective and efficient green bag distribution system.

## 2. LITERATURE REVIEW

### 2.1. Questionnaire and Interview

The purpose of qualitative research is to find out a person’s perspective. Questions which are perceived as invasion of privacy or confrontation can be better obtained from qualitative methods through a formal, structured-survey. Self-administered questionnaire must reconcile to closed-end questions which allow the respondents to simply checking a box or circling the proper response [1].

The assignment of numbers is made according to rules that should correspond to the properties of the question items. Four types of measurement scales are nominal (dichotomous “yes” or “no” scale), ordinal or rank order (comparative), interval (Likert, Stapel, semantic-differential), and ratio (certain scales with special instructions). Attitude rating scales are generally classified as for single-item scales and multiple-item scales. Single-item scales only have one item to measure a construct and the itemized-category scale is the most widely used although in some situation comparative scales, rank-order scales, or constant-sum scales are used. Multiple-item scales are commonly used to measure attitude toward complex objects [1].

Individual interviews are conducted face to face with the respondents and have two basic types: nondirective and semistructured where the differences lie in the amount of guidance the interviewer provides [1]. The success of interview depends on the interviewer, respondent, guiding skill of the interviewer, and the ambiance of the interview session. Unfortunately, face-to-face interview method may generate high cost and there is a possibility that the responses are affected by how the interviewer phrases the questions but structured interview can overcome this problem. Observation methods are often not considered due to its limitation in providing information on current behavior. Yet, direct observation is frequently used to obtain insights into research behavior or related issues. Observational methods suffer similar limitation as the face-to-face interview.

### 2.2. Descriptive Statistics

In practice, underlying probability distribution mass function is commonly unknown. However, it can be estimated through taking a random sample as representative sample. Data observations can be either categorical or nominal data. Categorical data record several categories or types an observation takes while numerical data may be either integers or real numbers [8]. Once a data set has been collected, it can be summarized by simply recording the frequencies of occurrences which later can be used to find the underlying necessary information.

### 2.5. Green Bags

Degradable plastic bag is a type of green bags which within reasonable amount of time, can be biologically broken down into their base compounds [4]. The synthetic bag is polyethylene blended with a prodegradant additive to increase the speed of decaying process. The disadvantage of this bag is if it ends up in landfill, they will degrade faster than conventional polyethylene bags which could potentially increase the degradation of food waste and contribute to greenhouse gas generation when they degrade [5].

Paper bag [5] has higher degradation rate, over a 6-month period, compared to other materials. Moreover, it is highly recyclable. Unfortunately, if it is compared to degradable plastic bag, it has higher contribution to global warming. This is because the pulping and bleaching processes produce higher air emissions and waterborne waste compared to plastics manufacture. Moreover, there is environmental impact of timber growing and harvesting on land degradation and biodiversity. Although the cost of paper bag is approximately 4-5 times more than plastic bag, paper bag is claimed to be more prestigious and commonly used in upper class society [10].

Cloth or so called reusable bag delivers environmental gains over the full life cycle of the bag. Reference [5] explains that supermarket sector has estimated an increase of 5 seconds in every transaction for using reusable bags which could result in

additional costs to the customers as well as other costs such as administration, stolen goods and equipment, auditing, monitoring, and education. Despite the fact that cloth bag will increase the costs, it give major benefits in material reduction or resource savings and reduction in litter.

### 2.6. Cloth Bag Materials

Drab or calico is a not fully processed plain-woven textile made from unbleached and may contain unseparated husk parts. Drab bag can be used for approximately 1 year and is stronger than plastic bag. The drawback of drab is the raw material requires 10% pesticide and 25% insecticide [5]. Frings [6] states that producing cotton with 100% pesticide and insecticide free will increase the cost up to 30%. Canvas [15] is an extremely heavy-duty plain-woven fabric. The modern canvas is made of cotton or linen and it comes in two basic types: plain and duck (tighter threads). It can also be made from polyester, acrylic to replace wool, or nylon to replace silk [14].

Jute is a rain-fed crop with little need for fertilizer or pesticides and is 100% biodegradable. IGD predicts by 2014, biodegradable bag such as jute bag will replace polyethylene bag [9] although currently is not preferable by the shopper because of its rough surface, not waterproof, and cost more [12, 3]. Spun bond nonwoven is a fabric-like material made from long fibers bonded together by chemical, mechanical, heat, or solvent treatment [11]. Typically, it is lack of strength unless densified by a backing. Spun bond nonwoven can be recycled after use, given the proper treatment and facility which make this bag eco-friendly compared to the other types of green bags [4]. Its fabric provides functions such as liquid repellence, resilience, stretch, softness, washability, and cushioning [6]. These properties allow this type of material achieve good balance between produce use-life and cost.

## 3. FIRST QUESTIONNAIRE RESULT ANALYSIS

### 3.1. Overall Customers' Behavior

For population with infinite number, a minimum of 349 responses is needed in order to have error rate up to 5%. The first questionnaire is distributed to Carrefour customers in five different stores in which each store represents each county in Jakarta: Carrefour Puri Indah (West Jakarta), Carrefour Menteng Prada (Central Jakarta), Carrefour Mall of Indonesia (North Jakarta), Carrefour Ambassador (South Jakarta), and Carrefour Cempaka Putih (East Jakarta). Approximately 70 responses are collected from customers in each representative store. This questionnaire consists of 15 items which measure customers' awareness level of environmental issue, Carrefour "Go Green" program, and, their preferences among grocery bags (degradable plastic bag, cloth bag, and paper bag). A total of 357 responses were collected for the first questionnaire with results as follow. Variation of the items sold (39%) and its strategic location (38%) become the important aspects for the customers to do grocery in Carrefour whereas price (19%) is ranked afterward (See Figure 1: **Customer's Main Reason Selecting Carrefour**). This implies that shall a strategy is chosen which requires an increase in item cost(s), such increment may not give significant impact which triggers Carrefour's customers to shop in other retailers because Carrefour competitive advantages are in location and the variation of the items sold.

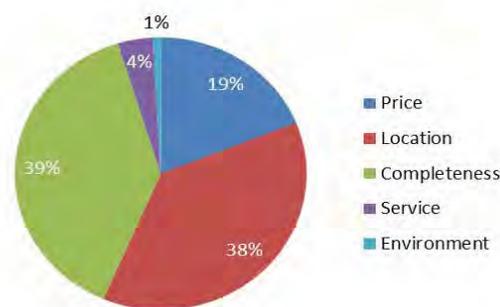


Figure 1: Customer's Main Reason Selecting Carrefour

95% of Carrefour customers are aware of the environmental issue can be supported through introducing green products to the society and 98% of the customers support Carrefour "Go Green" plan through the implementation of green bags. Among the three types of grocery bags, 50% of customers remain prefer degradable plastic bags compared to cloth bags (39%) and paper bags (11%) yet they believe that cloth bags (42%) and paper bags (36%) are environmental friendlier than degradable plastic bags. Apparently, as can be seen in *Table 1: Customers Reasons to Choose Selected Types of Bag*, the customers will choose degradable plastic bags mainly if it is environmental friendly (39%) and free of charge (32%). Similar observation was

conducted to the other two bags. Customer will choose cloth bag mainly if it is durable (31%) and paper bag will be chosen if it is environmental friendly (33%).

Table 1: Customers Reasons to Choose Selected Types of Bag

	Plastic bag (%)	Cloth bag (%)	Paper bag (%)
Free of charge	32	20	18
Durability/Reusability	18	31	19
Environment	39	19	33
Design	7	18	18
Others	5	11	11

By ranking the preference of the customers for each type of bag, it can be concluded that the main reasons for the customer choosing a particular bag is mostly due to its environmental friendliness, reusability or durability, and free of charge with weight quite indifferent among the three criteria (See Table 2: *Weighted Average on Customers' Preference of Each Type of* ).

Table 2: Weighted Average on Customers' Preference of Each Type of Bag

	Average	Plastic bag	Cloth bag	Paper bag
Free of charge	3.50	4	4	2.5
Durability/reusability	4.00	3	5	4
Environment support	4.33	5	3	5
Design	2.17	2	2	2.5
Others	1.00	1	1	1

The top three reasons are further evaluated except the environmental support factor. As for reusability factor, evaluation is conducted on the frequency of reusing the bag. A correlation is found between customer's preference on bags and its reusing frequency. As stated previously, the customers prefer degradable plastic bags (50%) compared to cloth bags (39%) and paper bags (11%). The frequency of reusing the bags is also reduced significantly from plastic bags to cloth bags and paper bags (see Table 3: *Frequency of Reusing Bags*) as their bag preference changes.

Table 3: Frequency of Reusing Bags

Reuse frequency	Plastic bag (%)	Cloth bag (%)	Paper bag (%)
Always	17	10	7
Usually	30	32	15
Sometimes	42	43	49
Never	11	15	28
Others	0	1	1

The last factor, free of charge, is then evaluated by obtaining input from the customers as for the price range for cloth bag. Degradable plastic bags are not evaluated because the cost of it by default is zero whereas the paper bags are evaluated yet not discussed considering paper bags are the least favorable grocery bags for Carrefour customers. 17.93% of the customers are willing to pay up to IDR 10,000, 17.37% of the customers prefer to have the bag for free, and 17.37% of them prefer to pay no more than IDR 5,000.

### 3.2. Gender Based Customers' Behavior

Clustering the responses based on gender (105 male and 251 female), in general there is no indifference as for the main reasons the customers shop in Carrefour, preference on grocery bags, frequency of reusing the bags, as well Carrefour's "Go Green" program. However, as for the awareness on environment friendly products, female respondents have different insight with the male respondents. 48% of the male respondents believe that paper bag is environmental friendlier than cloth bag (38%) whereas only 31% of the female respondents believe that paper bag is environmental friendlier than cloth bag (44%).

Moreover, the three main reasons female respondents will decide to use cloth bags are if the cloth bag is durable and reusable, has an attractive design, and free whereas the male respondents chose cloth bags if it is durable, reusable, supports environment, and free. As for paper bag, female respondents will choose such bag if it supports environment, durable, reusable, and has an attractive design, however, the males are focusing more onto its support towards environment, durable, reusable, and free of charge (see Table 4: *Customers Reasons to Choose Selected Types of Bag (Based on Gender)*).

Table 4: Customers Reasons to Choose Selected Types of Bag (Based on Gender)

	Plastic bag (%)		Cloth bag (%)		Paper bag (%)	
	M	F	M	F	M	F
Free of charge	32	31	24	18	18	18
Durability/reusability	18	18	30	32	20	19
Environment	39	39	27	16	36	32
Design	7	7	11	22	17	19
Others	4	5	9	12	9	12

By weighting customers' preference for each type of bag, as can be seen in *Table 5: Weighted Average on Customers' Preference on Grocery Bags (Based on Gender)*, both male and female respondents will choose a certain type of bag based on its support towards environment and reusability whilst free of charge and design becomes the third important aspect for male and female customers, respectively.

*Table 5: Weighted Average on Customers' Preference on Grocery Bags (Based on Gender)*

	Average	
	Male	Female
Free of charge	<b>3.33</b>	3.00
Durability /reusability	<b>4.00</b>	<b>3.83</b>
Environment	<b>4.67</b>	<b>4.00</b>
Design	2.00	<b>3.17</b>
Blank	1.00	1.00

Although in the overall, gender does not give significant effect on the behavior of the Carrefour customers, disparity between answers in certain factors are quite significant. For instance, while both degradable plastic bags and cloth bags are still favorable for both genders, the percentage disparity between these two bags is wider for male (19%) compared to female (7%). In addition, as for the necessity to "go green" issue, most of the female respondents chose "somewhat agree" whereas male customers show almost no difference between "agree" and "somewhat agree." This finding is confirmed further with the fact that 100% of the male respondents "somewhat agree" and "agree" that Carrefour shall "go green" whereas female respondents only 97%.

*Table 6: Cloth Bag Price (Based on Gender)*

	Male		Female	
	Max Price IDR 5,000	Max Price IDR 10,000	Highest	IDR 0
Max Price IDR 5,000	51.4	62.5	16	18
Max Price IDR 10,000	31.4	40.6	14	<b>19</b>
Highest IDR 0	16	18	<b>17</b>	18
IDR 5,000	14	<b>19</b>		
IDR 10,000	<b>17</b>	18		

From *Table 3: Frequency of Reusing Bags*, most of the male respondents are willing to pay up to IDR 10,000 per cloth bag and female respondents prefer to pay no more than IDR 5,000 per cloth bag. Carrefour female customers are more willing to spend compared to the male customers to obtain a cloth bag according to their preference.

### 3.3. Region Based Customers' Behavior

Region based clustering epics different information related to Carrefour customers' behavior. Customers in West, Central and North Jakarta believe that cloth bags are environment friendlier than the other type of grocery bags. However, South Jakarta customers believe the opposite and it is confirmed by 67% of them (highest response) supports the implementation of paper bags in Carrefour outlets.

East Jakarta customers equally believe that both cloth and paper bags are environment friendly. In fact, among the five regions, East Jakarta customers are the most supportive ones towards green bags (99%) as well as Carrefour "go green" program (100%). As for preference among bags, customers in all regions except North Jakarta prefer degradable plastic bags over cloth bags and paper bags. Whilst, customers in North Jakarta have equal preference amongst plastic and cloth bags and Central and East Jakarta considerably prefer plastic bags among the other bags (see *Table 7: Customers Preference on Grocery Bags (Based on Region)*).

*Table 7: Customers Preference on Grocery Bags (Based on Region)*

	West (%)	Central (%)	North (%)	South (%)	East (%)
Plastic bag	44	<b>54</b>	<b>46</b>	47	<b>55</b>
Cloth bag	37	34	<b>46</b>	41	37
Paper bag	17	11	7	11	8
Blank	1	0	0	1	0

For all regions, the top three customers' preference is indifferent for plastic bags: free of charge, durable, reusable, and support environment. As for cloth and paper bags, on the other hand, different region shows different preferences as can be seen in *Table 8: Customers Reasons to Choose Selected Types of Grocery Bags (Based on Region)*<sup>8</sup>. Design becomes an important factor for North and South Jakarta while free of charge, reusability, and support towards environment remain in the top three factors for the other regions.

Table 8: Customers Reasons to Choose Selected Types of Grocery Bags (Based on Region)

	Plastic bag (%)					Cloth bag (%)					Paper bag (%)				
	West (W)	Central (C)	North (N)	South (S)	East (E)	W	C	N	S	E	W	C	N	S	E
Free of charge	37	21	32	27	39	29	19	15	19	17	21	19	18	14	18
Reusability	15	11	30	20	14	31	39	34	30	24	23	19	20	26	10
Environment	33	57	27	43	35	12	23	30	20	11	28	41	35	39	23
Design	11	6	10	7	0	17	13	20	30	13	20	16	25	19	13
Blank	4	4	1	3	11	11	7	1	1	35	8	6	1	3	37

In overall, West, East, and Central Jakarta customers are indifferent. Their preference is on free-environment friendly-reusable bags, whereas South Jakarta emphasize not only on environment friendliness and reusability of the bag but also its attractive design. North Jakarta customers, on the other hand, prefer environment friendly and reusable grocery bags with equal importance level on free of charge and design.

Table 9: Weighted Average on Customers' Preference on Grocery Bags (Based on Region)

	West	Central	North	South	East
Free of charge	4.00	3.50	3.00	2.67	3.67
Durability /reusability	4.00	3.83	4.00	3.83	2.67
Environment	3.67	4.67	4.00	4.33	3.00
Design	2.33	2.00	3.00	3.17	1.67
Blank	1.00	1.00	1.00	1.00	4.00

As can be seen in Table 10: **Cloth Bag Price (Based on Region)**, Central and North Jakarta customers are willing to pay up to IDR 5,000 per cloth bag. West and East Jakarta customers are willing to spend up to IDR 10,000 per cloth bag whereas South Jakarta customers believe that they should get the cloth bag for free. It can also be seen from the table that Carrefour customers in West Jakarta is more willing to pay certain amount to obtain a cloth bag compared to the other regions.

Table 10: Cloth Bag Price (Based on Region)

		West (%)	Central (%)	North (%)	South (%)	East (%)
Cloth bag price	Percentage on each amount					
	IDR 0	15	10	17	24	21
	IDR 5,000	13	20	18	21	14
	IDR 10,000	23	17	15	10	24
Maximum amount will be spent for a cloth bag	IDR 5,000	65	57	61	54	58
	IDR 10,000	51	30	39	26	42

#### 4. SECOND QUESTIONNAIRE RESULT ANALYSIS

Based on the first questionnaire evaluation on region based responses, it can be concluded that 97% of North Jakarta customers, in fact, support Carrefour "go green" program and their preference between degradable plastic bags and cloth bags is indifferent. East Jakarta, on the contrary, is the most supportive towards Carrefour "go green" program (100%) despite the fact that degradable plastic bags (55%) become their preference.

Thus, second questionnaire and interview are completed for 350 respondents total in two Carrefour outlets (175 respondents on each outlet) to find the mean to distribute the cloth bag as well as their preference on the material used, size, design, and type of cloth bag. One outlet in each North Jakarta, Emporium Pluit, and East Jakarta, Tamini Square, are chosen as representatives of the best and worst possible success rate of cloth bag distribution system.

##### 4.1. Gender Based Cloth Bag Preference and Distribution System

Both female (269 respondents) and male (81 respondents) customers prefer to obtain one free cloth bag for every minimum amount spent instead of stamp collection program. Furthermore, to ensure sustainability of using the green bag, both genders agree on having point collection for every usage of green bag when they do their grocery in Carrefour which later can be exchanged to a gift or voucher as can be seen in Table 11: **Cloth Bag Distribution System**. Both male and female respondents prefer spun bond nonwoven tote cloth bag but male respondents prefer medium size cloth bag while female respondents choose large size cloth bag (see Table 12: **Cloth Bag Features**).

Table 11: Cloth Bag Distribution System (Based on Gender)

How to get the green bag?	M (%)	F (%)
Minimum amount spent	78	65
Stamp collection	21	35
Others	1	0

Reward on using the green bag in the next visit	M (%)	F (%)
Cash back	35	33
Point collection	<b>65</b>	<b>67</b>

Table 12: Cloth Bag Features (Based on Gender)

Material	Size		Carrying Style	
	M (%)	F (%)	M (%)	F (%)
Drab/Calico	16	17	Tote	<b>36</b>
Canvas	12	17	Handbag	20
Jute	12	17	Messenger bag	8
Spun bond nonwoven	<b>59</b>	<b>49</b>	Backpack	6

#### 4.2. Region Based Cloth Bag Preference and Distribution System

Irrespective the regions, as can be seen in the following Table 13: *Cloth Bag Distribution System (Based on Region)*, both North and East Jakarta customers prefer to obtain a cloth bag for every minimum amount spent and obtain point rewards every time they use the green bag instead of plastic bag for carrying the purchased items. Additionally, spun bond nonwoven large size tote green bag is preferable for both North and East Jakarta customers (see Table 14: *Cloth Bag Features (Based on Region)*).

Table 13: Cloth Bag Distribution System (Based on Region)

How to get the cloth bag?	North (%)	East (%)
Minimum amount spent	<b>65</b>	<b>71</b>
Stamp collection	34	29
Others	1	0

Reward on using bag the next visit	North (%)	East (%)
Cash back	34	32
Point collection	<b>66</b>	<b>68</b>

Table 14: Cloth Bag Features (Based on Region)

Material	Size		Carrying Style	
	North (%)	East (%)	North (%)	East (%)
Drab/Calico	20	14	Shoulder	<b>60</b>
Canvas	16	15	Hand	25
Jute	15	17	Messenger	7
Spun bond nonwoven	<b>49</b>	<b>54</b>	Backpack	9

#### 4. CONCLUSION

A descriptive research is conducted to find Carrefour customers awareness on Carrefour “go green” program and their preference on the attributes of the favorable green bags. Two questionnaires were distributed with 357 respondents for the first questionnaire and 350 respondents for the second one.

From the analysis of the first questionnaire, in the overall, the main reasons Carrefour customers choose a particular bag is mostly due to its environmental friendliness, reusability durability, and free of charge with weight quite indifferent among the three criteria. This is confirmed by performing further analysis which shows that customers’ preference among the green bags is positively correlated with the frequency of reusing the bags. As for pricewise, excluding degradable plastic bags, 17.93% of the customers is willing to pay up to IDR 10,000, 17.37% of the customers prefer to have the bag for free, and 17.37% of them prefer to pay no more than IDR 5,000. This explains why the current Carrefour “go green” program is quite unsuccessful.

Male and female respondents show indifferent focus on the attributes of preferable green bags: environment support and reusability. However, male customers prefer free of charge as the third important aspect from green bag distribution and they fully support Carrefour “go green” program. Design becomes the third important aspect for female customers and they prefer to pay no more than IDR 5,000 per cloth bag. Yet, they are more willing to spend compared to the male customers to obtain a cloth bag which comply with their preference.

North Jakarta customers somewhat is the least supportive on Carrefour “go green” program among the other regions and their preference between degradable plastic bags and cloth bags is indifferent. Shall they have to purchase a cloth bag with a maximum price of IDR 5,000 will trigger them to purchase the cloth bag as long as the design is according to their preference. South Jakarta also believes that attractive design is important, yet they prefer to get the cloth bag for free. East Jakarta is the most supportive towards Carrefour “go green” program despite the fact that degradable plastic bags become their preference

and they are willing to spend up to IDR 10,000 per cloth bag. West Jakarta customers are also willing to pay no more than IDR 10,000 per cloth bag.

Per the evaluation on the second questionnaire and interview, regardless the gender and best or worst possible regions, Carrefour customers prefer spun bond nonwoven tote green bag. The different is only for the size of the green bag whereas the male customers prefer the medium size whilst the female customers prefer the large size.

## 5. FURTHER RESEARCH

A standout design yet ergonomics green bag and minimum amount the customers are willing to spend shall be done as follow up on the results of this preliminary research to determine the most effective and efficient green bag distribution system. The transportation modes Carrefour customers use to go to the location shall also be taken into consideration in creating the most suitable grocery green bag.

In addition, considering the preference of green bags for most customers are remain in degradable plastic bags, whilst degradable plastic bag is somewhat the least environment friendly among the other type of green bags, further analysis shall be done to determine how much extra amount is the customers willing to pay for each plastic bag which will trigger them to switch to utilize cloth bag instead of plastic bags or decide to do their grocery in another retailer.

## 6. REFERENCES

- [1] David A. Aaker, V. Kumar, George S. Day, *Marketing Research*, John Wiley & Sons, 2003, Ch. 8, 11, pp. 189-216, 282-305.
- [2] B. Burrough. "Behind the greening of Wal-Mart," 14 May 2011. 10 October 2012. <[http://www.nytimes.com/2011/05/15/business/15shelf.html?\\_r=0](http://www.nytimes.com/2011/05/15/business/15shelf.html?_r=0)>.
- [3] F. Case. "The innovative world of nonwoven fabrics," *International news on Fats, Oils, and Related Materials*, INFORM, vol 15, no. 10, pp. 688-689.
- [4] R. Dilli. "Comparison of existing life cycle analysis of shopping bags alternatives: Final Report, " *Sustainability Victoria*, 2007.
- [5] Department of the Environment and Heritage, "Plastic shopping bags – analysis of levies and environmental impacts: Final Report," *Environment Australia*, 2002
- [6] G. S. Frings, G.S. *Fashion: From Concept to Customer*. New Jersey; Pearson Prentice Hall, 2008
- [7] K. Gupta. "Consumer responses to incentives to reduce plastic bag use: evidence from a field experiment in urban India," Kathmandu, Nepal: South Asian Network for Development and Environmental Economics (SANDEE), 2011.
- [8] Anthony Hayter, *Probability and Statistics for Engineers and Scientists*, Thomson Brooks/Cole, 2007, Ch. 6, pp. 265-277
- [9] M.A. Hossain. "Ensure fair price to jute growers." *The Financial Express*.
- [10] A. Kaplan. "Paper or plastic? Macy's won't ask: a Stalwart of style at prominent department stores, the paper bag with handles is no longer the norm." *McClatchy - Tribune Business News*: 1. Jun 29 2007. *ProQuest Research Library*. Web. 29 Dec. 2012.
- [11] S. Limem, S. B. Warner, "Adhesive point-bonded spun bond fabrics." *Textile Research Journal*, vol. 75 no. 1, pp. 63-72.
- [12] M. R. K. Munna. "Prospect of jute bags in the global perspective," *The Financial Express*.
- [13] S. Rejeki, Susie Berindra. "Reduce plastic bags, now!" (in Indonesian) *KOMPAS* 13 July 2012: 34.
- [14] L. M. Surhone, M.T. Timpledon, S.F. Marseken. *Resist Dyeing, Textile Dyeing, Tie-dye, Batik, Printmaking, Screen-printing, Reactive dye*. Mauritius: Betascript Publishing.
- [15] J. Udale. *Basic Fashion Design: Textiles and Fashion*. Worthing: AVA Publishing, 2008

# Value Chain Upgrading Scheme of Thermoplastic Recycling Manufacturing Systems: A Product Quality Perspective

Djoko Sihono Gabriel

Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail: dsihono@yahoo.com

## ABSTRACT

In this research, main problem of (thermo) plastic recycling system is focused in gaining more benefit through better quality of products. Therefore, how to measure product quality of recycled products and then to formulate appropriate quality improvement within its context in a value chain upgrading schemes are very important. Development of quality improvement and value chain upgrading scheme through its manufacturing system capability was carried out through literature survey as well as analyses based on its stages of operation.

A new set of capability indicators and indexes were proposed in this research, used in assessing a recycling system capability, both its strength and weakness, through a comprehensive comparison of recycled products characteristics to its virgin material. A focused direction within a comprehensive scheme of value chain upgrading in a perspective of product quality improvement also proposed based on manufacturing processes knowledge as reference in weakness elimination or reduction program within an individual firm.

This new constructed knowledge provides clear directions to (thermo) plastic recycling firms in improving product quality through their manufacturing capabilities enhancement which also important to policy makers, regulators as well as facilitators in supporting programs for plastic recycling industry development. Buyers of recycled plastic also can use it in evaluating quality of recycled (thermo) plastic according to raw material specification required by their end product.

## Keywords

*Plastic recycling, capability, value chain, product characteristics*

## 1. INTRODUCTION

Existence of post-consumer plastic cause a lot of environmental problems, but if managed properly, these material has some potential to be recycled. Previous research on plastic recycling performance according to Andradý [1], Dijkgraaf & Vollebergh [2], Grosse [3], Gunter & Kaulich [4], Manrich and Santos [5], Kaufman & Themelis [6], Simmons, Kaufman and Themelis [7], more focused on elimination of waste quantity and its negative impact to environmental quality. Recycling performance was also assessed in different perspective, financial benefits, like another business activities, as stated by Cokins [8], Vadgama [9], Gomes, Yasin and Lisboa [10], and Gomes, Yasin and Lisboa [11]. Ehrenfeld [12], the European Commission [13], Huisman and Stevels [14], Lal [15], Ouattara, Azzaro-Pantel, Pibouleau, Domenech, Baudet and Yao [16], and Prasad, Pagan, Kauter and Price [17] combined those two perspectives of assessment, known as eco-efficiency.

Assessment perspective of recycling systems that focused on value chain upgrading according to Kaplinsky and Morris concept [18] as well as its roadmap on value chain upgrading has not been a concern amongst current research. Manufacturing capability to produce recycled material based on the characteristics of virgin material become a strategic issue, so with a higher quality of product will strengthen financial and economic feasibility of the recycling business. More recycled plastic waste in better quality of product will be more financial and economic benefits as well as reduce more negative impacts and virgin material consumption in plastic goods industry.

### 1.1. Plastic

Polymers can be either rubber or elastomeric, and plastic. According to Barry, Baker and Mead [19] plastics can be classified further into thermoset and thermoplastic. Because of huge difficulties in recycling of thermoset, this research focused on one derivate of thermoplastic. Thermoplastic is in a solid state at room temperature, but transformed into viscous liquid when heated to a certain temperature, and so financially feasible to be produced in various forms of goods for many purposes. This type of plastic can be repeated cycles of heating-cooling without significant degradation that allow for recycling. Examples of thermoplastic are poly ethylene (PE), poly vinyl chloride (PVC), poly propylene (PP), poly styrene (PS) and nylon.

### 1.2. Plastic Consumption and Generating of Its Waste

According to the Coordinating Ministry for Economic Affairs [20], imports of plastic materials in Indonesia reached U.S. \$ 3,419 million and imports of processed plastic U.S. \$ 743 million, while its export values were respectively U.S. \$ 960 million and U.S. \$ 680 million in 2010. Production capacity of plastic polymer consisting of PE, PP, PVC and PS in Indonesia is 2,010 metric tons per year with a per capita consumption of 7.44 kg and generated 1.008 million metric tons waste as stated by Adibroto [21]. For all types of goods according Meidiana & Gamse [22], average waste generation was 1.12 kg/capita/year, of which 14% was in plastic waste, increased about 4 times from previous six years.

### 1.3. Problems and Opportunities

Recycled of thermoplastic is one of important alternatives of material or substitution of plastic virgin material. Recycled thermoplastic has more value if its properties meet a number of requirements in the manufacturing of plastic goods. Its value enhancements can be achieved through a value chain upgrading, which requires an effective strategic measurement of process capability.

Value enhancement of recycled thermoplastic will be achieved through availability of:

- (1) indicators and indexes that describe capability of a thermoplastic recycling, and
- (2) value chain upgrading schemes, developed based on those indicators and indexes, which also contribute a new knowledge within scope of this research.

## 2. MANUFACTURING SYSTEM OF THERMOPLASTIC RECYCLING

According to ASTM D5033-00 in Fisher [23], plastic, and also thermoplastic goods, can be recycled into raw materials with three different categories, with the fourth type of recycling called *quaternary recycling* does not produce material, but energy. *Primary recycling* produces material with characteristics similar to those of the original product or virgin material within this context. Product of *secondary recycling* has characteristics different from those virgin materials, and *tertiary recycling* produce basic chemicals or fuels from segregated plastic scrap or plastic material that is part of a municipal waste stream or other source. In a perspective of production by Manrich & Santos [5], primary and secondary recycling of (thermo) plastics called mechanical recycling with sequences: (1) identification, separation and classification of different types of Plastics; (2) grinding; (3) washing with or without addition of cleaning agents; (4) drying; (5) silos; (6) agglutination (films and products with fine thickness); (7) extrusion; and (8) granulation, can be viewed as a manufacturing system as shown in the figure below.

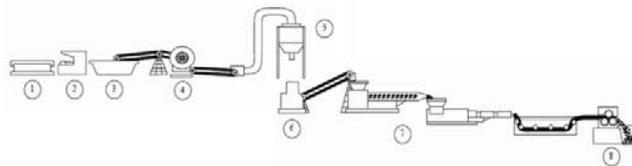


Figure 1.  
 Complete plastic recycling scheme of mechanical recycling (Manrich & Santos [5])

## 3. CHARACTERISTICS OF RECYCLED MATERIALS AS CAPABILITY INDICATOR

### 3.1. Purpose of Capability Indicator

According to Juntilla [24], quality of recycled (thermo) plastics are strongly influenced by operating capabilities of its manufacturing system and also related to its manufacturing performance. Operating capability is a performance integration of a complex tasks in producing output through implementation of technology and an efficient material flow, as stated by Hayes, Wheelwright, and Clark [25]. An appropriate indicator that able to recognize capabilities of a (thermo)plastic recycling system becomes an important tool in this context of research.

Indicators have numerous applications. They compress large amounts of information from different sources into a format easier to understand, compare and manipulate. Companies can use indicators to set targets and monitor consequent success. Interpretation becomes easier if targets can be set for the indicators themselves. These targets help the decision-maker visualize what actions will need to be emphasized in future. Gallopin [26] identifies the following major functions of indicators: (a) assessing conditions and trends in relation to goals and targets, (b) reflecting the status of a system, (c) providing early warning information, (d) anticipating future conditions and trends, (e) comparing across place and situations, and (f) highlighting what is happening in a large system.

More specific application, according to Azapagic and Perdan [27], indicators of sustainable production would enable identification of more sustainable options through: (a) comparison of similar products made by different companies, (b) comparison of different processes producing the same product, benchmarking of units within corporations, (c) rating of a company against other companies in the sector, and (d) assessing progress towards sustainable development of a sector. Krajnc

and Glavic [28] mentioned, to achieve sustainable production, a company should incorporate social and economic indicators as well. Most of the indicators included can be applied across industry. Capability indicators developed in this research will be used internally in measuring achievement of a (thermo) plastics recycling system. For this purpose it is necessary to evaluate quality indicators for optimizing its benefits. The four-phase criteria of indicator quality according to U.S. Environmental Protection Agency [29] are as follows: (a) conceptual relevance or soundness, (b) feasibility of implementation (current and future), (c) response variability, and (d) interpretation and utility.

### 3.2. Products and Materials

Plastic products are made of different types of polymer materials, so not all types of polymers tested in this research. Samples of virgin homo polymer pellet named Inflated Poly Propylene Film (IPP Film) and pellets of recycled products made from IPP Film produced by a factory in Solo and a factory in Bandung used as material in this research.

### 3.3. Measurement, Indicator and Index of Capability

In this research, quality of recycled (thermo) plastics pellets proposed as capability level of its recycling system. Characteristics of its virgin material (IPP Film), are used as important benchmark of capability measurement in assessing recycling system capability based on its quality of products. The required capability indicator is an indicator that able to identify discrepancy between quality of recycled (thermo) plastics pellets and quality of its virgin material pellets. Measurement of capability and its indicators are important in understanding capability of a manufacturing system. Recycling firms, policy makers and buyers of recycled products will take its advantages for their own interest.

Characteristics of plastic material by Shah [30] include mechanical, thermal, electrical, weather-related properties and optical properties and another hundreds of properties. Characteristics of material tested in this research were only properties that important for the products made from IPP Film homo polymers as its virgin material. Some mechanical, thermal and optical properties tested according to ASTM standards. Testing specimens prepared and tested by Polymer Technology Center - BPPT, Tangerang to test the melting point temperature and luminous transmittance level, and by Testing and Calibration Laboratory, Center for Chemical and Packaging, Jakarta to another tests.

In this research, a radar chart proposed in mapping of testing results of four types of specimens: virgin material of IPP Film homo polymer, brown recycled materials, green recycled materials and transparent recycled material. But information in this chart is very difficult to interpret directly, because of huge different between nominal testing results figures between characteristics of material. So, its nominal figures of testing result could be transformed in a more accurate manner. Purpose of radar chart will appear by using percentage of value, a comparison between testing result figures of recycled materials to its virgin material. Testing result of virgin material used as reference point with 100% score. Both higher and lower than figure of virgin material are assessed below than 100%.

In reviewing status of a recycling system capability, this research proposed a set of indicators which reflect discrepancies between characteristics of recycled materials and its virgin material. A recycled material is stated as perfect if it has characteristics similar to its virgin material. Discrepancies between characteristics of those materials reflect lower quality of recycled material compared to its virgin material. Higher discrepancies reflect lower quality of recycled material and proposed as lower capability of its recycling system.

Table 1: Specimen Characteristics Figures and Capabilities of Recycling Systems

Material characteristics	Measurement of specimen characteristic & capability indicator	Average Testing Results & Capability Indexes of Recycling System (%)			
		Virgin material	Brown recycled material	Green recycled material	Transparent recycled material
1 Density	Kilogram/liter	0.88	0.83	0.84	0.85
	Capability (%)	100%	94.3%	95.5%	96.6%
2 Tensile yield strength	Kilogram/cm <sup>2</sup>	374.08	364.54	356.95	367.36
	Capability (%)	100%	97.4%	95.4%	98.2%
3 Elongation yield strength	%	14.86	13.84	15.89	12.53
	Capability (%)	100%	93.1%	93.1%	84.3%
4 Notched Izod impact strength	Kg-cm/cm	7.28	7.31	7.56	7.08
	Capability (%)	100%	99.6%	96.2%	97.3%
5 Rockwell hardness	R scale	27.38	26.98	18.53	30.91
	Capability (%)	100%	98.5%	67.7%	87.1%
6 Vicat softening point	°C	160.73	160.63	158	159.87
	Capability (%)	100%	99.9%	98.3%	99.5%
7 Heat deflection temperature	°C	72.77	75.97	78.10	75.30
	Capability (%)	100%	95.6%	92.7%	96.5%
8 Melting point	°C	165.64	160.89	160.66	161.83
	Capability (%)	100%	97.1%	97.0%	97.7%

9	Luminous transmittance level (LTL) - total	%	23.61	13.34	11.00	19.55
		Capability (%)	100%	56.5%	46.6%	82.8%
10	LTL-NIR (near infra red)	%	35.71	23.5	20.55	30.43
		Capability (%)	100%	65.8%	57.5%	85.2%
11	LTL-Visible	%	23.11	11.28	8.36	18.74
		Capability (%)	100%	48.8%	36.2%	81.1%
12	LTL-Ultra Violet	%	4.27	0.54	0.48	2.93
		Capability (%)	100%	12.6%	11.2%	68.6%
<b>Average Capability Indexes of Recycling System</b>			<b>100%</b>	<b>80.0%</b>	<b>73.9%</b>	<b>89.6%</b>

Source:

Testing result by Polymer Technology Center, BPPT, Tangerang and Testing and Calibration Laboratory, Center for Chemical and Packaging, Jakarta

Stages of indicators measurement of a recycled material are as follow:

1. Result of a virgin material characteristic testing, i.e. 165.64 °C for its melting point, scored with 100%
2. Result of brown recycled material characteristic testing for its melting point is 160.89 °C, scored with  $1 - ((165.64 - 160.89)/165.64) = 0.971$  or 97.1%.
3. Both higher and lower figures of recycled material characteristic testing result reduce its quality with its nominal discrepancy to virgin material figure.

Figures of this indicator measurement reflect capability of a recycling system in a perspective of its recycled material quality, for the above example, its melting point. If a set of material characteristics considered, tested and calculated, will can be identified an overall indicators of a recycling system in those scope of material characteristics. Brown recycled material, show overall capability of its manufacturing system with 80.0%. This figure illustrates the overall capability index of a factory in Solo after produced a batch of brown recycled thermoplastic. Representation of these figures in a radar chart shows a visual interpretation with variation of discrepancies between material characteristics.



Figure 2. Radar Chart of Producers Capability for Four Sample of Materials

This chart revealed significant differences of capabilities between three manufacturing systems of thermoplastic recycling factories compared to the virgin material manufacturing system capabilities. For three samples of recycled material, its mechanical and thermal characteristics are assessed as “good” sample condition by the Testing and Calibration Laboratory. These results of mechanical and thermal characteristics testing are better than its optical properties, especially in luminous transmittance level for recycled material in brown and green. Overall index of capability of individual manufacturing system are 80.0%, 73.9% and 89.6% for brown, green and transparent recycled material producers. Specific capability index for each category of material characteristics especially with low and lowest capabilities reflect manufacturing problems at each factories of brown and green recycled products. For example in luminous transmittance level – ultra violet, manufacturing capability of brown recycled products has very deep discrepancy compared to its virgin material.

In managing thermoplastic recycling processes, these indicators and radar charts proposed as information as well as tools in measuring capabilities in a recycling systems. System status reflected by indicator figures can be used to measure effectiveness of management in a recycling system, in line with indicators implemented for sustainable development measurement by Bossel [31]. A weak status of a manufacturing system needs to be resolved through a product quality improvement scheme in a context of thermoplastic recycling system. For a recycled material, the higher its quality index, expected the higher its selling price. Quality index of a recycled material also reflects its capability to reduce virgin material consumption.

#### 4. VALUE CHAIN UPGRADING SCHEME

Value chain was introduced by Michael E. Porter in 1985 in a context of competitive advantage related to firm's cost and its uniqueness of capabilities. Diagram of a generic value chain was introduced by Ankli [32] as showed by the following figure. A more detailed value chain in thermoplastic recycling are constructed in eight series of major operation stages in term of plastic recycling processes sequence by Manrich & Santos [5].



Figure 3. Generic Value Chain by Porter According to Ankli [29]

Recycled materials in Indonesia are generally classified as *buyer-driven commodity*, therefore, its value chain categorized as *buyer-driven commodity chains* by Kaplinsky and Morris [18]. This fact is a serious problem in value chain upgrading of thermoplastic recycling systems, because specifications of products are more directed by dominant retailers or marketers that order recycled thermoplastic. Development of these class of products are more focused on product acceptance by customers, therefore recyclers have less attention in improving quality of their products products in broader perspectives of quality. In this type of business environment, producers have less opportunity to gain their advantages by selling product with higher price. Stakeholders interaction within this environment affected in a product category as secondary recycling with lower quality than its virgin material, so it can not be categorized into primary recycling according to Andradý [1].

If this buyer oriented paradigm not be resolved in a long term, producers are unable to optimize their quality of products. They are also unable to produce recycled thermoplastic with higher selling price, so the whole value chain is not in an optimum status. In other words, thermoplastics recycler in general tends to meet a market-driven pattern, to supply recycled thermoplastic material according to buyer's specifications, less consider initiative of producers. A breakthrough for this kind of market trap is urgently required in promoting role of recycled material producers. Appropriate capability enhancement is the answer in term of how to produce materials that exceed quality as buyer wants. Kaplinsky and Morris [18] proposed a comprehensive scheme named as value chain upgrading include: process upgrading, product upgrading, functional upgrading, and chain upgrading. Product upgrading as sub-scheme in thermoplastic recycling context directs producers to produce higher quality with better selling price rather than previous scheme directed by traders.

Product upgrading sub-scheme needs accurate information about recent quality of products that in a more specific purpose, reflected by characteristics of recycled thermoplastic as well as characteristics of its virgin material. Discrepancies between recycled thermoplastic characteristics and its virgin material plotted in a radar chart with supporting table of testing result figures. This set of information reflected capability indicator and index than can be used as a directive tool for product quality improvement, through a target of product quality. Target of product quality improvement should be followed with action plans based on detailed stage of operations in producing recycled thermoplastic. These efforts are categorized as process upgrading according to Kaplinsky and Morris [18]. Detailed value chain with eight consecutive processes adopted from Manrich & Santos [5] described in the following figure.



Figure 4.

Value chain in thermoplastic recycling system

- (1) identification, separation and classification; (2) grinding; (3) washing; (4) drying; (5) silos; (6) agglutination; (7) extrusion; and (8) granulation.

Product upgrading sub-scheme of brown recycled material illustrated pattern of action plans in a context value chain upgrading of thermoplastic recycling. This recycled product indicates low capability index of its manufacturing system in the characteristics of luminous transmittance level - visible, with 48.8% index. If this index will be upgraded from 48.8% to 70% for example, it is necessary to identify appropriate factors that influence its luminous transmittance level - visible. The next step is to evaluate its recent operations capability at eight stages of operation, starting from material separation to granulation. A comprehensive review identified a set of factors, impacts of influence and scheme of product upgrading related to each operation capability. The following table describes a value chain upgrading in a context of product upgrading sub-scheme, especially in improving recycling system's capabilities in order to enhance luminous transmittance level indicator of brown recycled pellet.

Table 2: Value Chain Upgrading Scheme in a Context of Product Upgrading Based on Luminous Transmittance Level Characteristics

	Affecting Factors on	Influence on Product	
--	----------------------	----------------------	--

No.	Operation*	Product Characteristics**	Characteristics**	Scheme of Capability Upgrading
1	Sorting of used thermoplastic	<ul style="list-style-type: none"> <li>Homogeneity of raw material type</li> </ul>	<ul style="list-style-type: none"> <li>Unpredictable characteristic of mixed material</li> </ul>	<ul style="list-style-type: none"> <li>Manual sorting improvement</li> <li>Automatic sorting improvement</li> <li>Optimization of sorting technology choice</li> </ul>
2	Grinding	<ul style="list-style-type: none"> <li>Homogeneity of size of grinded raw material</li> <li>Homogeneity of shape of grinded raw material</li> </ul>	<ul style="list-style-type: none"> <li>Not optimum washing process</li> <li>Not optimum flow of grinded material to the next process</li> </ul>	<ul style="list-style-type: none"> <li>Selection of optimum size of grinded raw material</li> <li>Selection of optimum shape of grinded raw material</li> <li>Optimization of size and shape of grinded raw material combination</li> </ul>
3	Washing or cleaning	<ul style="list-style-type: none"> <li>Residues and contaminants</li> </ul>	<ul style="list-style-type: none"> <li>Color of product</li> <li>Transparency of product</li> <li>Luminous transmittance level of product</li> <li>Visual performance of product</li> </ul>	<ul style="list-style-type: none"> <li>Selection of washing or cleaning methods</li> <li>Optimization of washing cost</li> <li>Optimization of method and cost of washing</li> </ul>
4	Drying	<ul style="list-style-type: none"> <li>Humidity level of material</li> <li>Humidity level and its homogeneity between part of materials</li> </ul>	<ul style="list-style-type: none"> <li>Color of product</li> <li>Transparency of product</li> <li>Luminous transmittance level of product</li> </ul>	<ul style="list-style-type: none"> <li>Selection of optimum humidity level</li> <li>Optimization of humidity level and its homogeneity between part of materials</li> </ul>
5	Feeding into silo	<ul style="list-style-type: none"> <li>Speed of feeding</li> <li>Continuity of feeding</li> </ul>	<ul style="list-style-type: none"> <li>Speed and quality of agglutination</li> </ul>	<ul style="list-style-type: none"> <li>Selection of optimum speed level</li> <li>Continuity of feeding improvement and control</li> </ul>
6	Agglutination	<ul style="list-style-type: none"> <li>Homogeneity of temperature</li> <li>Level of temperature</li> </ul>	<ul style="list-style-type: none"> <li>Homogeneity of plastic mass agglutination</li> <li>Color of product</li> <li>Transparency of product</li> <li>Luminous transmittance level of product</li> </ul>	<ul style="list-style-type: none"> <li>Selection of optimum temperature level</li> <li>Temperature of agglutination setting and control</li> </ul>
7	Extrusion	<ul style="list-style-type: none"> <li>Continuity of extrusion process</li> <li>Cooling temperature and process</li> </ul>	<ul style="list-style-type: none"> <li>More mechanical and physical characteristic rather than luminous transmittance level of product</li> </ul>	<ul style="list-style-type: none"> <li>Continuity of agglutination improvement and control</li> </ul>
8	Granulation	<ul style="list-style-type: none"> <li>Continuity of granulation process</li> <li>Size of granule</li> </ul>	<ul style="list-style-type: none"> <li>More mechanical and physical characteristic rather than Luminous transmittance level of product</li> </ul>	<ul style="list-style-type: none"> <li>Continuity of granulation improvement and control</li> </ul>

Source: \* Manrich & Santos [5]; \*\* Manrich & Santos [5] & Andrady [1]

## 5. CONCLUSION

Useful strategic knowledge for value chain upgrading of thermoplastic recycling systems were discovered by this research. Thermoplastic recycling systems as material producers need indicators and indexes of their capability as well as value chain upgrading schemes in improving their manufacturing capability. Producers are able to develop a more comprehensive value chain both of backward as well as forward value chain, therefore more innovative shared value will be created with more benefits for broader community according to Porter and Kramer [33].

On a broader scope of management policy makers, regulators and facilitators can also use these indicators as well as indexes in identifying capability of thermoplastic recycling systems in a region, which is useful in improving capabilities not only for a producer but also producers in a certain region. For public, especially users of recycled products can use these capability indicators and indexes in reviewing position of manufacturers in a context of their capabilities and product quality. They can choose recycled products which are appropriate for its specific uses in more optimum quality and cost, according to specifications required by the end product and its selling price.

## REFERENCES

- [1] Andrady, A.L., 2003. An Environmental Primer. In: Andrady, A.L., ed. *Plastic and the Environment*. Hoboken, New Jersey: John Wiley & Sons, Inc.

- [2] Dijkgraaf, E. and Vollebergh, H.R.J., 2005. Literature review of social cost and benefit of waste disposal and recycling, In: Rasmussen, C. & Vigsø, D. eds. *Rethinking the Waste Hierarchy*. Copenhagen: Environmental Assessment Institute.
- [3] Grosse, F., 2010. Is recycling “part of the solution”? The role of recycling in an expanding society and a world of finite resources. *Veolia Environnement*, vol. 3/1, p. 1-17.
- [4] Gunter, E. and Kaulich, S., 2006. Measuring Environmental Performance with EPM-KOMPAS Software Tool - Material Flow Analyses, Environmental Assessment and Success Control. In: Wagner, B. & Enzler, S., eds. *Material Flow Management. Improving Cost Efficiency and Environmental Performance*. New York: Physica - Verlag Heidelberg, A Springer Company.
- [5] Manrich, S. and Santos, A.S.F., 2006. An Overview of Recent Advances and Trends in Plastic Recycling, In: Loeffe, C.V., ed. *Conservation and Recycling of Resources: New Research*. New York: Nova Science Publishers, Inc.
- [6] Kaufman, S.M. and Themelis, N.J., 2009. Using A Direct Method to Characterize and Measure Flows of Municipal Solid Waste in the United States. *J. Air & Waste Management. Assoc.*, vol. 59, p. 1386-1390.
- [7] Simmons, P., Kaufman, S.M. and Themelis, N.J., 2006. Evaluating 110 Million Tons Calculation: State of Garbage in America Recycling Data Analysis. *BioCycle*, October 2006, p. 21-25.
- [8] Cokins, G., 2009. *Performance Management. Integrating Strategy Execution, Methodologies, Risk, and Analytics*. Hoboken, New Jersey: John Wiley & Sons, Inc.
- [9] Vadgama, A., 2006. SuperDraft: Activity-Based Costing/Management and Customer Profitability. In: Adkins, T., ed. *Case Studies in Performance Management, a Guide from the Experts*. Hoboken, New Jersey: John Wiley & Sons, Inc.
- [10] Gomes, C.F., Yasin, M.M. and Lisboa, J.V., 2004. A literature review of manufacturing performance measures and measurement in an organizational context: a framework and direction for future research. *Journal of Manufacturing Technology Management*, vol. 15/6, p. 511-530.
- [11] Gomes, C.F., Yasin, M.M. and Lisboa, J.V., 2007. An empirical investigation of manufacturing performance measures utilization. The perspectives of executives and financial analysts. *International Journal of Productivity and Performance Management*, vol. 56/3, p. 187-204.
- [12] Ehrenfeld, J.R., 2005. Eco-efficiency: Philosophy, Theory, and Tools. *Journal of Industrial Ecology*, vol. 9, number 4, p. 6-8.
- [13] European Commission, 2009. *Study on the calculation of recycling efficiencies and implementation of export article (Art. 15) of the Batteries Directive 2006/66/EC*. Brussels: Final Report 28.05.2009.
- [14] Huisman, J. and Stevels, A.L.N., 2006. Eco-Efficiency of Take-Back and Recycling, a Comprehensive Approach. *IEEE Transaction on Electronics Packaging Manufacturing*, vol. 29, 2, p. 83-90.
- [15] Lal, L., 2010. Enhancing Eco-efficiency in Agro-ecosystems through Soil Carbon Sequestration. *Crop Science*, vol. 50, p. 120-131.
- [16] Ouattara, A., Azzaro-Pantel, C., Pibouleau, L., Domenech, S., Baudet, P. and Yao, B., 2010. Eco-Efficiency Analysis for Chemical Process Design. In: Pierucci, S. and Ferraris, G.B., eds., *20th European Symposium on Computer Aided Process Engineering – ESCAPE20*. Elsevier B.V.
- [17] Prasad, P., Pagan, R., Kauter, M. and Price, N., 2004. *Eco-efficiency for the Dairy Processing Industry*. St Lucia: The UNEP Working Group for Cleaner Production in the Food Industry Environmental Management Centre, The University of Queensland.
- [18] Kaplinsky, R., and Morris, M., 2001. *A Handbook for Value Chain Research*. Prepared for the IDRC by the School of Development Studies. Natal: University of KwaZulu.
- [19] Barry, C. M. F., Baker, A. and Mead, J. L. 2006. Introduction to Polymers and Plastics. In: Harper, C. A., ed. *Handbook of Plastics Technologies*. New York: McGraw-Hill.
- [20] Coordinating Ministry for Economic Affairs - Kementerian Koordinator Bidang Perekonomian Republik Indonesia, 2011. *Statistik Perekonomian*. Jakarta: Volume 1 Nomor 5 – Triwulan I – 2011.
- [21] Adibroto, T. A., 2005. *Development of Sustainable Plastics in Indonesia in the Programme of Cooperation with ICS-UNIDO*. In: Expert Group Meeting, December 2005. Trieste, Italy.
- [22] Meidiana, C. and Gamse, T., 2010. Development of Waste Management Practices in Indonesia. *European Journal of Scientific Research*, vol. 40 no .2, p.199-210.
- [23] Fisher, M.M., 2003. Plastic Recycling. In: Andrady, A.L., ed. *Plastic and the Environment*. Hoboken, New Jersey: John Wiley & Sons, Inc.
- [24] Junttila, M. A., 2000. *Toward a Theory of Manufacturing Strategy*. Unpublished thesis, PhD., The University of Minnesota.
- [25] Hayes, R.H., Wheelwright, S.C. and Clark, K.B., 1988. *Dynamic manufacturing: Creating the learning organization*. New York: Free Press.
- [26] Gallopini, G., 1997. *Indicators and their use: information for decision making, sustainability indicators*. Report on the project on indicators of sustainable development. Chichester: Wiley.
- [27] Azapagic A. and Perdan S., 2000. Indicators of sustainable development for industry: a general framework. *Trans Inst Chem Eng*, vol. 78B, p. 244–246.
- [28] Krajnc, D. and Glavic, P., 2003. Indicators of sustainable production. *Clean Techn Environ Policy*, vol. 5, p. 279–288.
- [29] U.S. Environmental Protection Agency, 2008. *Indicator Development for Estuaries*. Office of Water Washington, DC 20460 EPA842-B-07-004. Available from: <http://www.epa.gov/owow/estuaries>, February 2008.
- [30] Shah, V., 1998. *Handbook of Plastics Testing Technology*. Second Edition. New York: John Wiley & Sons.
- [31] Bossel, H., 1999. *Indicators for Sustainable Development: Theory, Method, Applications*. Winnipeg, Manitoba, Canada: International Institute for Sustainable Development.
- [32] Ankli, R.E., 1992. Michael Porter's Competitive Advantage and Business History. *Business and Economic History*, Second Series, vol. 21, p. 238-236.
- [33] Porter, M.E. and Kramer, M.R., 2011. Creating Shared Value, How to reinvent capitalism and unleash a wave of innovation and growth. *Harvard Business Review*, January–February, pp 1-17.

# Implementing Design for Six Sigma in Green Manufacturing; a Case at a Food Industry

Dradjad Irianto andPrajna Paramitha

*Manufacturing Systems Research Group, Bandung Institute of Technology, Bandung 40132  
E-mail:dradjad@mail.ti.itb.ac.id*

## ABSTRACT

Industries are always searching for higher efficiency while maintaining a certain level of effectiveness of their product performances. However, these two objectives sometimes are progressing in opposite ways. This issue has become an important consideration in green or sustainable manufacturing. This paper is aimed at implementing the green manufacturing by using the design for Six Sigma method at a food industry. The material of non-conforming product has been analyzed and it is found that it can be reused partially and thus reducing waste. Accordingly, design for Six Sigma method is implemented, and it includes five stages, i.e. define, measure, analyze, design and verify. From the define stage, it was found seven critical to quality (CTQ) and it was measured that the process capability was very low. From the analyze stage it was found that the characteristic of dough (mixed of material including meal for reuse) had the highest priority for improvement. At the design stage, an experiment was done with dough hardness as a response and the experiment involved 3 factors, i.e. water, sugar, and meal (reuse material). The result showed that water and meal significantly influenced the dough hardness ( $p$ -value=0,000) and interaction of water and meal was significant at  $p$ -value=0,015. At the verify stage, the presence of meal as reused material met cookies thickness and diameter, but it caused instability of cookies weight.

## Keywords

*Green manufacturing, design for Six Sigma, Food product*

## 1. INTRODUCTION

The contribution of the primary industry, manufacturing sectors and service sectors in economies changed as per capita incomes increased. It has been studied by researchers in estimating development patterns of industries [1]. In case of Indonesia, after the economic crisis in 1998, contribution of industry to economic growth has been increasing. In 2011, the growth of industrial sector even is higher than national economic growth. By definition, industry converts and adds value of raw materials into products and services that are needed by customer. Industries are always searching for higher efficiency while maintaining a certain level of effectiveness of their product performances. However, these two objectives sometimes are progressing in opposite ways, and furthermore, industrial developments has been largely at the expense of the environment damage.

Environmental protection became an important issue following reports of disaster caused by industry [2]. This issue has become an important consideration in green sustainable manufacturing. It is important for industry to obtain significant benefit from its business using green or sustainable manufacturing strategy. Industrial competitiveness can be obtained through improved industry profitability, improvement in society and environmental sustainability. Pro-poor and pro-environment are inclusive in a comprehensive growth or profit manufacturing strategy, and it is known as the triple bottom line strategy. McCarty et al. [3] proposed Six Sigma method for industry to design and deploy environmental programs. Recent development makes green manufacturing a competing manufacturing strategy [4]. Recent development encourages researcher to study green or sustainable aspects in manufacturing systems (see e.g. [5], [6]).

Among industrial sectors, foods, drinks and tobacco has the highest contribution to industrial growth in Indonesia. However, food industry is still facing problem of producing a lot of waste from its production, including waste of raw material or rejected product. Tight standard and regulation is one factor of waste problem. Food industries are encouraged to improve their production processes. A company (abbreviated as KI) is one among food industries that implement continuous quality improvement of its production in order to reduce waste. KI has been successful in reducing waste, but still has problem of product inconsistency that at the end produce non-conforming product.

Research on non-conforming product resulted in an opportunity to reuse non-conforming product as an additional material in a limited amount. This paper deals with reuse of non-conforming product as an additional material at KI. Since it is new to KI, design for Six Sigma method is employed to set the level of the amount of non-conforming product as an additional material. This opportunity is also indicating the reduction of preparation process that may result in cost efficiency. The paper is

organized in chapters. After introduction, we will briefly discuss the benefit of Six Sigma method, and is followed by implementation of design for Six Sigma before concluding the paper.

## 2. SIX SIGMA

Six Sigma method uses a new approach for continuous quality improvement, which is adapted from Japanese Kaizen [7]. Six Sigma is aimed at reducing defects to near zero. It is fit with the Crosby's idea of quality performance known as zero defect. Crosby's idea uses the definition of quality as "conformance to requirement" where a non-conforming product can be considered as a defect product (see e.g. [8], [9]). Compared to Juran's "fitness for use" or Deming's "customer satisfaction", the "conformance to requirement" defines the lowest level of achievement of quality. However, "conformance to requirement" is a simple definition and well accepted especially by operator at the shop-floor level.

As a continuous quality improvement method, Six Sigma is a customer satisfaction oriented by producing zero defect [10]. The term "sigma" is used to mention unit of standard deviation in statistics and Six Sigma means that the specification limits is  $\pm 6$  standard deviation. Six Sigma primary concern is reducing defect to near zero level. Six Sigma views level of quality tougher compared with other statistical quality control approach that for decades used specification or tolerance limits  $\pm 3$  standard deviation that allows 2.7 defects per thousand opportunities. Six Sigma considers this 2.7 defects per thousand opportunities rate as 3 sigma level, and the target of Six Sigma is 6 sigma level. This target will result in a defect target rate at 3.4 defects per million while allowing bias up to 1.5 standard deviation. It means that if an industry is able to achieve 6 sigma level, then it is not necessary to control production process that may bias up to 1.5 standard deviation but still produces low defect rate. Accordingly, in case of no bias, the defect rate will be near zero per million opportunities.

Using this very low level of defect, not only at Motorola, some companies had experienced a lot of savings such as at GE and Allied Signal [11]. Following its initial fruitful results at Motorola and GE, many companies are also experiencing saving from Six Sigma implementations, including in Indonesian companies (see e.g. [12], [13]). Harry and Schroeder [7] stated that Six Sigma is a new strategy to improve business performance by increasing customer satisfaction level using various statistical tools. Moreover, Six Sigma is aimed at improving the bottom line by designing and monitoring daily business activities in order (i) to reduce waste and (ii) to increase customer satisfaction. The first objective is the basic consideration in lean manufacturing, which thus Six Sigma implementation is also known as Lean Six Sigma. Six Sigma for designing uses 5 steps of Define-Measure-Analyze-Design-Verify (DMADV), and for monitoring and improvement use 5 steps of Define-Measure-Analyze-Improve-Control (DMAIC). Description of these steps is given in Table 1.

Table 1: Steps in Six Sigma method.

Steps	Design	Improvement
1. Define	Define the project goals and customer needs	Define the defects and critical to quality
2. Measure	Measure customer needs and specification	Measure the level of defects and sigma
3. Analyze	Analyze the process options	Analyze the source of defects
4. Design/Improve	Detailed design the process	Perform improvement
5. Verify/Control	Verify the performance to meet customer needs	Control to eliminate defect

Critical to quality (CTQ) is a measurable characteristic of a product or process that has specification limits, in which the product or process is defined as conforming by the customer; otherwise it is defined as defect. A complex product or process can have more than one CTQs, which thus increase the number of opportunities of defect. Accordingly, Six Sigma implementation involves people with multidisciplinary backgrounds, and thus Six Sigma implementation is a group based quality improvement as in quality control circle (QCC) in Kaizen method. Moreover, authority in decision making makes Six Sigma implementation is performed in an integrated hierarchical arrangement called "people power" usually following organizational hierarchy, which is not common in Kaizen method. If necessary, external expert can be involved as "master black belt" with capability in practical and theoretical aspects of statistics.

## 3. IMPLEMENTATION AND DISCUSSION OF DESIGN FOR SIX SIGMA

KI produces cookies as "short dough" that is produced using mixed materials with low extensibility and elasticity. Short dough material usually consists more fat and sugar than water. The product is not only consumed for Indonesian market, but is also exported for 20 market in Asia and Pacific. Each market demand is specific, which thus lot of production for each market has its own specification. Today, KI is the biggest producer of cookies in Asia. In general, cookies production involves processes of material preparation, mixing, forming, baking and packaging. At material preparation process, all incoming raw materials are inspected and put into container in batch for mixing. The amount of ingredient for each batch is determined by R&D division to be suitable to specific customer needs.

At mixing process, bulk and solid ingredients are put into mixing container and are mixed using rotary mixer for 22 minutes using horizontal single arm peerless mixing machine. Afterwards, mixed ingredients are put into a container and sent to forming process. The weight of each batch of mixed ingredients is 1000 kg. Forming process is started with rolling process to form a layer with certain thickness. Rotary moulder is used to form cookies with certain dimension and texture. Formed cookies are then put on conveyor for baking process. The baking machine long is 100 m that is divided into 6 baking zones with different temperature. Subsequently, operator takes sample for each batch to observe visually the required texture and to measure cookies diameter and thickness. If ten samples are found as non-conforming, then all products in one batch are considered rejected. After baking process, cookies are transferred to sandwiching using long conveyor for cooling. The major production at KI is sandwich cookies with certain filler such as cream, chocolate, peanut butter or jam. Diameter and thickness are critical for packaging. KI uses fixed packaging in order to assure from damage in storing before it is opened by customer. This fixed packaged requires a certain precision of cookies dimension to be fitted to the package dimension. Table 2 exhibits some critical parameter of each process to assure the quality of the product.

Table 2: Critical parameter for each process.

Process	Critical parameter	Method of inspection
1. Mixing	Temperature	Thermometer at 3 location
2. Forming	Weight	Digital weigh scale for each sample
3. Baking	Water content	Water content analyzer
	pH	pH meter
	Weight	Digital weigh scale
	Dimension	Digital caliper for thickness and diameter
	Color and texture	Organoleptic and visual
4. Sandwiching	Weight	Digital weigh
5. Packaging	Leaking	Vacuum tester
	Weight	Digital weigh scale
	Code of production	Visual

In this research, the focus is production of base cake; a piece of cookies with texture on one side and flat on the other side, and then will be assembled to form of sandwich cookies. At least three quality characteristics of a cookies are considered important, i.e. (i) texture, and (ii) hardness level. The main ingredients are flour, fat and sugar. Sugar is the main ingredient affecting elasticity and cohesiveness. Accordingly, sugar affects the rough texture of cookies due to high rate of evaporation during baking process.

### 3.1 Define

KI operates 4 production lines producing different types of cookies. Observation was done at line 3 since it was the lowest production rate, and thus observation and experiment had minimum impact to shop floor operation. Initial observation for 6 production weeks of historical data found that weight, thickness and moisture had low process capability. It was an indicator of the existence of problem in line 3. Further observation found some defects as exhibits in Table 3.

Table 3: Defects in line 3.

Defects	Source of defects
Dough	Can be detected after baking; composition of ingredients in a batch; speed of mixer.
Over/under weight	Can be detected after forming or baking; composition of ingredients in a batch that impact dough hardness; control of moulder knife by operator.
Texture	Can be detected after forming or baking; moulder defect; composition of ingredients in a batch that impact dough hardness.
Thickness	Can be detected after forming or baking; gap between moulder and moulder knife;
pH	Can be detected after baking; composition of ammonium and water; oven temperature.
Moisture	Can be detected after baking; composition of ingredients in a batch; oven temperature.

Defect of pH is considered affecting customer health, and thus all defects product should be eliminated. Brainstorming in Six Sigma team (involving 5 manager and engineer) resulted in a decision to start with improving process capability of weight and thickness. These defects determine the weight of each ingredients that can be directly converted into production cost of

finished goods as an important strategic decision. As long as the production cost does not exceed the limit, then newly defined composition of ingredients is allowable for production.

### 3.2 Measure

Initial observation indicated a low process capability, which thus the measure step was performed to find the current process capability. Before collecting data, repeatability and reproducibility analysis was done to assure the accuracy and precision of measurement tools. Overview of sampling procedure was done to assure that operator performs inspection correctly. The data was collected during the period of January to March 2012 under condition that the machines and equipment's were in good conditions. However, at the end of January 2012, moulder was replaced, and thus the data only cover period of February to March 2012. Using 10 measurements, it was found that weight scale biased for 0.04 g, and caliper biased for 0,002 mm. Calibration could not be performed and thus all measured data during observation were compensate to amount of bias. Before calculating process capability, all collected data were evaluated for its stability. Figure 1 and Figure 2 exhibits example of stability analysis of weight and thickness respectively. It was found that only few data in unstable condition which then were eliminated only if they were caused by special or assignable causes.

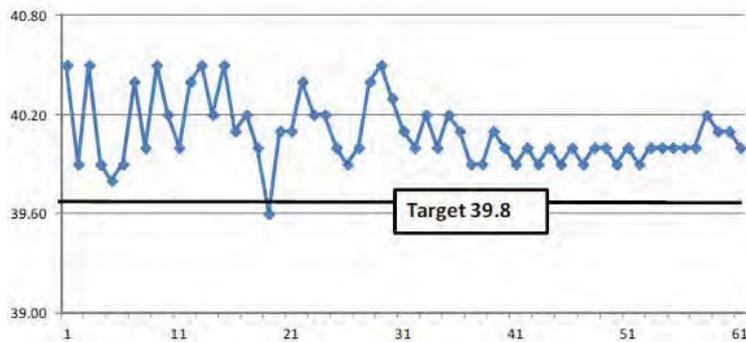


Figure 1: Example of data stability analysis of weight.

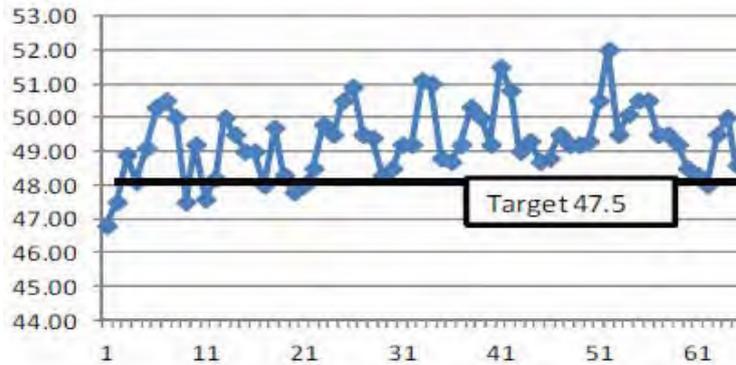


Figure 2: Example of data stability analysis of thickness.

Measurement of process capability used  $C_p$  or  $C_{pm}$  index as formulated in equation (1) and (2)

$$C_p = \frac{USL - LSL}{6\hat{\sigma}} \tag{1}$$

$$C_{pm} = \frac{USL - LSL}{6\hat{\sigma} \sqrt{1 + \frac{(\bar{X} - T)^2}{\hat{\sigma}^2}}} \tag{2}$$

where USL is upper specification limit, LSL is lower specification limit,  $\bar{X}$  is process mean,  $T$  is target value, and  $\hat{\sigma}$  is estimation of process standard deviation. For multiple characteristics, the standard deviation is a compound of standard deviation of weight and thickness. However, the team could not formulate multi response characteristics, and thus it is not necessary to analyze standard deviation as a compound standard deviation. KI determines specification limits of weight (37 g – 42.6 g), and for thickness is (46 mm – 49 mm). From the data it was found that estimate of standard deviation of thickness was

0.815 and estimate of standard deviation of thickness was 0.368. Bias of weight was 0.94, and bias of thickness was 1.21. Accordingly, process capability index of weight and thickness is given in Table 4.

Table 4:  $C_p$  or  $C_{pm}$  index of weight and thickness.

Factors	$C_p$	$C_{pm}$
Weight	1.14	0.75
Thickness	1.35	0.4

The capability process  $C_{pm}$  index of weight 0,75 was equal to 2.25 sigma level in Six Sigma measure, and  $C_{pm}$  index of thickness 0.4 was equal to 1.25 sigma level in Six Sigma measure, both with a possibility of deviation of 1.5 standard deviation. It can be concluded that the process capability of weight and thickness were low, and thus KI needed significant improvement.

### 3.3 Analyze

Different value between  $C_p$  and  $C_{pm}$  index indicated that KI had two problems caused in design and in manufacturing processes. Accordingly, Six Sigma with both approach of DMAIC and DMADV could come into consideration for improvement. To understand the low level of process capability, root caused analysis was done. At this stage, the Six Sigma team considered the use of defect material (called “meal”) to be used in the process. There was no standard of using meal for reuse in cookies production. Master formula and process operating guidelines (MFPOG) at KI only mention that meal can be used up to 80 kg, but KI did not have experience of using it.

Further analysis was conducted using FTA (fault tree analysis) and FMEA (failure mode and effect analysis) methods. From FTA, basic causes of low process capability were identified, i.e. no parameter for dough quality, calibration of measurement tools, inconsistent inspection procedure, and machine instability. From FMEA some potential causes were evaluated and found that the quality of dough had the highest risk priority number (RPN) compared to other causes. Accordingly, improving the quality of dough should have the highest priority. For this case, the use of meal was considered and at least two considerations were taken, i.e. conversion cost of ingredient composition, and (ii) health requirements. Brainstorming was conducted involving R&D division that resulted in permission for using defect dough material for health requirements. Further analysis was done to calculate the use of defect dough material to conversion cost and found that it was feasible.

### 3.4 Design

From the FMEA result, quality of dough was the main focus for improvement. The Six Sigma team discussed the suitable parameter to measure the quality of dough at mixing process and found that dough hardness was selected. Afterwards, the team preparing the measurement tool for dough hardness. Parameter dough hardness is also related to performance of moulder, which thus setting optimum value of dough hardness will determine the setting of moulder. To define the optimum level of dough hardness, a factorial experiment was designed.

Firstly, it was found that 11 factors affected the quality of dough, i.e. water, meal, mixing time, flour, vegetable oil, sugar, moulder speed, moulder knife gap, pressure of rubber roll, baking time, and oven temperature. Factors related to setting of machine or equipment was difficult to be included in the experiment. Some ingredients were also fixed, and thus only water, meal and sugar that were included as the variable of experiment. Using previous data, the level of experiment variable is given in Table 5.

Table 5: Level of experimental variables.

Variables	Low Level (-) in kg	High Level (+) in kg
Water	65	70
Meal	0	80
Sugar	138.85	277.7

Before performing the experiment, some preparations were made including raw material, experimental schedule, and experimental operator. For 3 factors in factorial experiment, 16 runs are required and performed randomly for two replications [9], and the result is given in Table 6. From this result water and meal were significant which was shown by p-value near zero and their main plot is given in Figure 3. Three combination of low level of water with high level of meal (run 5, 7 and 8) produced to hard dough hardness, and contrariwise four combinations of high level of water and low level of meal (run 2, 4, 11, and 15) produced to soft dough hardness, both were out of specification.

Table 6: Experimental results.

**Factorial Fit: Hardness versus Water, Meal, Sugar**

Estimated Effects and Coefficients for Hardness (coded units)

Term	Effect	Coef	SE Coef	T	P
Constant		2.5038	0.05416	46.23	0.000
Water	-1.3465	-0.6732	0.05416	-12.43	0.000
Meal	1.2113	0.6056	0.05416	11.18	0.000
Sugar	-0.2154	-0.1077	0.05416	-1.99	0.082
Water*Meal	-0.3359	-0.1680	0.05416	-3.10	0.015
Water*Sugar	-0.0714	-0.0357	0.05416	-0.66	0.529
Meal*Sugar	-0.0665	-0.0332	0.05416	-0.61	0.557
Water*Meal*Sugar	0.2083	0.1041	0.05416	1.92	0.091

S = 0.216632 PRESS = 1.50174  
 R-Sq = 97.36% R-Sq(pred) = 89.53% R-Sq(adj) = 95.09%

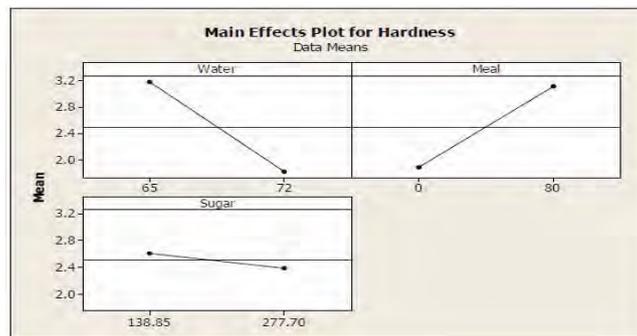


Figure 3: Main effect plot.

**3.5 Verify**

From the experiment, water and meal significantly affected dough hardness. More water reduced dough hardness but more meal increased dough hardness. There was no interaction between water and meal, and thus both factors affected dough hardness independently. Among experimental run, it was found that high level of water produced cookies weight closed to target (41.51 g) but was still higher than the target 39.8 g. However, if the meal was set at its higher level the weight was 41.46, slightly closer to the target, but had more variance (unstable). The effect of meal to the cookies thickness was not significant. This experiment verify that the use of meal as a reuse green manufacturing effort had a chance for production in the future, but detail experiment to find the optimal setting of using portion of meal still have to be done.

**4. CONCLUSION**

Concerns and practical efforts for green manufacturing processes are growing. This paper deals with an effort to reuse a certain amount of defect dough material known as meal, which supports implementation of green manufacturing. This effort is concurrently aimed at improving the quality of cookies using Six Sigma DMADV method. A factorial experiment method was performed at the design step of Six Sigma and found the possibility of using meal as reuse material. At the verify step, it can be concluded that the use of meal as an effort in green manufacturing had a chance for better production in the future, especially to improve cookies hardness. Further detail research is still to follow in order to set the optimal setting of amount of meal in the mixing process to produce the best product quality.

**REFERENCES**

- [1] N. Haraguchi, and G. Rezonja, "In Search of General Patterns of Manufacturing Development," UNIDO, Vienna, 2010.
- [2] S. Windsor, "An Introduction to Green Process Management," ASQ Quality Press, Milwaukee, 2011.
- [3] T. McCarty, M. Jordan, and D. Probst, "Six Sigma for Sustainability," McGraw Hill, New York, 2011.
- [4] A.M. Deif, "A System Model for Green Manufacturing," *Journal of Cleaner Production*, 19, 2011, p.1553-1559.
- [4] M. Harry, and R. Schroeder, "Six Sigma: The Breakthrough Management Strategy Revolutionizing The World's Top Corporations," Doubleday, Random House Inc., New York, 2000.
- [5] K. Igarashi, T. Yamada, and M. Inoue, "Optimal Design of Disassembly System with Environmental and Economic Parts Selection using Recyclability Evaluation Method," *Proceedings of 13th Asia Pacific Conference on Industrial Engineering and Management Systems*, 2012.

- [6] T.N. Wong, L.H. Lee, and Z. Sun, "CSR and Environmental Criteria in Supplier Selection," *Proceedings of 13<sup>th</sup> Asia Pacific Conference on Industrial Engineering and Management Systems*, 2012.
- [7] D.C. Montgomery, "Introduction to Statistical Quality Control", McGraw Hill, New York, 2007.
- [8] J. M. Juran, and A. B. Godfrey, "Juran's Quality Handbook," 5th edition, McGraw-Hill, Singapore, 1999.
- [9] T. Pyzdek, "The Six Sigma Handbook." McGraw Hill, 2003.
- [10] F.W. Breyfogle, "Implementing Six Sigma: Smarter Solutions Using Statistical Methods," John Wiley & Sons, Canada, 2003.
- [11] D. Irianto, and Tarsono, "Quality Engineering Using Six Sigma Approach to Reduce Rework Rate of Water Flowmeter Production," *Proceedings 4<sup>th</sup> National Industrial Engineering Conference*, 2007, p.455-460.
- [12] N.T. Putri, S.M. Yusof, and D. Irianto, "Self-Assessment of Quality Engineering Practices in Malaysia and Indonesia Automotive Related Companies," *Proceedings the 12<sup>th</sup> APIEMS Conference*, 2011.

# Manufacturing Cycle Time Reduction For Product Flavors Food And Tobacco At PT IFF Indonesia Using Six Sigma

Rahmat Nurcahyo<sup>a</sup>, Ade Rahman<sup>b</sup>, Ricky Firdaus<sup>c</sup>

<sup>a, b, c</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : rahmat.nurcahyo@yahoo.co.id

## ABSTRACT

Cycle time is the time it takes a process from start to finish the process. Reducing manufacturing cycle times have an impact on increasing productivity, capacity, and production. Six Sigma is a management tool that focuses on reducing variation to explore the company's overall production system. The purpose of this research is to reduce manufacturing cycle times in food and tobacco flavorings products by using the six sigma through DMAIC cycle and implementation of DMA (Dynamic Material Allocation). Based on the results of a study of the manufacturing cycle time reduction in flavors food and tobacco products can be deduced that by using the six sigma method and DMA as improvement, to reduce cycle time from initial sigma value of 1.45 to 3.43 and reduced manufacturing cycle times from an average of 1.775 hours 2.985 hours.

## Keywords

*Cycle time, six sigma, DMAIC*

## 1. INTRODUCTION

Increasing of industry developments lead to every company should have a competitive advantage in improving customer satisfaction. One of the factors that can increase customer satisfaction is the reduction of cycle time. Cycle time is the total elapsed time to complete an operation or set of operations. Reducing manufacturing cycle times have an impact on increasing productivity, capacity, and production.

IFF PT Essence Indonesia is engaged in a flavor for food, beverages, and tobacco in smoking and also produced perfume products. Actually the company is already implement continuous improvement principle on its quality management system through the implementation of ISO 9001:2008 quality management system. However this system only puts on continuous improvement efforts based on consciousness independent of management. The system does not give the right solution is supposed to result in dramatically improved to the level of zero defects and cycle time reduction.

To reduce cycle time and level of defect in IFF PT Essence Indonesia can be done by using Six Sigma. Six Sigma is a method in the field of quality management. Six Sigma is a rigorous, focused, and highly effective implementation of proven quality principles and techniques which has the goal to eliminate defects in production, clamping production time and reduce costs. Incorporating elements from the work of many quality pioneers, Six Sigma aims for virtually error-free business performance (Pyzdek, T., Keller, Paul A., 2003:3). Six Sigma can be used as measures of performance industrial systems that enable the company to perform a remarkable improvement with the actual breakthrough strategy.

Six Sigma can also be viewed as controlling industrial process that focuses on the customer by taking into account the ability of the process. Achieving six sigma there are only 3.4 defects per million opportunities (Pyzdek, T., Keller, Paul A., 2003:7). The higher sigma level is achieved then the industry is improving system performance.

The purpose of this research is to reduce manufacturing cycle times in IFF PT Essence Indonesia as an effort to improve productivity, production capacity.

## 2. BASIC THEORY

### 2.1 Flavors

Production at IFF-PT Essence Indonesia is divided into 2 parts, namely the production of flavorings and the production of perfume. Production part of flavor is divided into 3 divisions: powders, liquids, and extract division. Production liquid division produces flavorings in the form of emulsion and non-emulsion. Flavor emulsion used as cloudifier, and flavors of the syrup. Non-emulsified flavorings are used to flavor foods and beverages and tobacco flavorings for cigarettes. Equipment used to produce the flavor of food / drink is distinguished by the equipment used to flavor tobacco production because the production

of tobacco flavorings usually use alcohol solvent so that is feared to contaminate the taste of food / beverage that must meet legal criteria.

## 2.2 Six Sigma

Since 1920's, the word 'sigma' has been used by the mathematicians and engineers as a symbol for a unit of measurement in a variety of quality products (Note sigma is written in lower case 's' as used in the context of units of measurement in general). In the mid 1980s, engineers at Motorola Inc., USA using the 'Six Sigma' as an informal name for the company's initiative to reduce errors in the production process, because it reflects the high level of quality as appropriate (Tennant, Geoff, 2001:6). (Note, the use of the word Sigma is here written with a capital letter 'S' for Six Sigma in this context is the name of 'brand' for the initiative Motorola.). Motorola is one of many U.S. and European corporate where they launch the product (along with food and other snacks) eaten by the competition from Japan. And the leader of Motorola's terrible to admit that the quality of their products. Like many companies at that time, Motorola did not have a quality program. Motorola has several programs, but in 1987, out of a new approach of Motorola's communications sector, at the time headed by Georghi Thiler who later became a top executive at Kodak, innovative improvement concept was "six sigma" (Pande, P.S., R. P. Neuman and R. R. Cavanagh, 2000:7).

Sigma is taken from 18<sup>th</sup> from the Greek alphabet ( $\sigma$ ), and used in the statistical sciences as a symbol standar deviation. The term "Six Sigma" itself comes from the understanding that if a value in a state of  $6\sigma$  between the midpoint closest to the limit deviation, can be said practically no product will not fail.  $6\sigma$  process control approach from Motorola allow for a shift in the average value from industrial processes amounted to  $\pm 1.5 \sigma$  that will generate the level of discrepancy of 3.4 per million opportunities (3.4 DPMO = defects per million opportunities), meaning that every one million opportunities 3.4 will have the possibility of incompatibility (Tennant, Geoff, 2001:25). This differs from the concept of  $6\sigma$  theory calculated based on the normal distribution centered will generate the level of mismatch of 0.002 DPMO .

Six Sigma has two key methodologies: DMAIC and DMADV, both of them take the concept of the PDCA cycle (plan-do-check-act) of W. Edwards Deming. DMAIC is used to improve business processes that are running, and DMADV used to create a new product or process design for defect-free performance (De Feo, Joseph A.; Barnard, William, 2005).

DMAIC is defined as (De Feo, Joseph A.; Barnard, William, 2005):

1. Define, determine the topic of problems.
2. Measure, measure the performance of processes that are running.
3. Analyze, analyze weaknesses in the process (such as the sources of disability), and makes the weaknesses in these processes as opportunities for improvement.
4. Improve, make improvements to the performance of the processes that had been weak.
5. Control, control performance of the processes that had been repaired to maintain profits.

## 2.3 Cycle Time

Cycle time is the time it takes an operator to complete one cycle of work includes to perform manual labor and walk. Sometimes defined as the time required to produce one unit of product, in this case is determined from the longest process (bottleneck), whether human or machine work.

Hansen & Mowen (1996:412), defines a cycle time as " Cycle time is the length of time it takes to manufacture a product (time dividend by unit of product)." To improve the performance of the company then the company needs to make continuous improvement in its business activities primarily in the production activity because this activity plays a pretty big company. In this production activities must have a benchmark that is by using cycle time and speed. This benchmark is important because it is an essential to measure the ability of the company in terms of increased production capacity based on time.

## 3. RESEARCH METHODOLOGY

This research will be done with the Six Sigma methodology as follows:

1. Define. Begin with determine project time and customer voice, creating a process map, SIPOC and Top Down Chart.
2. Measure. This steps are: manufacturing cycle time data collection, normality test and initial baseline measurement.
3. Data Analysis. The processing and analysis of data that have been taken using six sigma tools, which use Pareto Diagram, Cause and Effect Diagram and Pouring Analysis.
4. Improve. This phase consist of DMA / Modify preparation fixbin
5. Control. Consist of Run Chart.

## 4. DATA COLLECTION AND PROCESSING

#### 4.1 Define

Phase define a first stage in the implementation of six sigma methodology. In this phase, the author defines some important terms that describe the conditions or problems that would become the object of research. Some important things are define opportunities, voice of customers and mapping process that applies to PT IFF Indonesia. Objective of define opportunities is to define or identify and validate improvements will be made, prepare an effective team, determine customer requirements, and illustrate the business process.

##### 4.1.1 Team Charter

Making the team charter is an importance in define phase because it aims to establish and validate the team charter.

##### 4.1.2 Voice of Customer

Voice of customer is an important part in the work process that is observed. Voice of the customer obtained from brainstorming with all employees contained in the production department and the results of meetings between management and leadership.

There are several major problems that cause customers feel not satisfied and complained of condition to the production. The problem in question is not yet rated companies to meet the demand for customer orders quickly, especially when customers want a rush order. It should be considered in translating VOC into the CCR's (Critical Customer Requirements).

##### 4.1.3 Process Map

The next stage is to determine the process map to understand the importance of determining the business processes, SIPOC diagrams, and top-down charts.

Here is the map production process:

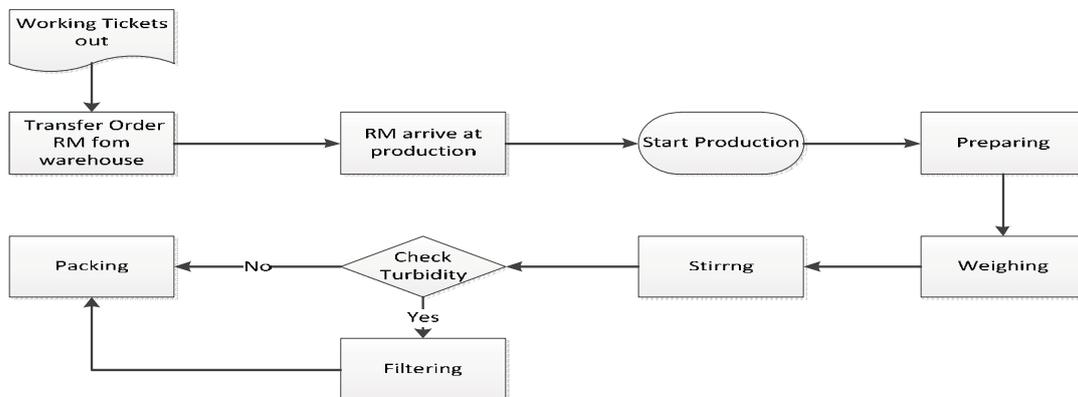


Figure 1: Manufacturing Process Map

##### 4.1.4 SIPOC

After known map process the next stage to determine SIPOC diagram. The steps to create SIPOC are as follows:

- Specify the name of the process
- Determine start and end points
- Specify output
- Determine customer
- List the main steps in the process
- Define input
- Determine supplier

<b>Project Name:</b>	<b>Manufacturing Cycle Time Reduction</b>
<b>Date:</b>	

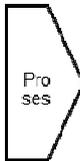
<b>Prepared By:</b>				
<b>Notes:</b>				
Suppliers	Inputs	Process	Outputs	Customers
RM Supplier	Raw Materials		Finished Product	Customer
Production Scheduler	Shop Floor Paper			
City electricity	Electricity			
Manufacturer	Equipment			
Air Conditioner	Temperature			
Suppliers	Packing Material			
	Compounder			
	Operators			

Figure 2: SIPOC Diagram

### 4.1.5 Top Down Chart

The next stage after making SIPOC is to determine the top-down chart which is a simple description of the process, using a top-down chart because it has two levels of levels that can explain the process. The first level is a major step in the process, while the second level is a list of sub-processes for each of these key processes.

Top-down chart serves to determine the factors that influence the production cycle time of this phase where we will get input, process and output indicators to be used as a measurement stage.

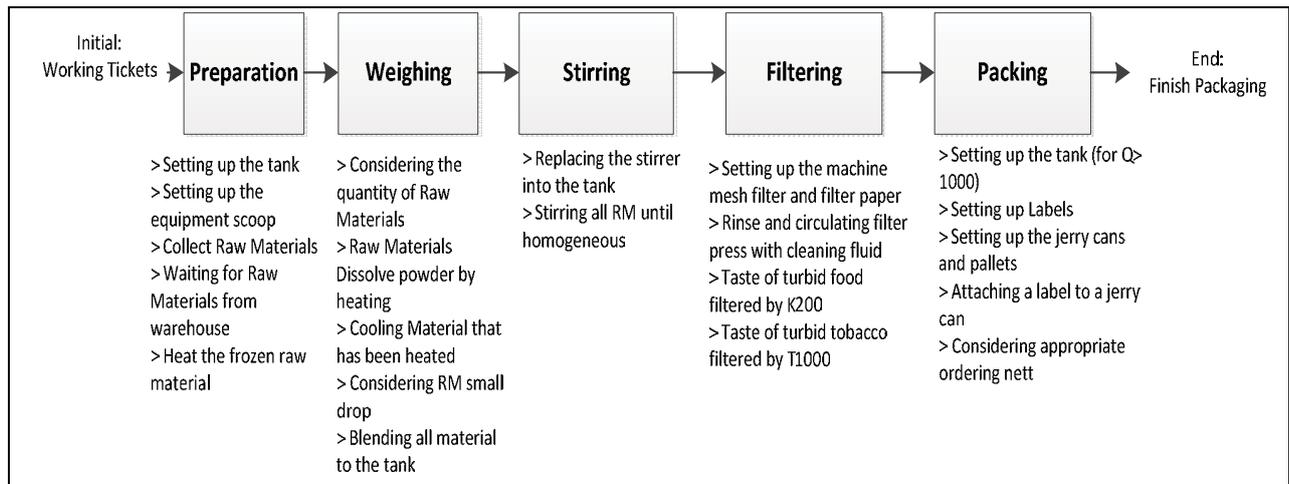


Figure 3: Top Down Chart Manufacturing Cycle Time

## 4.2 Measure Phase

After the voice of customer is translated into a critical part in the quality after that mapping the processes, then the next stage is to measure phase. Measure phase is a second phase in six sigma methodology. In this phase, the work process will be measured its ability to produce output based on the incoming input

### 4.2.1 Working Tickets Measurement

Data were collected during the twenty working days beginning on May 26<sup>th</sup> 2010 to June 18<sup>th</sup> 2010. During the twenty working days, the authors note that the number of working tickets produced for the flavor of food and tobacco are 75 tickets. Based the data of working ticket obtained as specified below.

Table 1: Results of Measurement Working Ticket

Parameter	Before Improvement
Sigma Level	1,45
Mean (hours)	2,985
Median (hours)	3,07
Modus (hours)	3,33
Standard Deviation	1,053
<i>p</i>	0,086
<i>n</i>	75
Preparing (hours)	32,34
Weighing (hours)	71,58
Stirring (hours)	30,3
Filtering (hours)	21,72
Packing (hours)	22,56

#### 4.2.2 Process Measurement Baseline

During the twenty days of observation obtained total Working tickets were observed is 75 Working tickets.

From the calculation results obtained defect rates by 52% so that the yield obtained at 0.83. Based on the obtained value of 173,333.33 DPMO and sigma value of 1.45. This indicates that process has outputs to the achievement of quality that is not fully optimized.

#### 4.2.3 Cause And Effect Diagram

To identify the root causes of the manufacturing cycle time used causal diagrams. This causal diagram is used to identify the root causes of a problem so that collective action can be taken to eliminate the cause.

#### 4.2.4 Cause and Effect Matrix

From the parameters of a causal diagram that was created, the next stage is to create a matrix of cause and effect of these data, in order to determine which data will be made to the measurement plan. Cause and effect matrix in this cycle time reduction can be seen in Table 4.

Table 2: Cause and Effect Matrix

No	----- Input/Process Indicators -----	Output #1	Output #2	Output Indicators	Measurement Plan
		10	10	Importance	
		Frequency of Occurrence	Overall Cycle Time		
		----- Correlation of Input to Output -----		----- Total -----	
3	Loss RM	9	9	180	Yes
5	Preparation	9	9	180	Yes
12	Filtering	9	9	180	Yes
19	Weighing	9	9	180	Yes
20	Packing	9	9	180	Yes

#### 4.2.5 Measurement Plan

After getting input / process indicators of the most influential, then we made measurements of the input plan. Measurement plan in this cycle time reduction can be seen in Table 5.

Table 3: Measurement Plan

No	Input/Process Indicators (X)	Operational Definition	Links to (Y)	Sample Size
1	Preparation time dan Material Loss	Time of Receiving Tickets compounder working until ready to weigh	Preparation time and time weighing Materials	75 Working tickets
2	Filtering	The time required from preparation to completion filtration filter machine	Filtering time	75 Working tickets
3	Weighing	The time needed compounder from start weighing raw materials until the beginning of the stirring	Weighing time	75 Working tickets
4	Packing	The time it takes operators starting from finished goods over the stirring until complete packing	Packing time	75 Working tickets

From that measurement plan we obtained the overall results as follows in table 6.

Table 4: Overall Results of the Measurements (in hours)

Input Indikator	Total Time	Mean	Modus	Median	Standard deviation
Preparation time dan Material Loss	40,44	0,54	0,50	0,50	0,25
Filtering	27,12	0,36	0,25	0,33	0,20
Weighing	89,49	1,19	1,00	1,00	0,66
Packing	28,24	0,38	0,25	0,33	0,25

## 5 DATA ANALYZE

Analysis of the data processing in this study, also the analyze and improve phase in six sigma methodology. The author uses data analysis and process analysis to identify what factors are affecting the manufacturing process cycle time.

### 5.1 Analyze Phase

#### 5.1.1 Analysis Using the Pareto diagram

The data from measurement phase is analyzed in advance using pareto diagram to know the longest stage which resulted in increased cycle time. Here is the result of cumulative data from 75 Working tickets analyzed. From the results of Pareto diagram can be concluded that 70.1% comes from the source of problems:

1. Weighing
2. Preparation time

To overcome the root cause is then necessary to determine the appropriate solution. For the weighting factor can be overcome with the purchase of new scales to cope with time while the preparation can be done through the regular preparation of the material in accordance with the frequency of usage.

#### 5.1.2 Pouring Analysis

Pouring analysis is an analysis of the casting material according to a certain quantity, this analysis is based on material consumption during the last 6 months. The data used is data in the period 1 January 2010 to 30 June 2010.

Pouring analysis was carried out on the shelves of material M, L, F, G, H, and Cool Room. With a neat placement of material compounder will more easily perform weighting in accordance with the materials listed in the Working ticket.

Pouring analysis was performed using the SAP transaction in the transaction ZDMA. The result is extracted into Microsoft Excel, and then analyzed. Here is a chart analysis conducted where results will be processed as a stage further improvements can be seen in table 7.

Table 5: Analysis of Pouring Shelf M, L, F,G,H

No	Input/Process Indicators (X)	Data Source and Location	Data Used	Sample Size
1	Placement of materials based on frequency of use	ZDMA Transactions in SAP from the rack (M, L, F, G, H)	Based on the usage of raw materials 6 months (1 January to 30 June 2010)	All raw material in rack M,L,F,G,H

## 5.2 Improve Phase

Improve phase, as described on the basis of theory, has the objective to find a solution to be implemented in order to create an amendment. The solution is an act which is considered able to eliminate the barriers that have been described in the analysis.

### 5.2.1 Measurement Improvement Results

After improvement is carried out measurements of the Working tickets with the same assumptions as the baseline measurement. The result can be seen in figure 9.

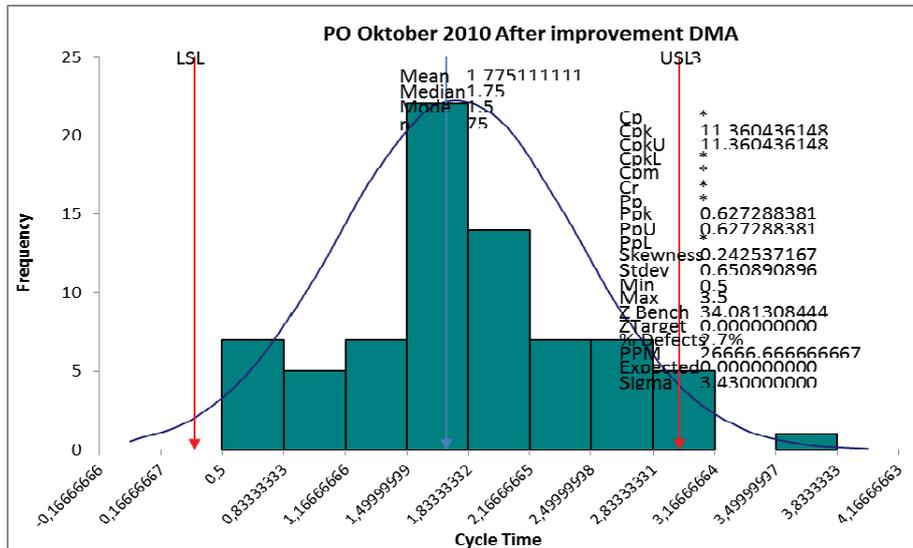


Figure 4: Sigma Level Oktober 2010 After Improvement

From the images obtained value of 3.43 sigma level. Thus an increase in the value of sigma from 1.45 to 3.43. The results are compared with the initial sigma measurement. The results can be seen in Table 11.

Table 6: Comparison of Sigma Level

Parameter	Before Improvement	After Improvement	Increasing
Sigma Level	1,45	3,43	1,98
Mean (hours)	2,985	1,775	-1,21
Median (hours)	3,07	1,75	-1,32
Modus (hours)	3,33	1,5	-1,83
Standard Deviation	1,053	0,651	-0,402
<i>p</i>	0,086	0,131	0,045

### 5.3 Control Phase

Control phase is the last stage of the analysis of Six Sigma projects that emphasize documentation and dissemination of action that has been done.

At this stage of control the thing done is to make a run chart of the Working ticket october 2010. At this stage the run chart serves to monitor the results that have been conducted over the use of six sigma method.

## 5 CONCLUSION

Based on the results of a study of the manufacturing cycle time reduction in flavors food and tobacco products can be deduced that by using the six sigma method and DMA as improvement, to reduce cycle time from initial sigma value of 1.45 to 3.43 and reduced manufacturing cycle times from an average of 1.775 hours 2.985 hours.

## REFERENCES

- [1] De Feo, Joseph A.; Barnard, William (2005). JURAN Institute's Six Sigma Breakthrough and Beyond - Quality Performance Breakthrough Methods. Tata McGraw-Hill Publishing Company Limited. ISBN 0-07-059881-9
- [2] Gasperz, Vincent, 2003, *Total Quality Management*, PT.Gramedia Pustaka Utama. Nasution, MN. (2001) *Manajemen Mutu Terpadu*, Jakarta: Ghalia Indonesia
- [3] Hansen Don R., Maryanne M Mowen, 1996, *Management Accounting Fourth Edition*. South- Western Collage Publishing Company
- [4] Pande, P.S., R. P. Neuman and R. R. Cavanagh, 2000, *The Six Sigma Way: How GE, Motorola, and Other Top Companies are Honing Their Performance*, McGraw-Hill
- [5] Pyzdek, T., Keller, Paul A 2003, *The Six Sigma Handbook: The Complete Guide for Greenbelts, Blackbelts, and Managers at All Levels*, McGraw-Hill.
- [6] Tennant, Geoff (2001). *SIX SIGMA: SPC and TQM in Manufacturing and Services*. Gower Publishing, Ltd.. p. 6. ISBN 0566083744.

# Design of Lean Manufacturing with VALSAT Method in Production Line IMV Type of Drum Brake – Case Study of PT AKEBONO BRAKE ASTRA INDONESIA

Yadrifil<sup>a</sup>, Taufik Kurniawan<sup>b</sup>, Irvanu Rahman<sup>c</sup>

Department of Industrial Engineering

<sup>a</sup> Faculty of Engineering University of Indonesia, Depok 16424

E-mail : yadrifil@ie.ui.ac.id<sup>a</sup>, taufikkurniawanui@yahoo.com<sup>b</sup>

## ABSTRACT

To be competitive, every industry in manufacturing or services are increasingly required to be able to produce goods or services economically, and can deliver products on time according to customer needs. It occurs in a company that produces IMV Type of Drum Brake, which have problem with wastes as research object. The company's strategy to reduce or eliminate wastes in its production is to apply the concept of lean production, as both a method and philosophy. Methods and tools used to identify and analyze the production of this waste, consist of Waste Relationship Matrix (WRM), Waste Assessment Questionnaire (WAQ) and Value Stream Analysis Tools (VALSAT). The end result is the production line gets more streamlined (lean) and improvement in production performance according to the proposed VSM.

## Keywords

*Lean Production, Waste Relationship Matrix, Waste Assessment Questionnaire and VALSAT.*

## 1. INTRODUCTION

A manufacturing company that focused in production of car components, and produce brake for two-wheels vehicle (two wheels) and four wheels, is PT. Akebono Brake Astra Indonesia, now is keep trying to improve its competitiveness both for domestic and export markets. The strategy pursued by company to make it happen is through the implementation of lean manufacturing concepts, to improve the operating system and continuous improvement by reducing or eliminating the wasteful at operation stages.

On the concept of lean production or lean manufacturing, production processes that do not provide added value for example can be seen from the accumulation of raw materials and intermediate goods (WIP) on production floor, it cause by bottleneck. Bottleneck can occur due to imbalance time of processing on production that where there is a process that requires a longer time than other processes.

One cause of the length of time the process is due to the inefficiency of the management of existing resources. Therefore, the factors that have contributed in it, such as human resources, machines, materials, etc. should always be evaluated whether it was relevant to the business that is run or the need for revision/repair [1].

Process efficiency improvement should be conducted in accordance with the capabilities and resources available in the company. Because of that needed is an approach that is relatively simple and well structured to be easily understood, such as the approach of Lean Manufacturing.

## 2. LITERATURE REVIEW

Technique of "lean manufacturing" can help companies to become competitive, especially in terms of reduction wastes in their operation process. Lean manufacturing is defined as reducer from waste in any form/conditions to maximize the value-added activities [2]. Meyers dan Stewart (2002) explain that Lean means an effort by all elements of the company to eliminate the wastes together and it is one of tools that can be used to achieve optimum company's competitive advantage [3].

In recent years, the concept of lean has a lot to get a positive response from various types of businesses, not only in manufacturing but also in businesses of service sector. Some research show that lean production can increasing productivity, quality, and responsiveness of firms to be high [5].

Lean manufacturing should begin with a perfect understanding of business processes, not only production process and material flow but also information flow. One tool that extremely affordable and simple are often used to capture this information is VSM (Value Stream Mapping) [6].

Various types of information are uniquely displayed in Current State Map, such as information flow using a paper or electronic, cycle times, changeover times, amount of inventory, machine uptime, and amount of worker, but all the things that is often overlooked. With the lean approach, flow of information and raw from company are described with value stream mapping. So that it can be discovered with an overview of the existing waste. The main purpose of VSM is to understand and document (all the) current state (existing condition) and then produced a Proposed State Map that led to improvement in the process itself [7].

### 3. METHODOLOGY

The purpose of this research was to obtain a design of Lean Production System in production line for the type IMV of drum brake from company. Steps performed in this research, as shown in Figure 1, consist of eight stages:

1. Identify the problem through observation, interviews, and the preliminary data required.
2. Calculate the standard time of each process.
3. Make the current state map (CSVSM).
4. Collecting data to find relationships between the wastes in the company by using Waste Relationship Matrix (WRM).
5. Perform the weighting of the WRM to know the weight or the magnitude of the relationship between wastes.
6. Make Waste Relationship Matrix (WRM).
7. Perform the weighting of waste assessment questionnaire with used algorithm of Waste Assessment Questionnaire (WAQ).
8. Analyze effect between wastes by using VALSAT.

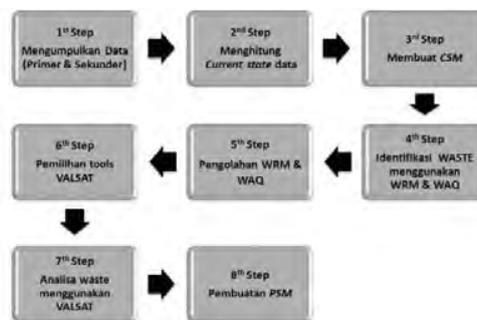


Figure 1. Flow of research

Area of research focuses on the backing plate assembly line that makes the brake drum type IMV for four-wheel vehicles, which consists of three work stations; those are backing plate welding work stations, work stations riveting and nut welding.

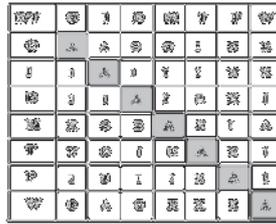
The first step, is taking measurements and collecting data in order for calculate the data needs to make current state map value stream map (CSMVSM). VSM is tool from lean manufacturing that for the first derived from the approach of Toyota Production System (TPS) which is known as “material and information flow mapping” [8]. Rother dans Shook (1999) define VSM as a powerful tool that not only can identify process inefficiencies, but also can be a guide in making improvements [9].

Jones dan Womack (1998) mention that VSM is a mapping flow of information and material which aims to set up methods and performance are better in a proposed future state map. This tool gives information flow of information and physic in system. In addition, the condition of production system such as lead time as required can also be described from each process characteristic that occurs [10].

After knowing the condition of production line through visualization of current state map value stream map, the next step to identify wastes used Waste Relationship Matrix (WRM) and Waste Assessment Questionnaire (WAQ). Use of the VALSAT techniques to analyze waste that occurs in a production line requires a proper weighting method so that tools selection and their correlation with wastes would be appropriate. Therefore, WRM & WAQ is used as a means to measure quantitatively relationship and types of waste that occurs in the production chain.

WRM is a matrix consisting of rows and columns. Each row shows the influence of each of six types of waste to other waste. Each column shows the waste that is affected by other waste. Diagonal matrix shows the relationship of the highest [11]. This indicates that each waste has a great relationship with itself.

Table 1: The Waste Relationship Matrix (WRM)



Explanation:

O = Overproduction  
 I = Inventory  
 D = Defect

M = Unnecessary Motion  
 T = Over transportation  
 P = Inappropriate process  
 W = Waiting

Table 2. Range Division of relationship between wastes

Range	Relation	Symbol
17-20	Absolutely necessary	A
13-16	Especially important	E
9-12	Important	I
5-8	Ordinary Closeness	O
1-4	Unimportant	U

While the Waste Assessment Questionnaire (WAQ) was made to identify and allocate the waste that occurs in the production line (especially the job shop type), Waste Assessment Questionnaire consists of 68 different questions, which represent the activity, condition or behavior in a specific production floor that can generate waste. Some questions are regrouped into a kind of "From" which means that the question refers to all types of waste that occurs which may lead to or result in the type of different waste. While the other questions that represent the type "To" which means all types of waste generated by other waste [11]. Each question consists of three pieces of the answer with their respective weights: 1, 0.5 and 0. Questions are categorized into 4 groups: man, machine, material and method.

Algorithm equations used to calculate tabulated in WAQ is using the following equation:

$$S_j = \sum_{k=1}^K \frac{W_{jk}}{N_i} \quad (1)$$

$$Y_j = \frac{S_j}{S_j} \times \frac{f_j}{F_j} \quad (3)$$

$$s_j = \sum_{k=1}^K X_k \times \frac{W_{jk}}{N_i} \quad (2)$$

$$Y_{jfinal} = Y_j \times P_j = \frac{S_j}{S_j} \times \frac{f_j}{F_j} \times P_j \quad (4)$$

Explanation:

$S_j$  = Sum of values in each column under each type of wastes (score of the waste).  
 $s_j$  = New score after the multiplication weight of answer each type of wastes.  
 $Y_j$  = Initial indication factor of each type of waste.  
 $Y_{jfinal}$  = Final waste factor each type of wastes.

With WAQ we obtained sequence of waste that occurs in production line based on their respective weights. Waste that has the greatest weight to the first rank and so on. The results obtained weight of each waste will be used to obtain the appropriate analysis tools VALSAT.

Value Stream Analysis Tools (VALSAT) use as a tool for detailed mapping which focuses on the flow of value adding process. Details of this mapping can be used to find the cause of waste that occurs [12]. There are seven kinds of detail mapping tools are used, are:

### 1. Process Activity Mapping

This tool maps each step of activity that occurs from operation, transportation, inspection, delay, and storage, and then classify them into types of activities available ranging from value adding activities, necessary non value adding activities, dan non value adding activities.

### 2. Supply Chain Response Matrix

This graph illustrates the relationship between inventories with lead time that can be used to identify and evaluate the increase or decrease inventory levels and long lead time in each area at supply chain.

### 3. Production Variety Funnel

This tool is used to identify the point at which a generic product is processed into a number of specific products. In addition, this tool can also be used to indicate areas of bottleneck in the design process used to plan inventory policy improvements.

### 4. Quality Filter Mapping

It is a tool that is used to identify the location of the problem of quality defects in the existing supply chain. Evaluation of the quality loss is often the case made for short-term development.

**5. Demand Amplification Mapping**

To visualize changes in demand throughout the supply chain. Information can be used in decision making and further analysis, either in anticipation of a change request, to manage fluctuations, as well as the evaluation of inventory.

**6. Decision Point Analysis**

Shows the various options of different production systems, the trade off between lead time of each option with a level of inventory required to cover during the lead time.

**7. Physical Structure**

This tool is used to understand the supply chain at the level of production. It is necessary to understand the industry condition, how its operations, and in directing attention to areas that may not get enough attention to the development.

The use from seven tools based on the proper selection based on the company itself. Selection of appropriate engineering tools with each type of waste is based on the weight system, as shown in Table 3.

Table 3: Relationship between VALSAT and 7 Wastes

Wastes/structure	Mapping tool						Physical structure (a) volume (b) value
	Process activity mapping	Supply chain response matrix	Production variety funnel	Quality filter mapping	Demand amplification mapping	Decision point analysis	
Overproduction	L	M		L	M	M	
Waiting	H	H	L		M	M	
Transport	H						L
Inappropriate processing	H		M	L		L	
Unnecessary inventory	M	H	M		H	M	L
Unnecessary motion	H	L					
Defects	L			H			
Overall structure	L	L	M	L	H	M	H

Note:

- H = High correlation and usefulness (multiplier factor of 9)
- M = Medium correlation and usefulness (multiplier factor of 3)
- L = Low correlation and usefulness (multiplier factor of 1)

Meanwhile, to get a tool where appropriate in the mapping process, the selection matrix is used as Table 4.

**4. RESULTS AND DISCUSSION**

After all data has been collected and processed into the current state, further data was made current state map. This Current state map shows the actual conditions that occur in production floor as Figure 2.

In the current state map is shown Total Lead Time in the production of drum brake plate assy that come from the Cycle Time of each process to the material delay in the inventory and transportation time from one work station to work station to another. From the sum of these three variables we obtained Total Lead Time = 3.64 days. In the current state map is also seen that the greatest contribution that make the lead time of 3.64 days are inventory at the beginning and end of the process of painting, and painting processes are carried out by the partner company which is for 3.5 days. Total value stream attribute the current state map can be seen in Table 5.]

Next step is to identify and analyze the waste in the backing plate assembly area that consists of three working station ie, backing plate welding (BDW-1), riveting (RVT-1) and nut welding (NWD). Material flow and cycle time of each process can be seen in Figure 2 the current state map.

**Result and Discussion of WRM.** On Table 6. can be shown that the from over production and from defect have the greatest percentage of 17.9%, which means that over-production waste and defects in the event have a considerable influence to cause another waste.

Table 4: Matrix of VALSAT Selection

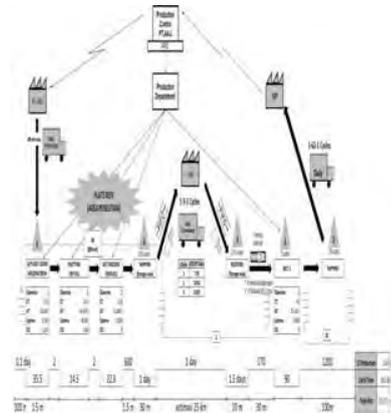
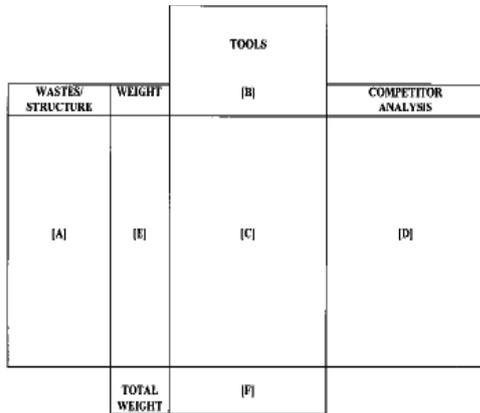


Figure 2: Current state map

Table 5: Metrics Current State Map

Metric	Baseline
Total Value stream Inventory	655 units
Total product cycle time	162.8 seconds
Total value stream lead time	3.64 days
Uptime	96.4 percent

Meanwhile, to inventory has the greatest percentage of 19.4% which indicates that the waste from inventory is the most waste resulting from the other waste. On the other hand inventory just resulted another waste of 12.7%.

**Result and Discussion of WAQ.**

In Table 7 it is found that the biggest waste caused by the inventory has a percentage of 20,41%. The second Waste is motion with 17.97%, and overproduction in the sixth with a 13.08%

Table 6: Waste Relationship Value

F/T	O	I	D	M	T	P	W	Score	%
O	10	10	6	8	8	0	6	48	17.9
I	4	10	4	8	8	0	0	34	12.7
D	8	6	10	8	8	0	8	48	17.9
M	0	6	6	10	0	6	6	34	12.7
T	4	8	6	6	10	0	6	40	14.9
P	6	2	6	6	0	10	6	36	13.4
W	4	10	4	0	0	0	10	28	10.4
SCORE	36	52	42	46	34	16	42	268	100
%	13.4	19.4	15.7	17.2	12.7	6.0	15.7		100

Table 7: Recapitulation of WAQ PT. AAIJ

	O	I	D	M	T	P	W
Score (Y <sub>i</sub> )	0.4927	0.7484	0.4243	0.7432	0.7243	0.7739	0.7346
P <sub>i</sub> factor	239.86	246.38	281.03	218.44	189.23	80.4	163.28
Final result (Y <sub>final</sub> )	118.19	184.40	119.25	162.35	137.06	62.22	119.94
Final result (%)	13.08	20.41	13.20	17.97	15.17	6.89	13.28
Rank	6	1	5	2	3	7	4

**Result and Discussion of VALSAT.** After getting the final results of the weighting process by using WRM and WAQ, the next step is selection of detail mapping tools appropriate to type of waste that occurs in the company. This selection process is done using VALSAT. Table 10. Shows the mapping tool according with waste type that occurs.

**Use of VALSAT**

Weight (bobot) that had been previously obtained through an assessment process using the WRM and WAQ, then calculated again using selection matrices for seven of VALSAT. Final calculation of matrix selection of seven VALSAT indicated on table 8.

From table 8 can be obtained the process activity mapping ranks first with a score 567.27, the second is supply chain response matrix with score 360.41, and the third is demand amplification mapping with score 262.78. Selection is made on two VALSAT analysis tools that have the greatest scores are obtained, the process activity mapping and supply chain response matrix.

From Table 9 then classified based on the activities of the value-added activities (VA), which is not value-added activities, but still needed (NNVA) and activities that have no value at all (NVA). Of the grouping can be known what the most dominant activity occurred on a production line backing plate assembly.

Table 8: Selection Result of VALSAT

Value	Weight	Mapping						
		Process Ability Mapping	Supply chain responsiveness	Production Validity	Quality Filter Mapping	Direct application Mapping	Discrepancy analysis	Physical status Mapping
Operational	133	133	325	0	133	325	325	0
Inventory	241	623	330	623	0	330	623	241
Defect	130	130	0	0	130	0	0	0
Unrecovery	129	129	0	0	0	0	0	0
Transportation	157	157	0	0	0	0	0	157
Inappropriate	69	69	0	26	69	0	69	0
Waiting	133	133	133	133	0	333	333	0
<b>TOTAL</b>	<b>927</b>	<b>3041</b>	<b>957</b>	<b>137</b>	<b>228</b>	<b>1420</b>	<b>333</b>	

Table 9. Process Activity mapping backing plate assembly

No	Aktivitas	Area/Mesin/Alat	Jarak (meter)	Waktu (seconds)	Jumlah Operator	Aktivitas					VA/VA/NNVA
						O	T	I	S	D	
1	Kedatangan bahan baku	Mobil Box	100	2400	1		x				NNVA
2	Menunggu antrian untuk di proses			1200							NVA
3	Transfer ambil bahan baku ke mesin	Manual	1.5	20			x				NNVA
4	Setting mesin			90				x			NNVA
5	Ambil dust cover letakkan pada jig			2.5			x				NNVA
6	Ambil backing plate letakkan pada jig			5	1 (operator yang sama)		x				NNVA
7	Proses welding	Mesin BDW		27.5			x				VA
8	Ambil backing plate hasil welding letakkan di mesin			5			x				NNVA
9	Ambil assy anchor dan pasang pada backing plate			3			x				NNVA
10	Proses rivet	Mesin Rivet		7			x				VA
11	Menunggu proses rivet			8							NVA
12	Ambil backing plate taruh di elektroda			3			x				NNVA
13	pasang nut welding 1			1.2			x				NNVA
14	Proses welding	Mesin Nut welding		3.2			x				VA
15	Angkat backing plate pasang nut kanan pada elektroda			2			x				NNVA
16	Proses welding	Mesin Nut welding		3.2			x				VA
17	Ambil backing plate taruh di polybox			2					x		NNVA
18	Transfer Hasil nut welding ke fixed trolley	Manual	1.5	60				x			NNVA
19	Ambil polybox berisi backing plate taruh di pallet	Manual	1	60	1			x			NNVA
20	Simpun pallet di area before shipping menunggu untuk		30	180				x			NNVA
21	Menunggu untuk painting	Store		7 jam					x		NVA
22	Ambil hasil painting taruh area receiving	Forklift	30	120	1			x			NNVA

Based on table 10, the time required for the entire process on the backing plate assembly are 29402.6 second. Total activity in this process as many as 22 activities. Of the 22 activities, 11 activities are operation activities, six transport activities, two activities of storage and only a single delay and inspection activities. Only four activities are classified on activities that value-added (VA) or at 0139% of overall activity, while for value-added activities that are not at all (NVA) as much as three pieces with percentage is 89.82% from NNVA by 10.046%.

Supply Chain Response Matrix consists of two axes, which are axes of vertical and horizontal. Vertikal axis express cumulative inventory in each stage on supply chain, while horizontal axis express cumulative lead time to plan and move the product. The data required in making of SCRM on line of backing plate assembly as follows:

- The cumulative data of raw material arrival.
- The cumulative data of component production result in area of backing plate assembly such as WIP.

Average needs and material making of dust cover and backing plate is 720 units/days and 90 units/decision while lead time just one hour. Part of PPIC has determined inventory duration (day's physical stock) keep in level 0.25 days. Table 11 below described days of physical stock for two of raw material.

Graph 1 shows lead times supply in production area of backing plate assembly during 1.1 days while the duration of inventory in system is 2.35 days so the total of response time supply in system is 3.45 days.

Table 10: Total Percentage Activity VA, NVA, NNVA

Aktivitas	Jumlah	Waktu (second)
Operation	11	62.6
Transport	6	2840
Inspection	1	90
Storage	2	25202
Delay	2	1208
VA	4	40.9
NVA	3	26408
NNVA	15	2953.7
<b>TOTAL WAKTU (second)</b>		<b>29402.6</b>
% VA		0.139
% NVA		89.815
% NNVA		10.046

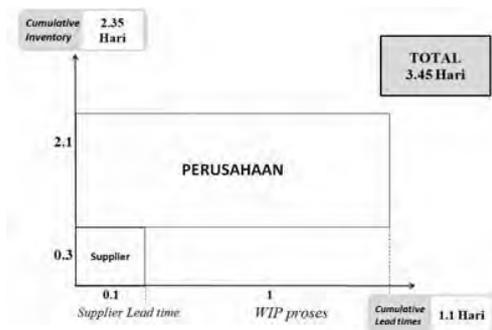
Table 11: Days Physical Stock and Lead Time Raw Material

Bahan Baku	Days physical stock	Rata-rata Lead times
Dust cover	0.25	0.1 hari
Backing plate	0.25	0.1 hari

Component of production result are dust cover and backing plate, they are assembled into a B/P Assy and then store as WIP to wait painting process. From data held by PPIC average length of WIP is system is 2.1 days while lead time from WIP until after painting process and until will process in next process takes 3.5 days can be seen on table 12 below.

Table 12: Days Physical Stock and L/T WIP

Nama komponen	Days physical stock	Rata-rata Lead times
B/P Assy	2.1	1 hari



Graph 1: Supply Chain Response Matrix

### Proposed value stream map

The focus of the proposed improvements are based on analysis has been done before by using process mapping activity and the supply chain response matrix. In both tools are clearly illustrated that the Inventory is a problem with the onset of production lead time is long enough. This is also supported by results assessment questionnaire of WAQ that mention Inventory ranks the first waste.

- **Eliminate waste inventory**

Process activity mapping shows amount of WIP that should wait to painting process is 7 hour and this activity is classified as non value added activity (NVA). Material results of backing plate assembly can not be directly applied to the work station BELT 3 because of having to go through the process of painting. The painting process conducts in outside the plant, which is a partner company. With the arrival of the cycle 1-3-3 then, the company must make a safety stock of WIP for 3.5 days which is useful as a buffer so that the process can be run normally. The Company is building a line so that the whole process of painting is not something to do outside. By conducting the processes of painting in the plant (in house) then, the waiting times are inevitable happens.

- **Eliminate waste transportation**

In the process mapping activity clearly illustrated that there is six times the transport process and all of which belong to the NNVA activity, activity that is necessary but not value added. During the observations made of this transport activity. distance between the work area should not be too far away and can be brought closer. In Figure 3 proposed value stream map shows that the receiving area close to the shipping area can reduce waste transportation along 11.

- **Eliminate waste waiting**

Waiting is the fourth largest waste by weight as 13:28% by WAQ assessment. waste waiting occurs at the time of raw material waiting to be processed and at operator of nut welding waiting backing plate that process result from welding dan riveting.

Work area of BDW dan RVT done by same operator is systematic working from welding process in machine of BDW and after that make do rivet in machine of RVT. Waiting occurs when the operator nut welding process must wait for B / P assy

results Rivet process. Because the actual standard time for this process amounted to only 14.5 seconds while machine time was only 4.2 seconds.

On the other hand BDW and RVT operator also have waiting time. After pressing the ON button on the machine operator BDW directly to process Rivet, because the cycle time of RVT is less than BDW so after rivet, operator still wait to finish BDW machine for welding and waiting time about 25 second. To eliminate the waiting time, incorporation three of machine ini with concept of U-cell shape and just run by one operator alone can save on labor while reducing the total cycle time in all three processes. In the proposed state map figure 3 can be shown the total cycle time of 125.5 seconds that before as 162.8 second, that there is a cutback of 37.3 seconds (22.9%).

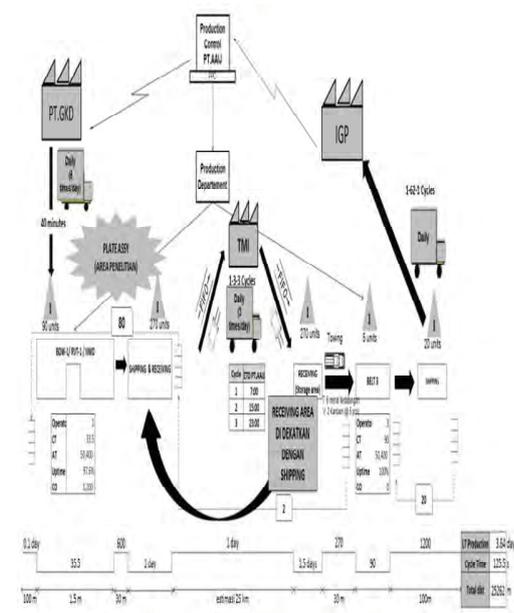


Figure 3. Proposed State map

## 5. CONCLUSION

1. Initial assessment of WRM and WAQ are obtained four types of largest waste according with order in their respective weights are: inventory by weight (20.41%), motion (17.97%), transportation (15,17%), and waiting (13.28).
2. Using the selection matrix of VALSAT for the fourth largest types of waste can be obtained two of detail mapping tools
  - Process Activity Mapping with score is 567.27
  - The second of Supply Chain Response Matrix score is 360.41
3. Process Activity mapping (PAM) showed that:
  - Activities that value-added (VA) for 0139% from total of all activities, activities that are not value-added but still required (NNVA) is 10.0% and not value-added activities (NVA) reached is 89.82%.

From supply chain response matrix shown total lead time of supply chain in area for backing plate assembly is 1.1 days, while inventory duration in system is 2.35 days so that the total of response time to supply in system is 3.45 days. This illustrates that the WIP process produces the greatest lead time and directly proportional to the existing inventory in system that cause companies must make a WIP for 2.1 days.

## REFERENCES

- [1] Kodradi Y., Soewignyo P., dan Rusdiansyah A. "Analisis Beban Kerja dalam Rangka Restrukturisasi Organisasi di PT. Petrokimia Gresik". Prosiding Seminar Nasional Manajemen Teknologi VIII. Program Studi MMT-ITS, (2008).
- [2] Forrester, R., 1995. "Implications of lean manufacturing for human resource strategy". *Work Study* 44, (3)
- [3] Meyers and Stewart, "Motion and time study for lean production", 3<sup>rd</sup> edition, Prentice hall Co, ltd, Pitsburg, 2002.
- [4] Hines P., and N. Rich, "The Seven Value Stream Mapping Tools", International Journal of Operations and Production Management. 17,1, 1997.
- [5] Motwani, Jaideep. "A business Process Framework for Examining lean production". Journal of industrial Management & data system Vol. 103, No.5, pp 339-346. Departement of management, Seidmean School of Business, 2003.
- [6] Rother, M. and Shook, J. Learning to See. "The Lean Enterprise Institute", Brookline, MA, 2003.
- [7] Oakes, Mark, "Remembering VSM - Industrial Engineer"; 40, 9; ProQuest Science Journals, hal. 24, Sep 2008.
- [8] Apel W., Li Yong J., and Walton V, "Value Stream Mapping for Lean Manufacturing Implementation", Worcester Polytechnic Institute, 2007.
- [9] Rother, M. and Shook, J, "Learning to See", The Lean Enterprise Institute, Cambridge, MA, 1999.
- [10] Womack J.P., Jones D.T., "Lean thinking: Banish waste and create wealth in your corporation"; New York, Free Simon & Schuster, 1998.
- [11] Rawabdeh, Ibrahim A. "A model for Assesment of waste in Job shop environments". International Journal of operations & production management Vol.25, No.8, 2005.
- [12] Hines P., and N. Rich, "The Seven Value Stream Mapping Tools", International Journal of Operations and Production Management. 17,1, 1997.

# Lean Manufacturing Improvement Program For Sustainability of Small and Medium Enterprise A Metal Processing Industry Case Application

Sri Indrawati<sup>a</sup>, Alber<sup>b</sup>

<sup>a,b</sup>Industrial Engineering Department, Universitas Islam Indonesia, Yogyakarta  
E-mail : sriindrawati@uii.ac.id

## ABSTRACT

Lean manufacturing is a proven approach for manufacturing industries efficiency strategies. Radical change of goal, system and organization culture is required in the transition to lean manufacturing. There are several manufacturing industries which failed to implement lean manufacturing system. In order to minimize the high failure rate of implementation, this research is conducted to analyze some factors affecting the lean manufacturing implementation in SMEs. The first part is focused on reviewing the lean practices based on SMEs characteristics. The data were then verified and used to evaluate some manufacturing waste. Further, a manufacturing improvement program is developed for sustainability of SMEs. The research shows that the SMEs faces some problems related to seven type manufacturing waste including overproduction, defects, unnecessary inventory, inappropriate processing, excessive transportation, waiting and unnecessary motion. Lean practices such as 5S, quality control, worker empowerment and supervision, production control and standardization are least investment cost and feasible to implement in SMEs.

## Keywords

*Lean manufacturing, Lean practices, SMEs*

## 1. INTRODUCTION

In the industrial world, the company has always put efficiency in various fields to improve the performance and profitability of the manufacturing company. There are some system or philosophy to realize that manufacturing company' goals. Lean manufacturing system has been broadly accepted by manufacturing industries in some areas to improve its operational performance.

Many researchers has studied and documented their analysis on lean manufacturing application. Lean manufacturing implementation will provide a better utilization of manpower and factory floor space which have a positive impact to productivity in a garment manufacturing industries [1]. This research also conclude that a good relationship among the workers will help the management to coordinate and integrate the factory production.

A significant positive relationship between lean production and firms' profitability of 50 manufacturing companies in Iran have been found [2]. To implement lean production to achieve a superior performance, company should distinguish customers needs and satisfy their needs. Further, managers should eliminate wastes within company. Beside that tools selection to improve manufacturing and generate desired advantage should based on focus area for improvement and current condition of the company [3]. Over all, lean manufacturing is a way for improving manufacturing to make the organization more productive, profitable, and customer oriented.

There are some tools which being used to implement lean manufacturing in a company. Based on the research, there are six tools were chosen by two Serbian food companies to implement lean manufacturing, namely: total productive maintenance, poka yoke, batch reduction, layout improvement, standardization of work and visual management [4]. The objective of green manufacturing is achieved through lean manufacturing tools such as six sigma and quality function development, just in time, poka yoke, flexible manufacturing system, supply chain management, cellular design and setup reduction [5]. Some value addition process and elimination of wastes can be used to improve productivity in Coal mining industry [6]. This process is done by using lean philosophy application in production process such as: elimination of waste activities and overall effective use of resources by less number of drill bits, grinding wheels, electrical power, human energy and more coal production to wheel the development of the nation.

Lean manufacturing tools can be easily implemented with radical change of goal, system and organization culture through the company. It is suggested that, if a company is to change to a lean organization, the company also needs to change the way they value the different dimensions of work [7]. The similar research also stated that there are some elements as critical success factors on lean production practices implementation in automotive sector of Brazil and Spain. The most impacting elements are: ethics and organization, personnel and human resources, customer/ supplier and organization rapport, product and product management [8].

PT. M, one of small and medium enterprise sector metal processing industry in Indonesia, have already introduce the concept of lean production in its daily production. The introduction phase of this concept is chosen as a way to minimize or eliminate some production problem such as down time of production process which often occur due to problems in production facilities, scheduling that do not correspond to the actual situation and so on. But the company faces some challenges in implementing this concept. In order to minimize the high failure rate of lean manufacturing implementation in PT M, this research is conducted to give manufacturing improvement program based on review of lean practices based on SMEs characteristics.

## 2. THEORETICAL BACKGROUND

Lean manufacturing is a systematic approach for identifying and eliminating waste through continuous improvement, moving the product at the pull of the customer in pursuit of perfection. This approach is different from traditional one which in practice does not emphasize on the elimination of waste and short output time (throughput time). Where both of that reduction can lead to low inventories. So the main purpose of lean manufacturing implementation is to increase productivity, improve quality, shorten lead times and reduce costs.

The main characteristics of lean manufacturing can be summarized as follows [9]:

- Production is based on customer demand
- All activities are organized and focused on the major role of product assembly lines with functional departments
- All activities are based on team and organization oriented more horizontally than vertically
- The overall system involves fewer people which integrated between each other
- There is a high level of information exchange between all the role and transparent financial structure
- Activities are coordinated and evaluated by the flow of work through the team or factory
- Discipline is very important in the system in terms of activating and shows the problems posed and total quality in the company and the supplier and dealer performance evaluation
- If possible, the responsibility was developed at the lowest level, the manufacturer or supplier
- Manufacturing systems based on stable production volumes but with the flexibility specifically in terms of product assortment
- Relationships with employees, suppliers, and dealers based on mutual obligations

The main elements of manufacturing can be summarized as three overlapping suppression element [10]. First is waste elimination. Secondly, the involvement of all staff in the improvement operations. The goal is to encourage personal responsibility, commitment and a sense of having a job. And third, the notion that improvement must be continuous (continuous improvement).

Waste is any non value adding activity in the process, in which those activities using only the resources but do not provide added value to customers. While variation is inconsistency or variability that occurs in the process so as to produce defective products. In general understanding of waste are [11]:

- Resources consumed by inefficient or unnecessary activities
- Excess material to leave the production process, or output that has no sale value
- Process or material that does not add value to the goods or services
- Non value added materials, storage, or disposal of material within a certain amount of environmentally harmful

Waste or better known as "muda" can be grouped into seven types, namely [12]:

- Overproduction  
Excessive production occurred when producing the goods when it is not needed, before the customer orders or before the next process begins its production. Excessive production is a result of the lack of flow of goods and information, and resulted in a lot of inventory that may interrupt the flow of material and decrease productivity and quality.
- Defects  
There are several types of defect, first is defect which contain a defective product that can not be economically repaired. Second, rework is a product that has experienced an error and can be fixed by reworking so that the product can be expected according to specifications. Third, customer returns is products returned by customers because it does

not correspond to the expected specifications. Fourth, customer dissatisfaction is some dissatisfied customers that lead to product claim.

- Unnecessary inventory  
 Basically inventory simply hide the problem and cause additional handling activities should not be needed. Inventory also resulted in extra space, extra cost. Too many goods stored in warehouses and delay the flow of information or product, resulting in increased storage costs and poor customer service.
- Inappropriate processing  
 It is a process that includes all unnecessary and inefficient additional processes or activities using improper equipment, system or procedure errors.
- Excessive transportation  
 Move the material or activity within a great distance from one process to the next process will resulted in the addition of material handling time. Too much movement of people, information, or material resulting in a waste of time, effort and cost.
- Waiting time  
 The length of waiting time for either the human, material and information will result in poor flow and long lead times.
- Unnecessary motion  
 Unnecessary movements due to poor facility layout arrangement or any movement of people and machines that do not add value to the goods or services will only adds time and costs only. Back and forth frantically looking for something is an activity that includes waste, because it gives no added value to product.

Some of the root causes of variation and waste in the workplace are:

- Bad factory and office layout
- Long setup of equipment and machinery
- Bad organization work
- Improper or insufficient training
- Working methods are not standardized
- Do not follow procedures and work instructions
- Low process capability
- Bad planning
- Material quality problems
- Inaccurate measurement equipment
- A poor work environment

Some approach that can be done to eliminate seven waste are as follow:

- Simplification is an approach to eliminate waste where a process will be simplified to reduce the core itself.
- Incorporation is an approach to eliminate waste by combining two kinds of tasks that can be performed by a single worker.
- Deletion is an approach to eliminate waste by eliminating the processes / activities that are not necessary so that processing time can be shortened.

### 3. RESEARCH METHOD

This research phase contains several steps that begins with problem formulation, observation and data collection then analyzing. First stage in this research is the study of existing production problem of metal processing industry in PT M Hospital Equipment Units for non stainless welding parts. Then data collection was generated to evaluate the production process based on lean manufacturing practices. The data is related to seven type manufacturing waste including overproduction, defects, unnecessary inventory, inappropriate processing, excessive transportation, waiting and unnecessary motion. Data is used to determine the root cause of each type of waste. Further, a depth analysis of real production system is done to develop a manufacturing improvement program based on lean manufacturing practices for sustainability of SMEs.

### 4. RESULT AND DISCUSSION

The analysis will be divided in two categories, presenting identified typical wastes and its root cause in PT M Hospital Equipment Units for non stainless welding parts. Second is analysis of possible manufacturing improvement program based on some lean tools in SME. The first category consist of:

- a. Overproduction (Excess Production)

Producing components by an amount that exceeds from its demand that caused by greater setup time than the processing time. Some components are produce in large batch such as in component 32901 and 73006 there are excess production in hinges, nut M5 and buss hinges as can be seen in Figure 1. The other cause is when a defective component occur, new parts are come from the warehouse component so the components will not be rework and become a waste. The root cause of excessive production are a process bottleneck, unbalanced production capacity, bad shipping, bad layout, more emphasis on the workers to continue working rather than maximizing the use of materials.



Figure 1: Over Production

b. Defects

Product defects resulting in rework or scrap cost. These costs include quarantining inventory, re-check, re-scheduling, and loss of capacity. There are some product defect occur in production process, such as chassis beds that do not match to its standard size and the welds are not strong. The other is center mat 73004 had a dent in its centre area as can be seen in Figure 2. The root cause of defective products is the presence of a processes variation while process control is weak, the amount of component inventory that is not balanced, poor instructions and human error.



Figure 2: Defect Components

c. Unnecessary inventory

Work in process is directly the result of excessive production and waiting time. Excess inventory tends to hide problems in the factory which should be identify and repair to increase the lead-time, productive use of floor space, the identification of issues to be delayed, and hinder communication. Based on observation, there are some components inventory which corrosion occurs as can be seen in Figure 3. This unnecessary inventory caused by demand uncertainty, forecast poorly, and poor market information. In production process also have some contribution to that, such as long production lead time, the time of set up time, and the capacity of the equipment used is not balanced.



Figure 3: Unnecessary Inventory

d. Inappropriate processing

Based on observation, there are inappropriate processing occur such as when welding box and parts box processing. Sometimes the welding point is too thick or large because high amperage is used during the process of grinding/ deburring trouble and proceed in long time. The other is component 33104, the base frame is too narrow so frond frame can't be



can be seen in Figure 7. The cause of this waste are messy work, arrangement of the components are not balanced, irregular work methods, work in large batch sizes, the component does not have a name and number information.



Figure 7: Unnecessary Motion

Based on that analysis of typical wastes and its root cause in PT M Hospital Equipment Units for non stainless welding parts, there are some possible manufacturing improvement program as follows:

- a. Use a pull system in production where a single product is produced according to the requirement or order, leveling production or heijunka, implementing kanban system, preventive maintenance independently by the operator.
- b. Produce product according to specification limit and based on standard operational procedures. Doing good material handling with standard capacity on each pallet and perform frequent inspection.
- c. Perform production line balancing and coordinate with component warehouse in order to adjust to the situation.
- d. Perform planning and scheduling with better balance or level out the workload, working on the production according to demand and standard operational procedures.
- e. Using five S (5S) method to reduce unnecessary movement through of identification and removing unnecessary items in the workplace, grouping goods, mark boundaries of each production area, make a production map and its characteristic, provision of hygiene, cleaning work, marking on a machine that can not be repaired, determination of control points and make a fixed place for each item.

## 5. CONCLUSION

The research shows that the SMEs faces some problems related to seven type manufacturing waste including overproduction, defects, unnecessary inventory, inappropriate processing, excessive transportation, waiting and unnecessary motion. To overcome this problem, a manufacturing improvement program such as 5S, quality control, worker empowerment and supervision, production control and standardization are least investment cost and feasible to implement in SMEs.

## ACKNOWLEDGEMENT

Researcher thank to the support of Manufacturing System Laboratory, Industrial Engineering Department, Universitas Islam Indonesia, Yogyakarta and PT M.

## REFERENCES

- [1] K.M.A. Haque, R.K. Chakraborty, M.M. Hossain, P. Mondal, S.A. Islam, 'Impmenetation of lean tools in RMG sector through value stream mapping (VSM) for increasing value added activities', *World Journal of Social Sciences*, Vol. 2. No. 5. August 2012.
- [2] H., E. Chamazkoti, H. Namadhchian, S.M.M. Davoudi, "The impact of lean production on firm's profitability", *Journal of Economics and Management*, Vol.1 Issue 7, October 2012.
- [3] K. Rakeh and K. Vikas, "Lean manufacturing: elements and its benefits for manufacturing industry", *Proceedings of the National Conference on Trends and Advances in Mechanical Engineering*, Oct 19-20, 2012.
- [4] I. Dekic, "Lean manufacturing in two Serbian food companies-case studies", *International Journal for Quality research*, Vol.6, No. 2, 2012.
- [5] S.,M Satao, G.T. Thampi, B. Patil, B.T. Srinivas, S.D. Dalvi, "Enhancing waste reduction through lean manufacturing tools and techniques, a methodical step in the territory of green manufacturing", *IRACST- International Journal of Research in Management & Technology*, Vol. 2 No.2, April 201.

- [6] M. Ade, “Lean manufacturing and productivity improvement in Coal mining”, *International Journal of Engineering Science and Technology (IJEST)*, Vol. 4 No.05 May 2012.
- [7] N. Nordin, B.M. Deroz, D.A. Wahab, M.N.A. Rahman, “Validation of organizational change management framework for lean manufacturing implementation”, *Advanced Processes and System in Manufacturing*, 2011.
- [8] F.A. Calarge, F.H. Pereira, E.G. Satolo, L.E.C. Diaz, “Evaluation of lean production system by using SAE J4000 standard; case study in Brazilian and Spanish automotive component manufacturing organizations”, *African Journal of Business Management*, Vol. 6(49), pp. 11839-11850, 12 December, 2012.
- [9] D. T. Jones, “*Beyond the toyota production system: the area of lean productivity, in manufacturing strategy process and content*”, edited by C. Voss., London: Chapman & Hall Jones, 1992.
- [10] J. Shivnan, J. Harhen, and J. Browne, “*Production management systems: an integrated perspective*”, Second Edition, Addison Wesley, 1996.
- [11] Cakrawijaya, “*Seven waste shopfloor improvement specialist*”, Yogyakarta, 2008.
- [12] G.C. Pude and G.R. Naik, “Waste reduction by value stream mapping: a literature review”, *International Research Publication House*, Volume 4, Number 3, 2012.

# Production System Design Using Value Stream Mapping and Object Oriented Simulation in Dairy Toddler Industry

Teuku Yuri M. Zagloel<sup>a</sup>, M. Misbahul Muzakki<sup>b</sup>

<sup>a</sup> Industrial Engineering, Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : yuri@ie.ui.ac.id

<sup>b</sup> Industrial Engineering, Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : m.misbahul@ui.ac.id

## ABSTRACT

All companies want to achieve optimal productivity, but on the other hand achieving optimal productivity has many obstacles. These obstacles that often occur in the production system area are seven wastes (over production, over inventory, inefficient transportation, unnecessary motion, waiting, defect and inappropriate process). Reducing this waste can use Value Stream Mapping (VSM) which is one of Lean Manufacturing tools. Advantage of Value Stream Mapping can describe activity flow of Value Added (VA), Necessary but Non Value Added (NNVA) and Non Value Added (NVA). Result of Current VSM is used as basic of improvement in production system. Besides that, doing improvement at some workstations will deliver Propose VSM and doing simulation of Value Stream Mapping will give approach or mimic the real situation. This research have some purposes, like to reduce some wastes that inhibit productivity of Industry Dairy Toddlers, get Value Stream Mapping of the production flow to achieve Lean Manufacturing, and get design a better production system through object oriented simulation. Results of this research are reduction of lead time to be faster 19%, reduction of transport activity by 11%, reduction in inventory by 16% and increase production throughput by 24%.

## Keywords

*Lean manufacturing, value stream mapping, simulation, waste*

## 1. INTRODUCTION

In the past decade, consumer goods industries have a very significant growth that be driven by increasing of consumption. One of significant grows of consumer goods is toddler dairy industry. Increasing demand for dairy goods toddler is an opportunity to do business in this field. Management of this industry always works harder to improve of productivity and efficiency of the activity production to obtain the optimal profit. But on the other hand, achieving optimal productivity has many obstacles. These obstacles that often occur in the production system area are seven wastes (over production, over inventory, inefficient transportation, unnecessary motion, waiting, defect and inappropriate process).

Lean manufacturing is a systematic approach to identify and eliminate seven wastes through continuous improvement activities. Reducing seven wastes of production system will be faster of lead time, on time products delivery, reduce production costs, reduce the amount of work in process (WIP) and increase the utilization of production resources, so that companies can increase productivity (Rother, 1999). One of Lean Manufacturing tools to reduce wastes is Value Stream Mapping or VSM (Liker, 2004). Advantage of VSM can be visualization Value Added (VA), Necessary but Non Value Added (NNVA) and Non Value Added (NVA). Value Stream Mapping can describe information and material flows that are not neat, so it is easy to identify and redesign for improving system production (Liker, 2004).

Companies that have traditional approaches to their manufacturing systems will difficult to be commitment implementation of lean manufacturing (Abdulmalek, 2007). Managers have also been hesitant to adopt lean manufacturing tools because of other characteristics that are typical in this sector. These include large, inflexible machines, long setup times, and the general difficulty in producing in small batches (Abdulmalek, 2007). One of tools that can transformation redesign traditional manufacturing to lean manufacturing is simulation. Using of simulation for lean manufacturing approach, especially in the Value Stream Mapping was developed by Standridge (2006). Simulation is process to design a model in the real system and be connected in the experiment. Simulation tries to approach in the real situation (Solding, 2009). The use of simulation in the Value Stream Mapping is an interesting because the simulation will be known miniature movement of materials and information on the actual production system, without disrupting the continuity of manufacturing conditions that exist today (Solding, 2009). The information from simulation can be compare current condition and propose condition after have done some improvement (Detty, 2000).

The research gap of this paper is still a bit of research that combines value stream mapping and object oriented simulation on the dairy industry toddler in Indonesia, so that this study becomes important looks into this matter. This research have some purposes, like to reduce some wastes that inhibit productivity of Industry Dairy Toddlers, get Value Stream Mapping of the production flow to achieve Lean Manufacturing, and get design a better production system through object oriented simulation.

## 2. OVERVIEW OF LEAN MANUFACTURING AND VALUE STREAM MAPPING

Lean manufacturing is a systematic approach to identify and eliminate waste (Non Value Added) activities through continuous improvement. Lean manufacturing approach tries to neat in flow of products with pull system by attention of customer satisfaction viewpoint (Tapping , 2002). Lean manufacturing concept was originally introduced by Taiichi Ohno (Toyota Motor Corp.) that this concept is commonly called the Toyota Production System (TPS). Furthermore the concept of lean manufacturing is adopted by several large companies in the U.S. and Europe for their industrial application, because the concept proves successful to improve productivity through the elimination of wastes production.

Value Stream Mapping (VSM) is one of lean manufacturing tools that is proven effective to eliminate waste (non-added value) and tries mapping information and material flow in production systems. Value Stream Mapping was first introduced by Moki Rother and John Shook in his book "Learning to See", this book explains how uses of mapping process flow of value added activity and non value added activity in production floor to achieve lean manufacturing conditions. Value Stream Mapping was born from the concept of Toyota Production System (TPS), in which the TPS is known as "Material and Information Flow Mapping (MIFC)".

Value Added (VA) activity is all of process that provides transformation raw material to be more added value, wherein the previously raw material less valuable is transformed to more valuable and the customer is willing to pay for this activity (Liker, 2004). Necessary but Non Value Added (NNVA) activity is all of process that not adds value to the product but this process must be done, whereas Non Value Added (NVA) activity is all of process that does not provide added value to a product, and has potential to use of higher cost (Womack, 1994). All activities of Value Added (VA), Necessary but Non Value Added (NNVA) and Non Value Added (NVA) will be transformed into units of time (cycle time), where times of NNVA and NVA activity will try to be reduced, that is expected to become more effective and efficient in its production system.

There are several steps that must be done to make Value Stream Mapping (Rother, 1999), these stages are:

- i) Select target of product family that will be improvement. The selection of product family is essential because this can focus on one product, clear boundaries and not be bias.
- ii) Describe the Current VSM that important part captures how current conditions of production systems.
- iii) Identify of waste that exist in Current Value Stream Mapping.
- iv) Make improvements in some areas.
- v) Describe Propose VSM which displays images of the production system after improvement activity.

Besides that, Methodology to establish Value Stream Mapping and Simulation in this research is presented in this following;

- Gathering Data of Cycle time or processing time
- Gathering Data of Changeover time.
- Gathering Initial data collection on overall cycles times, waste time, in-process queue time.
- Gathering Data gathering for % rejects and work-in-process
- Establishing Current Value Stream Mapping
- Improvement
- Establishing Propose Value Stream Mapping
- Making Simulation
- Verification and Validation of simulation
- Analysis

## 3. ANALYSIS AND DISCUSSION

### 3.1 Collections Data

Data was taken in one of dairy toddler industry that has 5 workstation; premix/ribbon, prior, tumbler, filling and packaging. Data of cycle time and changeover time each workstation can look in table 1. Cycle time is added value activity that will be described in Current Value Stream Mapping. Changeover time occurs when there is replacement a type of product, whereas these activities includes of dry cleaning and deep cleaning.

*Table 1: Data of Cycle Time and Changeover Time*

	Unit	Premix/Ribbon	Prior	Tumbler	Filling	Packaging
Cycle Time	Seconds	1224.4	785.7	876.1	1449.9	1072.1
Changeover Time	Seconds	5400	2700	0	2700	1800

Inventory and work in process (WIP) have functions as buffer on production system. This buffer has function to keep production system running in smooth flow and no idle the next process. The data of inventory and WIP is as follows:

Table 2: Number of Actual Inventory

	Place or Workstation	Number of Inventory
Raw Material	Batching Area	60 pallets
Work In Process	Preparation Batching	7 pallets
Work In Process	Beside of Tumbler and Filling	3 BIN
Finish Goods	Warehouse Finish Goods	20 pallets

### 3.2 Data of Takt Time

Takt time is ideal time to complete making one product in production system (Rother, 1999). Takt time is very useful to know how the actual condition of the speed of the production process should be run. In this case study, Takt Time is composed of 2 kinds, it is Box and BIN. It is occurred because the unit in this system production is difference. In the station of premix, prior, tumbler and filling use BIN unit, so the form of takt time in this area shaped takt time BIN. Whereas, in the packaging area and warehouse use Box unit. So we call takt time Box.

$$\text{Takt Time} = \frac{\text{net available time}}{\text{demand produksl}} \quad (1)$$

$$\text{Takt Time BIN} = \frac{25.200 \text{ second}}{18 \text{ BIN}} = 22,5 \frac{\text{minutes}}{\text{BIN}}$$

$$\text{Takt Time Box} = \frac{25.200 \text{ second}}{1316 \text{ Box}} = 19,14 \frac{\text{seconds}}{\text{box}}$$

Takt time BIN 22.5 minutes/BIN indicates that the ideal time of workstation premix, prior, tumbler and filling finish its job every 22.5 minutes. Takt time Box 19.14 seconds/box indicates that ideal time of workstation packaging finish its job every 19.14 seconds. Besides that, instruction withdrawal of finished goods uses term of pitch. Pitch is the time interval required to take goods in the form of a finish goods (Tapping, 2002).

$$\begin{aligned} \text{Pitch} &= \text{Takt Time} \times \text{Pack Out Quantity} & (2) \\ \text{Pitch} &= 19.14 \times 54 \text{ boxes} = 1034 \text{ seconds} = 17 \text{ minutes } 13 \text{ seconds} \end{aligned}$$

Pitch value 17 minutes 13 seconds indicates that there is a withdrawal of finish goods from the packaging station to finish goods warehouse area. This pitch will be the basis for calculating the waiting time finish goods in warehouse.

### 3.3 Current Value Stream Mapping

Current VSM describes actual condition as baseline of production system before doing some improvement. This is necessary to know gap of target condition and actual condition. Current VSM has 3 main components:

- Time line consists of value added and non-value added.
- Material flow from raw materials to finished goods
- Command information production and information supply chain on the supplier and customer.

Figure 1 describes a Current VSM that suppliers come every 3 hours, whereas the finished goods are taken by truck every 2.5 hours in the shipping area. Lead time material from raw material until delivery finish goods needs 22 hours 36 minutes. Whereas the Value Added activities have done for 1 hour 10 minutes 48 seconds, and Non Value Added activities have done for 21 hours 26 minutes 24 seconds. This Current VSM describes that actual lead time in this company approximately 94% is non value added activities and just 6% is value added activity. From actual condition, it has to do improvement in some workstation.

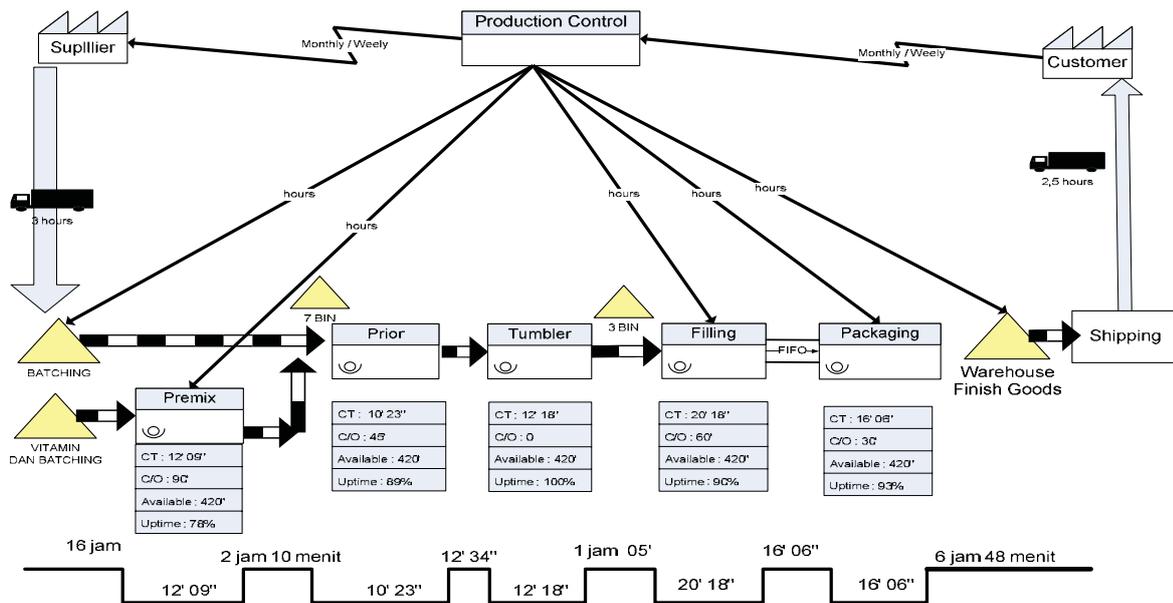


Figure 1: Current Value Stream Mapping

Visualization of current value stream has been established, and then is done some improvement at some point to increase the efficiency of the company. The summaries of improvement activity will display in table 3.

Table 3: Summaries of improvement

	Improvement	Reason	Result
1	Improvements of placement raw material in area batching, this improvement by grouping of raw material so that the operator easy takes of raw material.	Some of raw material mingled with another raw material. Operator search with difficulty of raw material presence.	Searching of material by operator will be easier and will reduce raw material out of date.
2	Reduction operators from 3 operator becomes 2 operator in area premix	Cycle time of this area still under from takt time. So that, there is idle of operator	Efficiency of using operator
3	Improvement of transfer box in workstations premix, there must be a special door to entrance the material and a special door to exit the material	During this time, the entrance and exit of material in premix area just have one door, whereas the door was busy quite high. So there is waste waiting in this area.	Materials will be more smooth flow and will reduce waiting time on the process material
4	Using safety stock of inventory is 2 BIN between workstation tumbler and filling.	In the actual safety stock of inventory in this area is 3 BIN that become waste inventory	Occurred saving time 1200 seconds
5	Using supermarket design to pull finished goods in warehouse.	In the before arrangement of finished goods in the warehouse so less of tidy, not in accordance with the pitch and not use the FIFO concept	There is no delay in sending finished goods to consumers

### 3.4 Propose Value Stream Mapping

Propose VSM will be used as new system production that has been develop by some improvement. Lead time material from raw materials until becomes finished goods needed 17 hours 24 minutes. Reducing time occurred because done some improvement in the factory, so that the continuous flow can run better and some waiting time can be reduced.

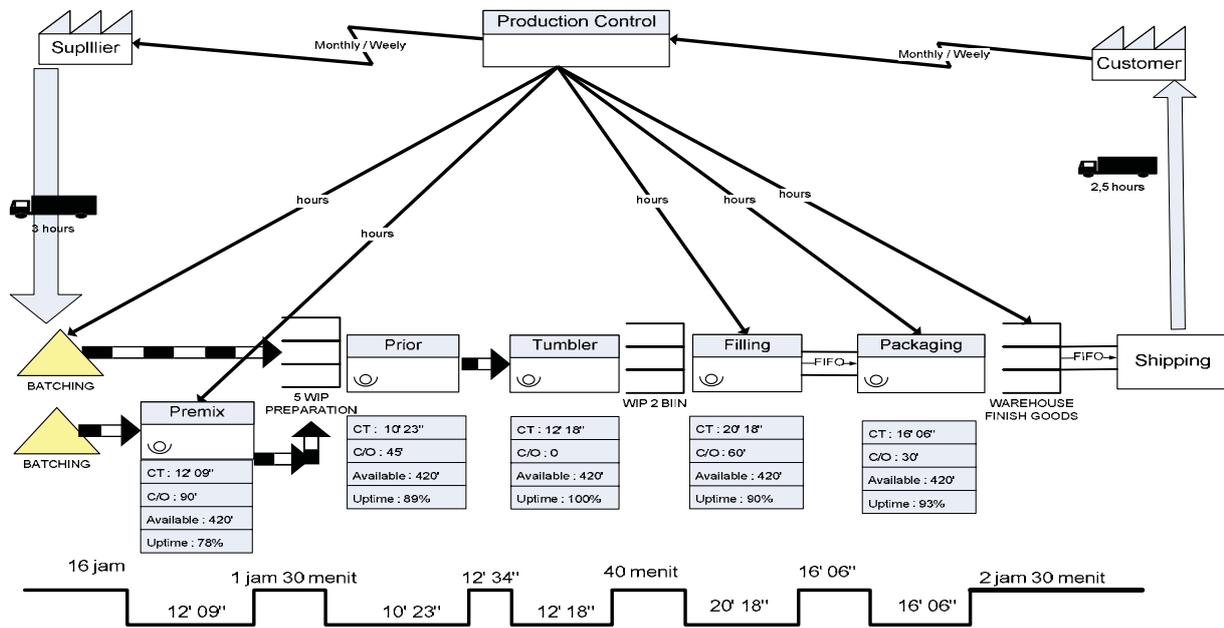


Figure 2: Propose Value Stream Mapping

In the Propose VSM shows that there are several points using of supermarket, where the supermarket serves as a place to put inventory with FIFO and there are maximum and minimum standard. So it becomes clear inventory limits in place. Because in previously system production, limitation of inventory is not clear inventory number of maximum and minimum.

### 3.5 Simulation Model of Current VSM and Propose VSM

The model will be simulated of Propose Value Stream Mapping. The simulation model will be known whether the model Propose VSM can be applied or not on production systems. In this research, before making simulation models of Propose VSM in plant simulation software, the authors made simulation model of Current VSM to testing verification and validation of simulation model.

#### 3.5.1 Verification

Verification has goal to see whether the logic and simtalk models are correct or not that has been made in plant simulation software. Some things must be done in the verification is as follows

- check all code models, entities, and the variables used.
- observe the material flow simulation and whether the model is in accordance with reality.

At the time the model was running, if the debug dialog screen appears, the model was still not able to run as expected by the user. So, users have to do the repairs continued until the model is correct and there is no display debug dialog. After some verification had done on the model and when the model was run, if the debug dialog was not reappear, the model had been verified correctly.

#### 3.5.2 Validation

After verifying the model Current Value Stream Mapping, the next step was validation model. Purpose of validation was whether the model was going according to the real condition or not. Validation of this study was done by comparing the output of the process in a real situation and output in the computer simulations. In the simulation model of Current VSM run for 8 hours produces 19 units of output, whilst the average output in real terms is 18 units. Outputs between simulation and real conditions have different 1 unit or 6%. So, the current simulation model is validated.

### 3.6 Comparison of Current Condition and Propose Condition

Table 4: Comparison of Current Condition and Propose Condition

No	Comparison	Current Condition	Propose Condition	Unit
1	Lead Time	22.6	17.4	Time (Hours)
2	Throughput Production	19	25	Pallet
3	Waste Transportations	187.4	167.4	Meters
4	Inventory & WIP	90	76	Pallet & BIN

Lead time Current VSM from raw material until becomes finish goods and ready delivery to customer needs 22 hours 36 minute. Beside that, lead time of Propose VSM needs 17 hours 24 minutes in new system production. In the propose condition there is a reduction about 19%, time reduction occurs because there are some improvement on the workstation layout premix, transfer box setting in workstation premix, fixes the amount of inventory at some point, reduction of waste transport in finished goods warehouse.

Production throughput can be viewed by plant simulation software. The simulation model is run for one shift of 8 hours and there is time reduction with time of rest, prayer and meals for 1 hour, so we got the net available time during 420 minutes or 7 hours. Throughputs Current VSM in this simulation model are 19 units. Whereas, the resulting throughput on Propose VSM is 25 units, there is an increased throughput by 24%. This is occurring because there are some of the improvements.

Transport distance at the Current VSM is 187.4 meters. Transportation consists of batching area, preparation, premix, prior, tumbler, filling, packaging and finished goods warehouse. Whereas this research will improve the finished goods warehouse area, which was added in the form of rail conveyors. So, the finish goods directly fed into the conveyor and immediately pushed forward in the rail conveyors. This design will reduce traveling activity by the operator. The results of calculation transportation savings in Propose VSM is 11%. After the improvement of transport distance becomes 167.4 meters.

Amount of inventory in Current VSM is 90 units. Whereas amount of inventory in Propose VSM is 76 units, there is 16% reduction inventory after improvement. This is the analysis of it, in the batching area there is not reduction inventory because in this area will need enough material to prepare processed in next 11 hours letters. After there is improvement in preparation area, Work In Process of this area becomes 5 units. Waiting time required after improvement becomes 1 hour 32 minutes (5 units x 1114 seconds = 5571 seconds).

In the area between workstation tumbler and filling amount of the previous Work in Process is 3 BIN, but after the count and using the existing Work in Process improvement in this area becomes 2 BIN because the condition of the filling process is longer than the tumbler. Target Work in Process becomes 2 BIN in this area to keep handy if there is fluctuation of demand or any engine problem on the previous workstations. Through this reduction of Work in Process, waiting time will become just 40 minutes.

At the area of finish goods warehouse was done improvements by using rail conveyor. Whereas the mechanism for finish goods be placed in the rail conveyor, so that the queue of finish goods become FIFO (first in first out). Every 2 hours and 30 minutes will be transported as many as 8 units to 9 units. Using this rail conveyor becomes no material that settles again in area of finish goods warehouse. Overall inventory reduction in the production system is 11 units or 16%.

### 3.7 Analysis of Simulation

Throughput of Current VSM for 2 shifts is 35 units. Whereas throughput on the first shift is 16 units, so throughputs the second shift after all materials filling buffer stock of each workstation are 19 units. Besides that, Throughput of Propose VSM is 45 units during the second shift, where the throughput on the first shift of Propose VSM is 20 units, so throughput the second shift is 25 units. This simulation can describe that throughput of Propose VSM increase to be 24%. Simulation model using Plant Simulation Software of Propose VSM can be seen in this Figure 3.

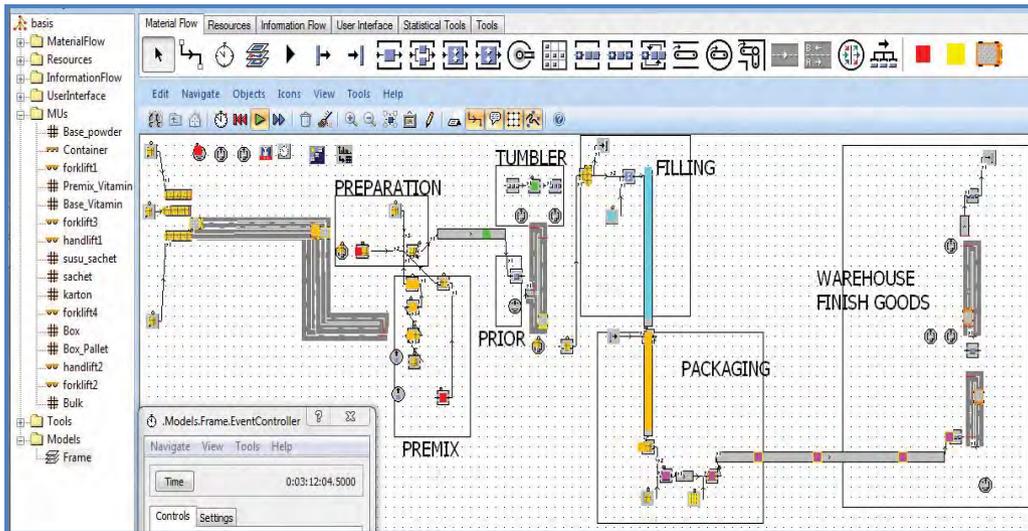


Figure 3: Simulation Model of Propose Value Stream Mapping

The performance of simulation Current VSM and Propose VSM can be seen in this comparison table 5 and 6. Several name in this simulation differ with Value Stream Mapping because this simulation have been broken-down becoming some machine to approach detail condition. Several object of this simulation are tumbler, dismantleStation, konveyor\_filling, ribbon, blend, prior, konveyor\_packaging, packaging\_karton, palletisasi and coins. The comparison performance by simulation of Current VSM and Propose VSM for all categories show that model Propose VSM better than the current VSM.

Table 5: Simulation Result of Current VSM

Object	Working	Waiting	Blocked	Failed	Paused	Unplanned	Set-up	Empty
tumbler	35.37%	64.63%	0.00%	0.00%	0.00%	0.00%	0.00%	64.63%
DismantleStation	0.02%	27.21%	46.16%	14.00%	12.60%	0.00%	0.00%	27.21%
konveyor_filling	39.13%	48.54%	12.33%	0.00%	0.00%	0.00%	0.00%	48.48%
ribbon	72.29%	0.48%	7.92%	6.71%	12.60%	0.00%	0.00%	0.48%
Blend	11.13%	42.21%	34.05%	0.00%	12.60%	0.00%	0.00%	0.00%
prior	36.84%	11.19%	39.36%	0.00%	12.60%	0.00%	0.00%	11.19%
konveyor_packaging	40.15%	59.12%	0.73%	0.00%	0.00%	0.00%	0.00%	59.10%
packaging_karton	39.50%	39.67%	0.70%	7.53%	12.60%	0.00%	0.00%	0.39%
Palletisasi	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
recehan	17.08%	70.31%	0.00%	0.00%	12.60%	0.00%	0.00%	70.31%

Table 6: Simulation Result of Propose VSM

Object	Working	Waiting	Blocked	Failed	Paused	Unplanned	Set-up	Empty
tumbler	44.06%	55.94%	0.00%	0.00%	0.00%	0.00%	0.00%	55.94%
DismantleStation	0.03%	32.08%	53.20%	2.28%	12.60%	0.00%	0.00%	31.89%
konveyor_filling	51.04%	39.89%	9.07%	0.00%	0.00%	0.00%	0.00%	39.81%
ribbon	76.21%	0.59%	4.03%	6.56%	12.60%	0.00%	0.00%	0.59%
Blend	12.95%	50.28%	24.17%	0.00%	12.60%	0.00%	0.00%	0.00%
prior	44.23%	8.89%	34.28%	0.00%	12.60%	0.00%	0.00%	8.89%
konveyor_packaging	52.51%	46.38%	1.11%	0.00%	0.00%	0.00%	0.00%	46.36%
packaging_karton	51.65%	34.69%	1.06%	0.00%	12.60%	0.00%	0.00%	0.59%
Palletisasi	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
recehan	18.75%	1.76%	66.89%	0.00%	12.60%	0.00%	0.00%	1.76%

#### 4. CONCLUSION

Implementation of Lean Manufacturing is an effort to increase the productivity of the company. Lean manufacturing proved effective in reducing waste in the production system. Through the identification of all the waste, it will be easier to solve the problem and be better condition of production system. The conclusions of this study are as follows:

- The application of continuous flow on premix workstation layout can be achieved with improvements in the area of premix. Earlier in this area often have bottlenecks at the transfer box door because the door is only one transfer box. Having improvement door transfer box into two where there is a separation between the entrance and the exit of material, so the material can be run smooth flow.
- The production lead time is faster; the Current VSM takes 22 hours 36 minutes, whereas on Propose VSM has a lead time for 17 hours and 24 minutes, there been a reduction in production lead time is around 19%.
- Throughput on Propose VSM increases by 24%. In the Current VSM throughput of production is 19 units, whereas the throughput of Propose VSM is 25 units.
- Transport activity of Current VSM is far as 187.4 meters, whereas transport activity of Propose VSM is far as 167.4 meters. It is saving transport waste by 11%.
- The number of inventory before improvement is 90 units. After re-calculation and improvement in some areas, the number of inventory becomes 76 units in the whole system. It is reduction of inventory by 14 units or 16%.

#### REFERENCES

- [1] Abdulmalek, F. A., Rajgopal, J. 2007. Analyzing the benefits of lean manufacturing and value stream via Simulation. International Journal of Production Economics
- [2] Abdullah, F., Rajgopal, J., 2003. Lean manufacturing in the process industry. Proceedings of the IIE Research Conference, CD-ROM, Portland, OR, IIE, Norcross, GA
- [3] AR, Rahani., al-Ashraf, Muhammad, 2012. Production Flow Analysis through Value Stream Mapping: A Lean Manufacturing Process Case Study. Procedia Engineering 41 1727 – 1734
- [4] Bangsow, Steffen. 2010. Manufacturing Simulation with Plant Simulation and SimTalk: Usage and Programming with Examples and Solutions. Springer-Verlag Berlin Heidelberg.
- [5] Detty, R.B., Yingling, J.C., 2000. Quantifying benefits of conversion to lean manufacturing with discrete event simulation: a case study. International Journal of Production Research 38 (2), 429–445.
- [6] Freivalds, A., Benjamin, N., 2003. Methods, Standard, and Work Design 11<sup>th</sup> Edition. Mc. Graw-Hill. New York
- [7] Liker, J. 2004. The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer. McGraw Hill.
- [8] McDonald, T., Van Aken, E.M., Rentes, A.F., 2002. Utilizing simulation to enhance value stream mapping: a manufacturing case application. International Journal of Logistics: Research and Applications 5 (2), 213–232.
- [9] Raph, M. Barnes. 1980. Motion and Time Study: Design and Measurements of Work, 7<sup>th</sup> edition, New York; Willay
- [10] Rother, M., Shook, J., 1999. Learning to See: Value Stream Mapping to Create Value and Eliminate Muda. Lean Enterprise Institute, Cambridge, MA.
- [11] Singh, Bhim., Garg, Suresh K., Sharma, Surrender K., 2011. Value stream mapping: literature review and implications for Indian industry, Int J Adv Manuf Technol
- [12] Solding, P., Gullander, Per., 2009. Concepts for Simulation Based Value Stream Mapping, Jönköping, Mölndal, SWEDEN
- [13] Stephen L., Woehrle, Louay, Abou-Shady. 2010. Using Dynamic Value Stream Mapping and Lean Accounting Box Scores to Support Lean Implementation, Minnesota State University, Mankato
- [14] Tapping, D., Luyster, T., Shuker, T., 2002. Value stream management: eight steps to planning, mapping, and sustaining lean improvements. Productivity press, New York .
- [15] Womack, J., Jones, D., 1994. From Lean Production to the Lean Enterprise. Harvard Business Review , 72 (2), 93-103
- [16] Womack, J., P., Jones, D., T., 2003. *Lean Thinking: Banish Waste And Create Wealth In Your Corporation*. New York: Free Press.

# Analysis and Measurement of Intangible Factors for Automotive Part Manufacture by TEAM Model

Tiena Gustina Amran<sup>a</sup>, Nataya Charoonsri Rizani<sup>b</sup>

<sup>a</sup>Faculty of Engineering, University of Trisakti, Jakarta 11440  
E-mail : tiena\_amran@yahoo.com, tiena@trisakti.ac.id

<sup>b</sup>Faculty of Engineering University of Trisakti, Jakarta 11440

## ABSTRACT

This research is a part of the Total Ergonomic Approach Model (TEAM) that measures 8 aspects consisted of 4 tangible aspects, such as muscle measurements and working condition, and 4 intangible factors. This paper presents industrial performance design which considers worker's measurements in cultural and environmental aspects as intangible aspects. The analysis includes four related aspects: information, time, socio-cultural and human-machine interaction. Preliminary research in shop floor found that manual production result note taking, non-computerized and duplicated process in the existing business process, delayed decision making by the Top Management, low worker loyalty, low worker welfare, and the non-existence of display application use. In this research, the measurement of intangible factors is analyzed: information and time aspects using the Time Function Mapping method, socio-cultural and human-machine interaction aspects using questionnaire. After measuring the weight, the research found poor result in information, time, socio-cultural aspects and very poor result in human-machine interaction aspect that required immediate attention for improvement.

## Keywords

*TEAM, measurements, socio-cultural, human-machine interaction.*

## 1. INTRODUCTION

According to Adiatmika (2011) Total Ergonomic Approach Model (TEAM) is an implementation of total ergonomic approach in the industrial environment. The concept adopted is to introduce simple ergonomic concepts to workers or officers based on their daily working conditions. By understanding each working conditions, officers will know which working condition is ergonomic and which is not. The officers will realize and seek to conduct simple improvement using resources available in their working environment. The improvement concept from expert center to worker center according to Kogi (2006); Manuaba (2000); Sutajaya (2005), in Adiatmika (2011) is a concept of change by empowering workers through total ergonomic approach. In this matter, workers can be trained to improve their knowledge in ergonomic through seminars, workshops, and classes so that they are aware of the ergonomic aspects of their work and working conditions and willing to improve them. The total ergonomic approach [1] [2] was used as a form of ergonomic intervention that is willing to gain a more humane, competitive, and lasting method. This approach begins with problem identification consisted of 8 aspects: (a) nutrition, (b) work posture, (c) muscle use, (d) work environment, (e) time condition, (f) information condition, (g) socio-cultural condition, (h) human-machine interaction. The total ergonomic approach by Manuaba, (2004, 2005) in Adiatmika (2011) is a form of approach using a systemic, holistic, inter-discipline, and participative or known for short as SHIP. In choosing the working condition corrections, several aspects were taken into consideration. They are technical, economic, ergonomic, socio-cultural, energy save, and environmental friendly (the proper use of technology).

This research was conducted in an automotive parts and components manufacturer. These products require good worker stamina since the manufacturing processes involve heavy materials and repetitive works. The problem appears as there are no measurement standard for intangible aspects such as information and time. This research analyze information and time using time function mapping method, and socio-cultural and human-machine interaction aspect in cooperation to implement ergonomic principle as solution. The purpose is to analyze and design work condition (socio-economic and culture) measurement as part of Total Ergonomic Approach Model (TEAM), especially intangible factors.

## 2. METHOD

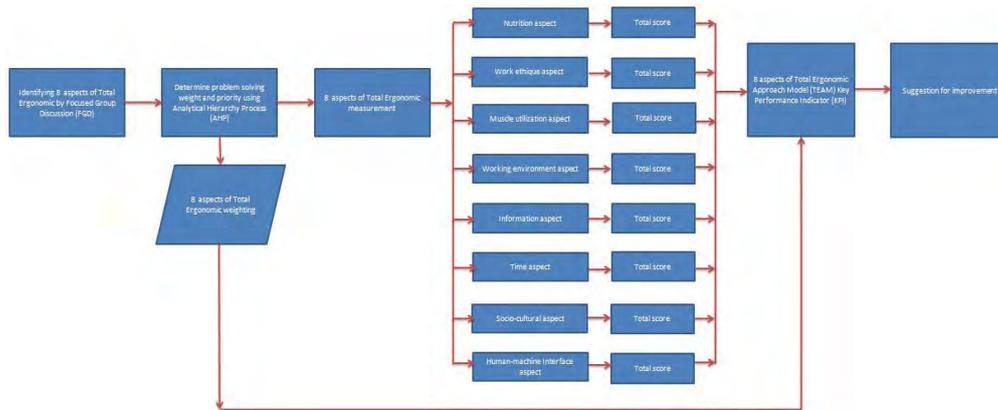


Figure 1: Research methodology

## 3. RESULTS AND DISCUSSION

The findings from the measurement of the nutrition aspect are analyzed using the Body Mass Index (BMI) method. The work posture aspect is analyzed using the Rapid Upper Limb Assessment (RULA) method. The muscle use aspect is analyzed using the Recommended Weight Limit (RWL) and Lifting Index (LI) and the work environment aspect is analyzed using the OSHA 1910.95 method scale. Analysis shows that the company is bad and need immediate improvements.

### 3.1. Information and Time Aspects

Analysis of information and time aspects are based on *Business Process Existing* (BPE) where in BPE there were many duplications and wasted time that needs to be reduced using Time Function Mapping method.

Table 1: Scoring Standard Operating Procedure

Information Delay Time (day)	Classification	Score	Information Delay Time (day)	Classification	Score
<3	Very good	5	6 - 8	Average	3
3 - 5	Good	4	9 - 11	Poor	2
			>12	Very Poor	1

Financial department has 20 days delay time - scored 1, PPIC Manager 6 days delay time - scored 3, QC Manager 11 days delay time - scored 2 to the Director. The conclusion is that majority (66.67%) of information transfer to Director are delayed with average classification score of 2.

### 3.2. Socio Cultural Aspect

**1. Validity Test :** 30 questionnaire regarding employee's welfare is distributed to 30 respondents with degree of freedom = 30, trust level 5%, hence  $r_{tabel} = 0.361$ . Validity test was run by comparing Corrected Item-Total Correlation with  $r_{tabel}$ . If Corrected Item-Total Correlation  $> r_{tabel}$  then the instrument point is declared valid and vice versa. Result showed one instrument point KES03 that is not valid. Validity test with Corrected Item-Total Correlation more than  $r_{tabel}$  (0.05; 30) = 0.361, then accept Ho. Result showed all instrument points tested are valid.

**2. Reliability Test :** Instrument point is declared reliable, if Cronbach's Alpha value  $> 0.7$ . Calculation showed Cronbach's Alpha value is 0.944 ( $> 0.7$ ), then accept Ho. Result showed 23 instrument points tested are reliable.

### 3.3. Organizational Culture Aspect

**1. Validity Test:** 30 questionnaires regarding employee's welfare were distributed to 30 respondents with degree of freedom = 30, trust level 5%, hence  $r_{tabel} = 0.361$ . Validity test was run by comparing Corrected Item-Total Correlation with  $r_{tabel}$ . If Corrected Item-Total Correlation  $> r_{tabel}$  then the instrument point is declared valid and vice versa. Result showed 4 instrument points (BUD01, BUD02, BUD03, and BUD27) not valid. Validity test with Corrected Item-Total Correlation more than  $r_{tabel}$  (0.05; 30) = 0.361, then accept Ho. Result showed all instrument points tested are valid.

2. Reliability Test : Instrument point is declared reliable, if Cronbach's Alpha value > 0.7. Calculation showed Cronbach's Alpha value is 0.892 (> 0.7), then accept Ho. Result showed 26 instrument points tested are reliable.

Table 2: Socio-cultural Aspect Measurement Scoring

Very good	Dominant score is 5	Average	Dominant score is 3
Good	Dominant score is 4	Poor	Dominant score is 2
		Very poor	Dominant score is 1

Respondents' answer to socio-cultural questionnaire showed 2 as the modus scored. This means that the respondents consider the socio-cultural value is poor.

### 3.4. Human-Machine Interface Aspect

Human-machine interface aspect is analyzed based on the use of company display attribute. The company is not using any display so the evaluation result is as below

Table 3: Direct Observation Result on the Use of Display Attribute

No	Statement	Answer		
	<b>Detection</b>			
1	Visibility	Good	<input type="checkbox"/>	Poor <input checked="" type="checkbox"/>
2	Angle	Good	<input type="checkbox"/>	Poor <input checked="" type="checkbox"/>
3	Parallax presence	Yes	<input type="checkbox"/>	No <input checked="" type="checkbox"/>
4	Contrast view with surrounding (e.g. any advertisement board or trees blocking view)	Good	<input type="checkbox"/>	Poor <input checked="" type="checkbox"/>
5	Glaring	Yes	<input type="checkbox"/>	No <input checked="" type="checkbox"/>
6	Adequate lighting	Good	<input type="checkbox"/>	Poor <input checked="" type="checkbox"/>
	<b>Recognition</b>			
7	Visual acuity	Good	<input type="checkbox"/>	Poor <input checked="" type="checkbox"/>
8	Display's shape	Good	<input type="checkbox"/>	Poor <input checked="" type="checkbox"/>
9	Character or picture size	Good	<input type="checkbox"/>	Poor <input checked="" type="checkbox"/>
10	Color of background	Good	<input type="checkbox"/>	Poor <input checked="" type="checkbox"/>
	<b>Understanding</b>			
11	Color contrast between characters and background	Good	<input type="checkbox"/>	Poor <input checked="" type="checkbox"/>
12	The use of correct symbol or codes	Good	<input type="checkbox"/>	Poor <input checked="" type="checkbox"/>
13	Language	Understandable	<input type="checkbox"/>	Not <input checked="" type="checkbox"/>
14	Sentences	Understandable	<input type="checkbox"/>	Not <input checked="" type="checkbox"/>

Table 4: Display Aspect Measurement Scoring

Score 5	Very good	11 - 14 display attribute fit and 0 - 1 attribute unfit
Score 4	Good	8 - 10 display attribute fit and 4 - 6 attribute unfit
Score 3	Average	5 - 7 display attribute fit and 7 - 9 attribute unfit
Score 2	Poor	2 - 4 display attribute fit and 10 - 12 attribute unfit
Score 1	Very Poor	No display attribute exist

Observation showed that the company did not use any display, so the score for human-machine interface aspect is 1 very poor.

## 4. CONCLUSION

Based on the analysis result, it can be concluded that the ergonomic problem identification through the intangible factors. The Total Ergonomic Approach Model (TEAM) is more comprehensive in dealing with the company's ergonomic problem by providing integrated improvement to obtain a total solution. The result for Information and Time aspect using *Time Function Mapping* method is 66.67% immediate redesign is needed.

Socio-cultural aspect using questionnaire method means company needs to improve work condition and worker welfare. Human-machine interface aspect is very poor, therefore immediate attention and improvement is needed. Redesigning Information and Time aspects should not be using Business Process Existing (BPE) because it does not represent the real condition, has many duplication of process, and wasted time. Proposed solution for Socio-cultural aspect are to create solid regulation and punishment, salary adjustment, and benefits improvement for workers. From the point of view of Human-machine interface, it is recommended for the company to apply the use of visual display instead of auditory display due to noisy environment, company's performance indicating the overall working environment as 'poor' and improvement is needed.

## ACKNOWLEDGEMENT

The authors thank the Industrial Engineering Department Trisakti University for sponsoring this research for Quality In Research 2013.

## REFERENCES

- [1] Adiatmika, I Putu Gede, *Total Ergonomic Approach Model Untuk Mendukung Program Patient Safety Industri Kesehatan di Rumah Sakit. Proceeding 11<sup>th</sup> National Conference of Indonesian Ergonomics Society 2011*, ISSN: 2088-9488, Depok, 14-15 September 2011.
- [2] Adhit, *Visual Display: Pengetahuan Umum*. <http://sitahoo.com/blog/visual-display-pengetahuan-umum/18/03/2012>, 2011.
- [3] Budi, Ichsan Setiyo, *Manajemen Strategis: Konsep*. Edisi 10. Diterbitkan dari David, Fred R. 2005. *Strategic Management: Concepts and Cases. 10<sup>th</sup> ed*, Jakarta: Salemba Empat, 2008.
- [4] Heizer, Jay and Barry Render, *Pearson International Edition: Operations Management*, Eight Edition. New Jersey: Pearson Prentice Hall, Inc., 2006.
- [5] Nurmiyanto, Eko, *Ergonomi Konsep Dasar dan Aplikasinya*. Edisi Kedua. Surabaya: Penerbit Guna Widya, 2008.
- [6] Oesman, Titin Isna dan I Putu Gede Adiatmika, *Aplikasi Model Total Ergonomic Approach Pada Industri Kecil-Suatu Pendekatan Praktis*. Seminar Nasional Aplikasi Sains dan Teknologi, 2008, IST AKPRIND, Yogyakarta, 2008.
- [7] Stanton, Neville, *Handbook Of Human Factors and Ergonomics Methods*, CRC Press, 2005.
- [8] Udaya, Jusuf, *Teori Organisasi: Struktur, Desain, dan Aplikasi*, Edisi 3. Diterjemahkan dari Robin, Stephen. P. 1990, *Organization Theory: Structure, Design, and Applications*, Jakarta: Penerbit Arcan, 1995.
- [9] Wignjosoebroto, Sritomo, *Ergonomi Studi Gerak dan Waktu Teknik Aplikasi Untuk Peningkatan Produktivitas Kerja*, Edisi Pertama. Cetakan Kedua, Surabaya: Penerbit Guna Widya, 2000.
- [10] Yuniastuti, Ari, *Gizi dan Kesehatan*, Edisi Pertama, Yogyakarta: Graha Ilmu, 2008.

# Usability Software: Application to Exponentially Weighted Moving Average Control Chart

Christine Puteri Utama<sup>a</sup>, Laurence<sup>b</sup>, Helena J.Kristina<sup>c</sup>

<sup>a,b,c</sup> Industrial Engineering Department, University of Pelita Harapan 15811  
E-mail : laurence.uph@gmail.com

## ABSTRACT

Moore's Law stated that number of inexpensive transistors that placed in printed circuit board will be double every 1.5 years, even though the theory was developed long time ago in the mid of 1960s, nowadays it is unquestionable reality that the development of semiconductor enable high speed computing process. The rise of semiconductor industry over the year helped the software industries to develop product that will be used by students and engineers, either for research or business purpose. Minitab is one of the well known application software used not only for statistical computation purpose, but also quality control and design of experiment. The research focused on usability according scheme of dimensions defined by Nielsen (1993) and ISO-9241. Learnability measured by pre-test and number of module seen by respondent. Efficiency calculated from time of completion the task and correction recorded in pretest. Number of mistakes is accumulated to be defined in error dimension. Memorability is defined in number of mistakes during post test, while satisfaction as the last dimension is obtained based on satisfaction through questionnaires. Activities covered in the research include decision on experiment location, criterion of respondent, indicator for usability, module creation and questionnaire, training, pretest, post test, and filling the questionnaire. Experiment applied to 58 industrial engineering active students of class 2008-2010 resulted that usability of EWMA control chart is 0,61 (*good*), in details for every dimension as followed: learnability 0.71 (*good*), efficiency 0.64 (*good*), errors 0.44 (*moderate*), memorability 0.30 (*poor*), and *satisfaction* 0.81 (*excellent*).

## Keywords

*Usability, learnability, efficiency, memorability, satisfaction*

## 1. INTRODUCTION

Usability is part of the concept Human Computer Interaction, where the study area is make the computer system easy to be learned and used (Preece et al. 2002). Usability study consists of several dimension according to Nielsen (1993) and ISO-9241, which are learnability, efficiency, memorability, errors, and *satisfaction*. Result of the study can be used by user in condition of choosing software that is user friendly, comfortable, not take long time to operate and achieve user's objective. On software developer side, usability study will benefit the team to develop product that meet close customer needs.

### 1.1. Objective

Usually software house attach the control chart module to equip the product to be more powerful. The control chart itself is widely used in business and education since first time invented by Shewhart and tested through long period of application. The research is designed to measure usability EWMA control chart built in Minitab software.

### 1.2. Scope

The respondents are limited to the IE active students, range from class of 2008 until 2010. There is consideration why the respondent taken from the same department, there is probability that in other engineering, the control chart is not taught yet or not included in curriculum.

## 2. RESEARCH METHODOLOGY

Initial phase of the research begin with searching important literature study such as the theory released by Nielsen and official document from ISO 9421 that will be used as reference point for further steps. After that, next is to define the objective, to measure usability using dimensions covered in the theory. The experiment was initiated with location decision, material - tools selection, respondent criterion, research indicators, module creation, training the respondents, and fill the pre-test until post test and finally distributing-collecting questionnaire. The test divided

into two different period, pre-test consists of three problems with each of the case have different number of step to be completed and then one week after pre-test, the respondents enter post-test phase which require them to redo the same questions and then each students need to fill the questionnaires. Tests applied are normality, homogeneity and mean test using ANOVA or Kruskal-Wallis applied to observation data, while for questionnaire result will be examined by validity test using corrected item-total correlation approach, and reliability test based on cronbach alpha. Normalization phase run with objective to have one measurement scale between dimension, before the whole total value and each factor of usability taken place.

### 3. DATA COLLECTION AND DISCUSSION

In the initial phase, some type of data such as variable and attribute data were collected and summarized in one table. Table 1 below showed the average and standard deviation of the pre-test score, time to finish the task given, time required to correct mistake and number of mistake made by respondents. Number of dimension covered in first phase is three, while memorability and satisfaction will be conducted on the next stage.

Table 1: Data Collection Phase 1

Class	Learnability Dimension							Efficiency Dimension					
	a. Pretest Score						b. Avg part of module seen	a. Time to Finish Pre-Test (second)					
	Mean	Stdv	Mean	Stdv	Mean	Stdv		Mean	Stdv	Mean	Stdv	Mean	Stdv
	Q1	Q1	Q2	Q2	Q3	Q3	Q1	Q1	Q2	Q2	Q3	Q3	
2008	77.19	8.75	84.69	6.18	91.56	5.69	3.44	98.25	25.54	148.50	32.11	178.94	28.35
2009	86.20	7.54	90.60	5.46	96.20	3.89	2.44	51.08	16.59	122.76	19.17	135.80	19.68
2010	78.82	6.97	81.76	6.74	89.41	4.96	3.88	99.41	24.68	163.29	24.95	187.12	31.44
Error Dimension													
Class	Number of Mistake						b. Time to Correct Mistake (second)						
	Mean	Stdv	Mean	Stdv	Mean	Stdv	Mean	Stdv	Mean	Stdv	Mean	Stdv	
	Q1	Q1	Q2	Q2	Q3	Q3	Q1	Q1	Q2	Q2	Q3	Q3	
2008	4.56	1.75	3.06	1.24	1.69	1.14	4.56	5.53	13.94	8.93	23.44	14.92	
2009	2.76	1.51	1.88	1.09	0.76	0.78	1.08	0.95	6.28	6.75	11.04	8.15	
2010	4.24	1.39	3.65	1.27	2.12	0.99	5.12	5.44	13.53	11.79	21.82	9.84	

After the data collection of the first stage finished, the respondents gathered again to finish the same task given. They were tested to know whether still remember the steps to finish the problem and do the mistake. Table 2 summarizes the average error of comparison between pre-test and post-test.

Table 2: Data Collection Phase 2

Class	Memorability Dimension											
	Average Error of Test						Stdev Error					
	Q1	Q1	Q2	Q2	Q3	Q3	Q1	Q1	Q2	Q2	Q3	Q3
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
2008	4.56	6.00	3.06	4.63	1.69	2.69	1.75	1.86	1.24	1.63	1.14	1.14
2009	2.76	4.52	1.88	3.68	0.76	1.72	1.51	1.39	1.09	0.90	0.78	0.89
2010	4.24	6.35	3.65	4.76	2.12	2.59	1.39	1.77	1.27	0.75	0.99	1.18

To measure satisfaction score, the respondents were given questionnaire to filled and submitted to surveyor. They had to complete 20 questions using likert scale from lowest 1 which is strongly disagree until the highest 5 if they are strongly agree about satisfaction using EWMA control chart of the software. The accumulation maximum score will be 5800, get from multiplication number of highest likert scale of 5 number of questions and number of respondents.

$$\% \text{Satisfaction} = \frac{4.181}{5.800} \times 100\%$$

$$\% \text{Satisfaction} = 72.086\%$$

The score 4181 of total 5800 result around 72% and this value belongs to category satisfy in range 61% - 80%.

#### 3.1. Normality Test

Null hypothesis in normality test using Kolmogorov Smirnov state that data is normally distributed, while H<sub>1</sub> is vice versa. The p-value needs to be larger than 0.05 in order null hypothesis accepted. The normality test result that only time taken to finish pre-test is normal distribution, but for pre-test score, time to correct mistake, number of error, and number of error in post-test as followed: *Box-Cox Transformation, Largest Extreme Value, 3-Parameter Lognormal, and 3-Parameter Weibull.*

Table 3: Normality Test

Normal Distribution Test: Kolmogorov Smirnov				Non Normal Distribution	
Dimension	Item	P-value	Normal Distribution?	AD Score	Distribution
Learnability	Pre-test score	0.01<0.05	N	2.894	Box Cox Transformation
Efficiency	Time to Finish pre-test	0.15>0.05	Y	-	-
Efficiency	Time to Correct Mistake	0.01<0.05	N	6.206	Largest Extreme Value
Error	Number of Mistake	0.01<0.05	N	2.989	3 Parameter Lognormal
Memorability	Number of Error in Post-Test	0.01<0.05	N	2.055	3 Parameter Weibull

### 3.2. Homogeneity Test

Homogeneity test with prerequisite condition that data is normally distributed using Bartlett method was run to test whether two or more samples of same population also have the same variance. This will be applied to time taken to conduct pre-test for the reason that it is the only one that passed the category. Null hypothesis for homogeneity test states that there is no difference in variance between three cases if p-value greater than 0.05. The p-value from computation using software is 0.537, therefore null hypothesis is accepted.

### 3.3. ANOVA Test

ANOVA test is run to test whether there is mean difference between the three problems in pre-test. Furthermore, the same test will be applied to see whether difference between the classes of respondents. In condition there is difference among the mean, next Post Hoc Test assumed equal variance with Tukey method will take place to reveal which population is distinctive, which required data normally distributed and homogenous. Table 4 exhibits the significant value of both ANOVA test is zero which is less than 0.05, so it can be stated to reject the null hypothesis since there is mean difference between each case and between each class.

Table 4: ANOVA Test

	Between Class Respondents					Between Three Problems				
	Sum of Squares	df	Mean Square	F	Sig.	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	79868.484	2	39934.242	21.034	.000	224429.011	2	112214.506	106.551	.000
Within Groups	324649.889	171	1898.537			180089.362	171	1053.154		
Total	404518.374	173				404518.374	173			

Table 5 section post hoc tests between cases exhibits that beside all significant value are less than 0.05, there are star sign in mean difference for each row which mean the three cases have mean significant different. Same approach applied to post hoc test between class and the result is significant different between class 2008-2009 and 2009-2010.

Table 5: Post Hoc Test

Post Hoc Test Between Case					Post Hoc Test Between Class				
(I) Case	(J) Case	Mean Difference (I-J)	Std. Error	Sig.	(I)Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.
Case 1	Case 2	-63.483 <sup>*</sup>	6.026	.000	2008	2009	38.683 <sup>*</sup>	8.054	.000
	Case 3	-84.483 <sup>*</sup>	6.026	.000		2010	-8.045	8.762	.630

Case 2	Case 1	63.483 <sup>+</sup>	6.026	.000	2009	2008	-38.683 <sup>+</sup>	8.054	.000
	Case 3	-21.000 <sup>+</sup>	6.026	.002		2010	-46.728 <sup>+</sup>	7.908	.000
Case 3	Case 1	84.483 <sup>+</sup>	6.026	.000	2010	2008	8.045	8.762	.630
	Case 2	21.000 <sup>+</sup>	6.026	.002		2009	46.728 <sup>+</sup>	7.908	.000

### 3.4. Kruskal Wallis Test

Kruskal Wallis Test which is similar with ANOVA test is non-parametric technique used to measure mean difference from non-normally distributed data. The point of interest is where  $H_0$  state no difference between the mean and null hypothesis accepted if sig value is greater than 0.05. Mann-Whitney test will be applied as the next step after Kruskal Wallis Test, similar with Post-Hoc Test in ANOVA. Data that will be examined in the test as follow: pre-test score, time to correct the mistake during pre-test, number of error during pre-test and number of mistake during post-test.

Table 6: Kruskal Wallis & Mann Whitney Test

Dimension	Item	Sig Value		Note	Mann-Whitney Test's Sig Value		Note	Note
		Case	Class		Case	Class		
Learnability	Pre-test score	0.000	0.000	Reject Ho	<0.05	<0.05	Case & Class 1, 2, 3	Mean Different
Efficiency	Time to Correct Mistake	0.000	0.000	Reject Ho	<0.05	<0.05	Case & Class 1, 2, 3	Mean Different
Error	Number of Error in Pre-Test	0.000	0.000	Reject Ho	<0.05	0.556	Class 2008 vs 2010	Not different for class 2008 vs 2010
Memorability	Number of Error in Post-Test	0.000	0.000	Reject Ho	<0.05	0.927	Class 2008 vs 2010	Not different for class 2008 vs 2010

### 3.5. Validity Test

In this validity test, the objective is to measure is the satisfaction of respondent when using the software by looking value of Corrected Item-Total Correlation. The questionnaire valid if the counted r-value is larger than r-table from Product Moment. Degree of freedom is 56, resulted from number of respondents deducted by 2. As with degree of freedom 56 not included in the table, the calculation to get result is by using interpolation.

$$\frac{56-55}{60-55} = \frac{r-0.266}{0.254-0.266}$$

$$r = 0.2636$$

R-value for each of 20 questions are larger than 2.636, with 0.278 is the minimum value of r. Therefore as all the value pass r-table, it can be concluded that 20 indicators is valid.

### 3.5. Reliability Test

Reliability test using statistical software show that the cronbach'alpha score 0.833 as shown in table which is greater than 0.7. Therefore with confidence level 95%, the questionnaire distributed to students is reliable.

Table 7: Reliability Test

Reliability Statistics	
Cronbach's Alpha	N of Items
.833	20

### 3.6. Normalization

The purpose on this activity is to eliminate the unit from each attribute, so that each will have the same measurement unit. It is necessary step for five dimension to test whether the usability of this control chart's software good or not based on category table 8, which defined by Chiew and Salim 2003.

Table 8: Category of Normalization Value

Points, x	$0 \leq x \leq 0,2$	$0,2 < x \leq 0,4$	$0,4 < x \leq 0,6$	$0,6 < x \leq 0,8$	$0,8 < x \leq 1,0$
Usability Level	Bad	Poor	Moderate	Good	Excellent

First step in normalization is summarize data per respondent as follow: the average score of each respondent for pre-test score, frequency of number of module seen which can be zero if respondent not looking the module, average time needed for each respondent to complete the pre-test, average time to correct mistake, average number of mistake, average number of error for pre-test, average number of error for post test. Next is to calculate normalization value for each respondent. For instance, when calculating pre-test score it is known that the bigger the score the better the usability value, so divide score each respondent for each category with the biggest value on that column. After normalization for each dimension is completed, the final step is compute an average usability value to represent the level usability level of the software

$$\begin{aligned}
 Usability\ Level &= \frac{\text{Average Normalization Every Indikator Usability}}{\text{Number of indikator usability}} \\
 &= \frac{0.87 + 0.55 + 0.61 + 0.68 + 0.44 + 0.30 + 0.81}{7} \\
 &= 0.61
 \end{aligned}$$

When the average value 0.61 compared with the table 8, the score fall into category good where its range is vary between 0.6 until 0.8. It means that the usability level for EWMA control chart of this software is good.

#### 4. CONCLUSION

From the experiments, it can be concluded overall usability of the software is good with the score 0.61, however not all dimension belong to good category. The result good category is the same for the first two dimension, where learnability get 0.71, efficiency get 0.64, but error dimension get moderate score of 0.44, memorability get poor level of 0.3, and satisfaction get 0.81 which is excellent.

#### REFERENCES

- [1] Chiew, Thiam Kian and Siti Salwa Salim. "Webuse: Website Usability Evaluation Tool." *Malaysian Journal of Computer Science* Vol. 16, No. 1 (June 2003).
- [2] CSUQ. "Computer System Usability Questionnaire," *CSUQ Online*. Home page on-line. Available from <http://oldwww.acm.org/perlman/question.cgi>; Internet; accessed 5 November 2011.
- [3] Dix, A., J. Finlay, G. Abowd and R. Beale. *Human Computer Interaction*. London: Prentice-Hall, 1993.
- [4] Ferre, Xavier, Natalia Juristo, Helmut Windl, and Larry Constantine. "Usability Basics for Software Developers." *IEEE Software* (January/February 2001).
- [5] Jeffrey Rubin, Dana Chisnell, *Handbook of Usability Testing*, Wiley 2008.
- [6] International Ergonomics Association. "Ergonomics Human Centered Design," *International Ergonomics Association Online*. Home page on-line. Available from <http://www.iea.cc/01what/What%20is%20Ergonomics.html>; Internet; accessed 10 November 2011.
- [7] Intel website about Moore Law Technology. <http://www.intel.com/content/www/us/en/silicon-innovations/moores-law-technology.html>
- [8] Minitab. "Software for Quality Improvement," *Minitab Online*. Home page on-line. Available from <http://www.minitab.com/en-US/company/company-info/default.aspx>; Internet; accessed 2 November 2011.
- [9] Montgomery, Douglas C. *Statistical Quality Control: A Modern Introduction*, 6<sup>th</sup> ed. New York: John Wiley & Sons, 2009.
- [10] Nielsen, Jakob. *Usability Engineering*. United Kingdom: Academic Press Limited 1993.
- [11] Preece, J., Helen Sharp and Yvonne Rogers. *Interaction Design: Beyond Human-Computer Interaction*. New York: John Wiley & Sons, 2002.
- [12] QUIS. "Questionnaire for User Interface Satisfaction," *QUIZ Online*. Home page on-line. Available from <http://hcibib.org/perlman/question.cgi?form=USE>; Internet; accessed 7 November 2011.
- [13] Sanjay J.Koyanl, Robert W.Balley, Janke R.Nall, Susan Allison, Conrad Mulligan, Kent Bailey, Mark Tolson. *Research Based Web Design and Usability Guidelines*
- [14] Sarwono, Jonathan. *Metode Penelitian Kuantitatif dan Kualitatif*. Yogyakarta: Graha Ilmu, 2006.
- [15] Sastramihardja, Husni S. "Perancangan Kerja dalam Perangkat Lunak Interaktif." *Jurnal Teknik Informatika ITB* Volume 1 Nomor 1 (1999).
- [16] SUMI. "Software Usability Measurement Inventory," *SUMI Online*. Home page on-line. Available from <http://sumi.ucc.ie/en/>; Internet; accessed 9 November 2011.
- [17] Sutalaksana, Iftikar Z., Ruhana Anggawisastra, John H. Tjakraatmadja. *Teknik Perancangan Sistem Kerja*. Bandung: Teknik Industri Institut Teknologi Bandung, 2006.

# Economic Analysis of Middle Class Residential With Solar Cell: Case Study of Cyber Orchid Town Houses in Depok

Farizal<sup>a</sup>, Patricia Hanna J<sup>b</sup>

<sup>a</sup>Faculty of Engineering, Universitas Indonesia, Depok 16424  
E-mail : farizal@ie.ui.ac.id

<sup>b</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : patricia.hanna@ui.ac.id

## ABSTRACT

Given the fact that Indonesia is on the equator zone with abundant sunshine, the utilization of solar cell technology to generate electricity is still not well developed. On the other side, demand for electricity is steadily increasing, especially from household consumers. This study aims to determine the technical utilization of solar power system as a source of electricity generator and its feasibility to be used in middle-class residential houses. Two types of solar power system being reviewed are stand-alone system and grid connected system. The result shows that installation of the system in a middle-class resident may not be economically rewarding due to high cost of the solar system investment compared to the electricity cost from conventional system. However, the sensitivity analysis shows the systems are being economically feasible in certain circumstances.

## Keywords

*Solar cell, feasibility study, middle-class residential houses, sensitivity analysis*

## 1. INTRODUCTION

Electrical problem in Indonesia begins from the fact that the energy need increases more than the ability of the State Electric Company (Perusahaan Listrik Negara, PLN) fulfills the required energy. Electricity demand from year to year increases with rate about 7.2% per year while the electricity generation capacity development grew steadily of 5.1% per year [1]. According to the reference [2], household and industry sector are the biggest electrical energy consumers. This fact is supported by the population of Indonesia reached 237 million with the population growth rate of 1.49% per year (BPS, 2010). Electricity demand growth in Indonesia causes existing primary energy deposit is diminishing. This prompts the government to look for alternative energy resource to produce substantial amount of energy but does not have negative impact for the environment.

Solar energy is one of potential renewable energy sources to use in Indonesia. The energy received by the earth's surface is only 51% of the total solar radiant energy. On a sunny day, solar radiation can reach 1000 watt/m<sup>2</sup>. If a semiconductor device (solar cell module) of 1 m<sup>2</sup> has an efficiency of 10%, then, it is capable to provide electric power in about 100 Watt. Right now the efficiency of commercial solar cell modules ranging from 5% -15%. As addition to energy, solar cell panels do not produce pollution.

One constraint on the solar cell utilization in Indonesia is technology availability for its production. Indonesia has only solar cell assembly industry. Raw materials are imported from other countries. Because of this, the solar cell price is expensive. The life time of solar cells commonly referred as photovoltaic (PV) that currently applied is 25 years [3]. Based on data collection from 18 locations in Indonesia, solar radiation in Indonesia can be classified as follows: in Western Indonesia has approximately 4.5 kWh/m<sup>2</sup> daily with monthly variation 10%, and in Eastern Indonesia has approximately 5.1 kWh/m<sup>2</sup> daily with monthly variation 9%. For this reason Indonesia has a quite large potential of solar energy. With the high potential solar radiance in Indonesia, it is expected that the use of solar cells as a source of electrical energy in residential house can be a part of proper solution. Thus, the objectives of this study is to investigate what system and capacity of solar panels can be used as the source of electrical energy in the middle-class resident. This research is continued to determine the feasibility of using solar cell as a source of electrical energy with the most favorable scenario and the most influential factor in the investment project.

## 2. METHODOLOGY

### 2.1 The Technical Calculation of Solar Power System

For technical system design installation of solar cells, the type of house and direction of the building are identified. This study is using Cyber Orchid Town Houses Residential. The house classification is used for estimating future technical (mounting of the tilt) of solar panels to be placed on the roof area.

Category A, building's size: 85, building's side: north - south

Category B, building's size: 85, building's side: west - east

Category C, building's size: 40, building's side: - south

Category D, building's size: 40, building's side: west - east

Area of all roof is evenly 32 m<sup>2</sup>. The monthly electrical energy usage for each house is known from PLN Depok. The result, the average electric energy utilization per day is 10.03 kWh. Hence, in calculating the area of solar power system to generate that amount of energy can use the formula:

$$\frac{E_L}{G_{av} \times \eta_{pv} \times TCF \times \eta_{out}} = PV \text{ Area}$$

The average daily consumption of electric energy in this residential ( $E_L$ ) is 10.03 kWh.  $G_{av}$  is the value for daily isolation every hour approximately 0-1 kWh/m<sup>2</sup> from 06:00 until 18:00 (according to the daily sun movement).  $\eta_{pv}$  is the value of the solar panel efficiency 14.5%. The value of  $\eta_{out}$  is the compound of all components efficiency of the solar power system. Solar system also consists of battery, inverter and controller. Then, the  $\eta_{out}$  value gets from the multiplication of the components efficiency.

$$\eta_{out} = \eta_b \times \eta_i \times \eta_c = 0,95 \times 0,97 \times 0,98 = 0,903$$

Standard temperature for the solar panels can work well is 25°C. Meanwhile, according to geographic data from NASA, the maximum temperature is 27.1°C in Depok. So there will be a reduction in generated power when the temperature rises. So, the TCF value is 0,9895. If the values of  $G_{av}$ ,  $\eta_{pv}$ , TCF,  $\eta_{out}$  are being substituted to the formula of PV area, then the result is:

$$\frac{10.03 \text{ kWh}}{3,3 \text{ kWh/m}^2 \times 0,145 \times 0,9895 \times 0,903} = 24,748 \text{ m}^2 \approx 25 \text{ m}^2$$

Components of solar power system are as follows:

- Solar Panel. Solar panel in this case is using the same specification with ASL-M50 from PT. Azet Surya Lestari. This solar panel has capacity at standard conditions 50 watt-peak. The area of solar panels which is used in the installation plan of solar power system is a 25 m<sup>2</sup>. It can be filled with 56 pieces of solar panels. The solar panel arrangement is divided into two sections to the side of the roof. Installation is directed to the north at an angle of 25° on both sides of the roof [4]. Because of Depok is located in the south of equator (6°LS), the solar panel should be oriented to the north.
- Battery. Battery capacity in the solar power system is a deep cycle battery which has a capacity of storing energy by 1000 ampere-hour and voltage of 2V. The cycle of this battery is specifically designed for energy storage. This battery is suitable for renewable energy systems because it has long life cycles (thousands cycles) and has a capacity of 80% for use before recharging. Ideally, a battery's bank of energy should be able to store electrical energy for 3-5 days. If the battery bank capacity is less than 3 days, it will affect the cycle of battery life that will make the battery life becomes shorter.
- Inverter. The inverter is using the same specification with SUNNY BOY 5000TL.
- Controller. Controller in this case is using the same specification with Sunny Backup 2200.

The solar power system is generally divided according to the configuration of its components. There are 2 types of solar power system which is widely known.

- The grid connected system. This system is the union of solar power system with other power lines (conventional or grid electricity from renewable energy systems). The most important component in this system is inverter. Inverter serves to convert the DC which generated by solar panels into AC and it is adjusted to suit the requirements to other connected power grid. In this system, other components are not necessary because electric energy from batteries which generated from solar panels will be replaced by conventional power grid (in this study is PLN). When the solar panels are not generating the electrical energy, conventional grid will fulfill of the electrical energy needs.
- The stand alone system is designed to operate in producing electrical energy self-sufficient for electricity needs in one place. In other words, the type of power system is only activated by solar panels. The most important component in stand-alone solar power system is battery because it is used for backup storage and distribution of electrical energy generated. When the solar panels cannot generate electricity, then the electrical energy will be drawn from the battery.

## 2.2 Calculation of Solar Power System Feasibility

The period of the study is 25 years (the life time of solar panel). The feasibility of the investment of solar power system can be calculated by following methods [5]:

- Net Present Value (NPV). The calculated value of cash flow to get the NPV is the sum of the value of money in period zero or known by the present value to the value of net cash flow (income minus expenses) are calculated using the present worth factor as a benchmark for the balance of the existing present value.
- Payback Period (PB) is the length of the period to restore the value of the investment through revenues generated by the project. Discounted payback period (DPB) is the refund period is calculated using the discount factor.
- Benefit Cost Ratio (BCR) is another method for validating the results of the evaluation projects that has been done with other methods before. This method is properly to use in order to evaluate the government projects that have direct impacts in communities (public government project).

The components of the initial investment costs: cost for solar power system components, rack panel installation costs and installation costs the system. The component cost of solar power system is for solar panels, batteries, inverter and controller. Because there are two types of solar power system which are being studied then there are also 2 types of investment options:

- Investment of stand-alone solar power system: Rp. 389 542 418, -
- Investment of grid connected solar power system: Rp. 226 584 018, -

Yearly operational and maintenance cost for solar power system is generally calculated as 1% of the total initial investment cost for components of solar power system [6] Therefore, the total cost of operation and maintenance of both types of systems solar power in the case study research are:

- Operational and maintenance (O&M)costs for stand-alone solar power system = 1% x (Rp 126 million, - + Rp. 17,795,798, - Rp. 162 958 400, - + Rp. 23,888,220, -) = Rp. 3,306,424, -
- O&M costs for grid connected solar power system = 1% x (Rp 126 million, - + Rp. 17,795,798, - Rp. 23,888,220, -) = Rp. 1,676,840,-

Component for an income or cash-in in stand-alone solar power system is monthly electricity bill which is saved of using solar power system. Cash-in for grid connected in cash flow of solar power system is from the electrical energy sold to PLN system and being valued according to the feed-in-tariff regulations. From the regulation of Minister of Energy and Mineral Resources No. 4 of 2012, the cost of purchasing electric energy from renewable energy sources is Rp. 1.004,-/kWh for Java-Bali region. While in President Regulation no. 8/2011 explains the cost of electricity for household level is Rp. 790,-/kWh up to Rp.795,-/kWh.

### 3. RESULTS AND DISCUSSION

Tables 1 and 2 below show calculation results of stand-alone and grid connected system, respectively. The tables indicate none category of the resident has positive NPV. Considering that the initial investment of this project is very large (approximately Rp. 390.000.000,-) but the money saved from the electric bill is very small (only about Rp. 400.000,-) monthly. In addition, solar power system is also incurred operating and maintenance cost each year that further reduces the cash inflow values. In conclusion, this project is not economically feasible. For the grid connected system (table 2), PLN buying price is Rp. 1.004, -/kWh. This value of is apparently not big enough to recover the huge amount of initial costs. For the house category A and category B their PB is unknown due to the value of the cash-in flow is smaller than the cash out flow.

Table 1: Results from Stand Alone Solar Power System

House Category	Feasibility Indicator		
	Net Present Value (NPV)	PB (year)	B/C Ratio
Category A	(Rp. 382.532.914,-)	63	0,089
Category B	(Rp. 371.910.857,-)	54	0,31
Category C	(Rp. 376.963.904,-)	57	0,27
Category D	(Rp. 376.963.904,-)	57	0,27

Table 2: Results from Grid Connected Solar Power System

House Category	Feasibility Indicator		
	Net Present Value (NPV)	PP (year)	B/C Ratio
Category A	(Rp. 241.694.242,-)	-	0,15
Category B	(Rp. 232.818.351,-)	-	0,15
Category C	(Rp. 222.700.150,-)	63	0,15
Category D	(Rp. 225.990.353,-)	81	0,15

Sensitivity analysis was then performed to see how any changes in the cash flow components such as lowering the initial investment cost, reduction of O&M cost, rising PLN buying price and increasing solar system efficiency influence the NPV (see figures 1 and 2).

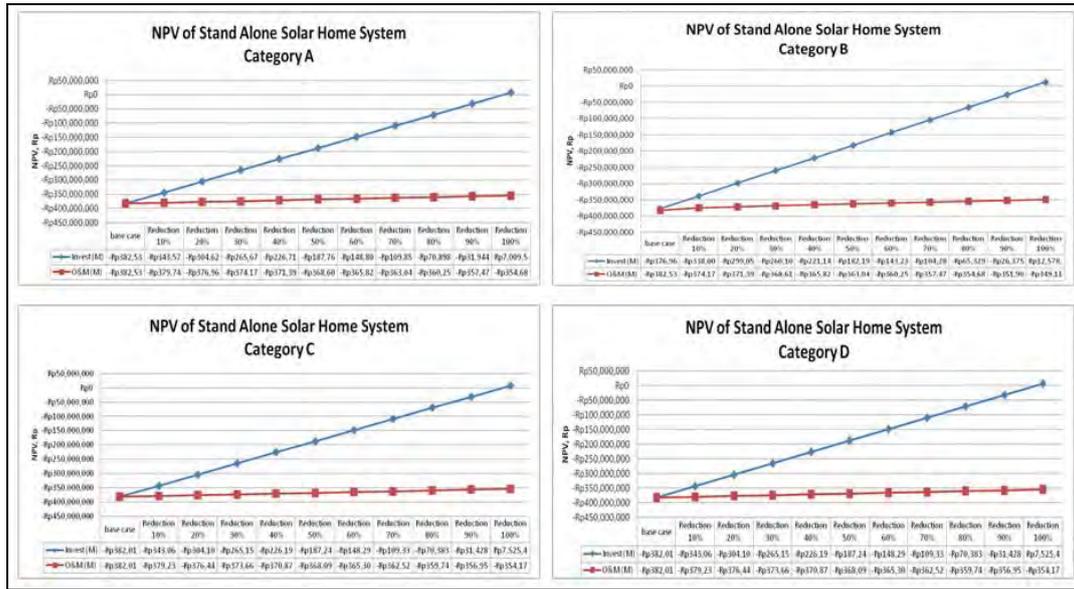
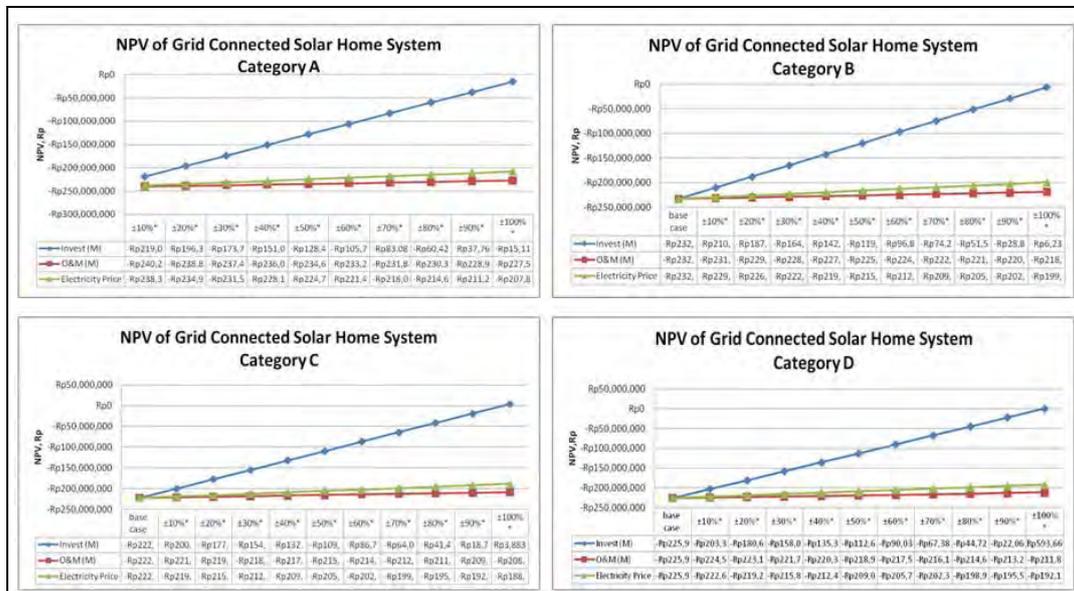


Figure 1: Sensitivity Analysis Cash Flow for Stand Alone Solar Power System

Figure 1 and 2 show that the NPV turned out to be positive if the initial investment decreases by 100%. This condition might be applicable if the government totally subsidizes PV likes happen on the kerosene to liquefied petroleum gas (LPG) conversion program. At that time, the government provides incentives by giving the LPG bottle freely (Presidential Decree 104/2007). As for the change in the operational and maintenance costs, they do not give significant effect on the NPV values. The slopes are fairly flat. The situation also occurs for the electricity buying price. The NPV is not changed much. Even the impact is slightly less than the impact of O&M costs likes the slopes depicted.



\*- for reduction investment and yearly O&M cost; + for the rising of selling price of electricity

Figure 2: Sensitivity Analysis Cash Flow Grid Connected Solar Power System

Sensitivity analysis results for 2 variables such as changes in initial investment costs and in O&M costs stand alone solar power system are shown in figures 3 and 4. A decrease of 100% is equated with the concept of calculation of leveling cost of

electricity (LCOE) [7]. The results shows that for all types of houses, the NPV will be positive when the initial investment reduced by 100% and O&M costs by 10%.

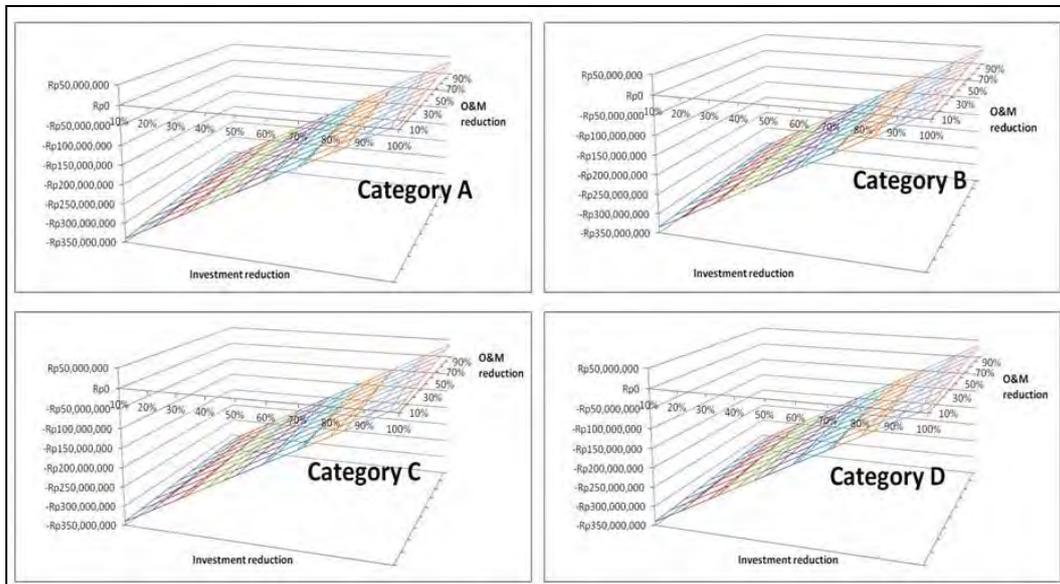


Figure 3: Sensitivity Analysis Cash Flow Stand Alone Solar Power System

For the grid connected system, the NPV is checked when a combination of falling prices and rising investment occur. The graph shows the changes of slope which means both components are the most sensitive to affect the NPV. Figure 4 shows the NPV will be positive if the initial investment drops by 100% and the electricity price increases at 30% -50%.

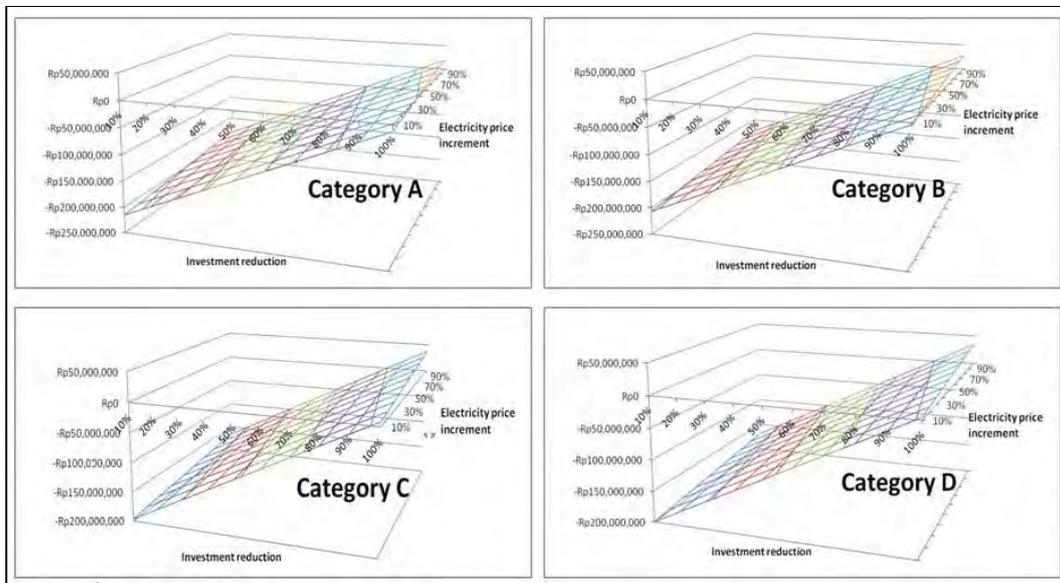


Figure 4: Sensitivity Analysis Cash Flow Grid Connected Solar Power System

Figure 5 shows the effect of efficiency to the NPV. Currently the solar panels achieve the highest efficiency at the rate of 18% - 20%. This efficiency is quite small compared to other power generation systems, for example landfill gas combustion engine efficiency. The waste power plant efficiency rate is 84.2%. Figure 5 clearly shows that even with efficiency 80%, the NPV is still not positive. In this case, to have NPV positive the efficiency should reach 95%. None generating system can produce 100% efficiency.

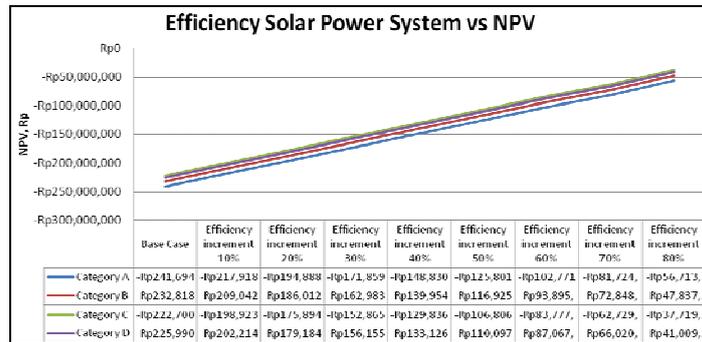


Figure 5: NPV versus Efficiency Grid Connected Solar Power System

#### 4. CONCLUSION

Solar power system suitable for middle-class residential should be designed to generate power up to 1.1 kW as the needs of electricity from Cyber Orchid Town Houses, Depok indicated. With that design, the solar system can generate electrical energy of approximately 10.95 kWh daily or 3997 kWh yearly. However, the NPV calculated for 25 years of the system life time ends up as negative. This means solar cell system is not suitable to be used as electricity generator for middle class houses. The result is reasonable due the fact that the initial investment of the system is very high. But, on the other side, it gives a very small cost saving each year. Sensitivity analysis results show the most sensitive factor for NPV is the decreasing of investment costs and raising electricity price. Sensitivity analysis also shows that optimal system to be used is solar cell system with battery.

#### REFERENCES

- [1] Kementerian Energi dan Sumber Daya Mineral, "Master Plan Pembangunan Ketenagalistrikan 2010 – 2014," in press.
- [2] Badan Pusat Statistik, "Ekonomi dan Perdagangan 2009," in press.
- [3] Bernal-Agustin, Jose L. and Rodolfo Dufo-Lo'pez, "Simulation and Optimization of Stand-Alone Hybrid," in *Renewable Energy Systems*, Spain: Elsevier, 2009, pp. 2111-2118.
- [4] Romasindah, Karlina, "Optimasi Kinerja Panel Surya Melalui Pengaturan Susunan Panel Sebagai Sun Shading untuk Menekan Biaya Listrik Bangunan" Depok: Universitas Indonesia, 2008.
- [5] Canada, J.R., W.G. Sullivan, and J.A. White, "Capital Investment Analysis for Engineering and Management, 3th ed.," New Jersey: Prentice Hall, Inc. Upper Saddle River, 2006.
- [6] Kaltschmitt, Martin, Wolfgang Streicher and Andreas Wiese, "Renewable Energy: Technology, Economic and Environment," Berlin: Springer-Verlag Berlin Heidelberg, 2007.
- [7] Ramadhan, Mohammad, "The Cost Benefit Analysis of Implementing Photovoltaic Solar System in the state of Kuwait," in *Renewable Energy, Spain: Elsevier*, 2011, pp.1272-1276.

# Intervening Variables to Motor Cycle User Satisfaction: Positive and Negative Impacts of Vehicle Operation Discipline and Knowledge

Djoko Sihono Gabriel<sup>a</sup>, Rahmat Nurcahyo<sup>b</sup>, Yunita Ramanda<sup>c</sup>

<sup>a,b,c</sup> Faculty of Engineering  
University of Indonesia, Depok 16424, Indonesia  
Tel.: (+6221) 7270011 Fax.: (+6221) 7270077  
E-mail: dsihono@yahoo.com

## ABSTRACT

*Main problem of how to improve motorcycle user satisfaction as dependent variable is not only to find independent variables and its impacts, but also intervening variables and its types and magnitude of intervention. This proposition is a new and better construct than current mainstream of customer satisfaction paradigm that more focused on finding out of independent variables and its impacts. So, objectives of this research were to define those intervening variables and to show empirical evident of its intervention coefficients. Subject of this research were two group of motor cycle users based on type of vehicle, automatic and manual category of motor cycle, in Jakarta, Bogor, Depok, Tangerang and Bekasi. They were asked to indicate their perceptions on the six-point Likert-type scale. Structural equation modeling (SEM) applied to manifest the model suitability and develop a standard questionnaire to obtain user's perceptions about customer satisfaction and its independent as well as intervening variables. This research found out a new empirical evident that both Vehicle Operation Knowledge and Vehicle Operation Discipline intervened between those relationship. This conclusions provide valuable insight into motor cycle manufacturers that their efforts in improving product quality, performance and reliability were not always resulted with better user's satisfaction.*

## Keywords

*satisfaction, intervening variables, motor cycle*

## 1. INTRODUCTION

Motorcycles have become a very interested transportation for most of society in Indonesia. Motorcycles are regarded as means of transport which are relatively easily affordable to buy, both in urban and rural areas. The low of income, bad infrastructure and undeveloped mass transportation system making the society choosing the motorcycle became an important transportation tool.

Competition between manufacturers continually increase along with the rapid growth of Motorcycle Industry. Therefore, it is a challenge for the motorcycle to improve the company's competitive advantage in order to be successful in capturing market share competition.

For that purpose, the company's ability to meet the needs and satisfaction of the customers is one very important thing. This ability was strongly influenced by level of quality provided. The higher of company quality level given to customers, it can increase the level of customer satisfaction. But, if there is a gap between the level of quality provided the company with customer expectation, it will causes dissatisfaction of customers that affect to decrease the company market share

## 2. LITERATURE STUDY

Customer satisfaction has a direct relationship with sales and profit. If customer satisfy, they can be a loyal customers. The loyal customers not only repeat to buy but also recommend the product to other people based on the quality of products they experienced as stated by Conklin [1].

The determination of product quality dimension may refer to Garvin Eight Dimensions [2]:

1. *Performance*, the product's primary operating characteristic, especially with a function. It is main characteristic that people consider to buy the product.
2. *Features*, are additional characteristics that enhance the appeal of the product or service to the user.

3. *Reliability*, Probability of successfully performing a specified function for a specified period of time under specified conditions
4. *Conformance*, Degree to which a product's design and operating characteristics meet established standards.
5. *Durability*, reflection of the economical age or product lifetime
6. *Serviceability*, ease of service or repair when needed.
7. *Aesthetics*, it is about display, packaging, flavour, sound, smell.
8. *Perceived Quality*, quality are received or accepted by customer.

Chiu, et al. in 2011 [3] shows some factors that can affect to customer satisfaction of car at Taiwan. These factors are *Image*, *Customer Expectation*, *Perceived Quality* and *Perceived Value* as following picture:

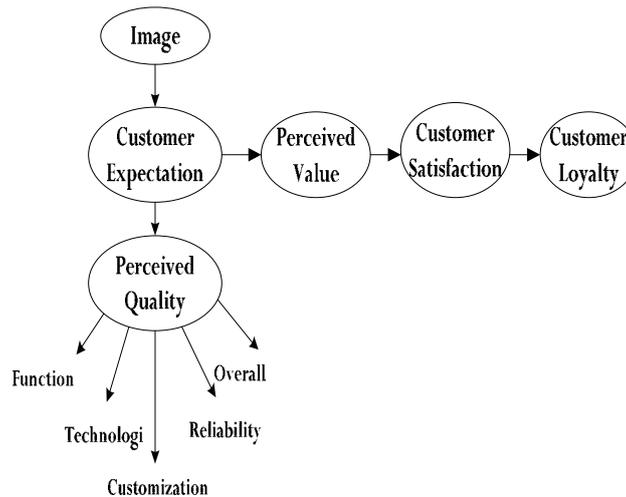


Figure 1: Cars Customer Satisfaction Model at Taiwan [3]

### 3. METHODOLOGY

This research was conducted to determine the comparative relationship some subject with sample of respondents examined through data capture in the short term. The population was observed in this study are the users of motorcycles with the type of duck and matic in Jakarta, Bogor, Depok, Tangerang and Bekasi. Because the population is too large, the research uses sampling method.

This research using Structural Equation Modeling method [4] usually abbreviated with SEM. Below is the initial model of the research that will be tested first.

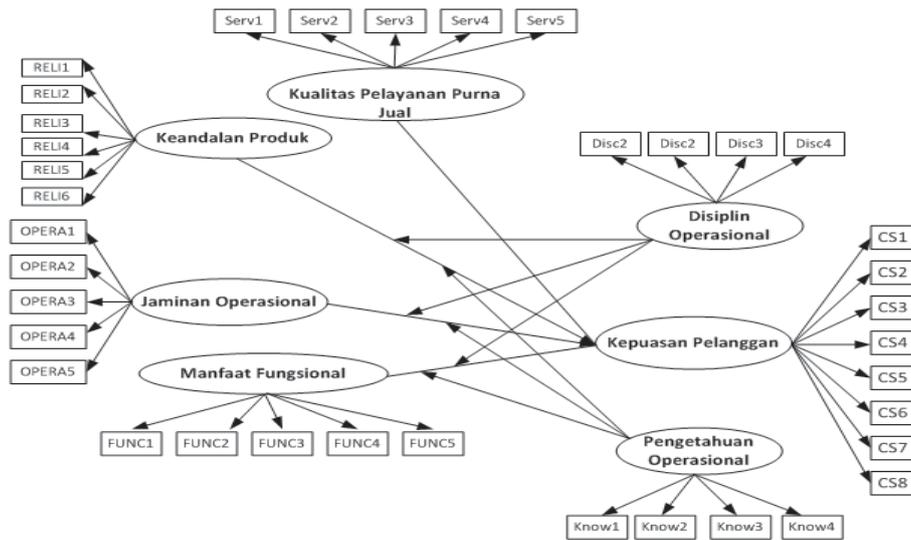


Figure 2: Research Initial Model

The hypothesis will be tested in this research is:

- H1: Customer satisfaction motorcycles positively influenced by fulfillment of Functional Benefits.
- H2: Customer satisfaction motorcycles positively influenced by fulfillment of Operational Guarantee.
- H3: Customer satisfaction motorcycles positively influenced by fulfillment of Vehicle Reliability.
- H4: Customer satisfaction motorcycles positively influenced by fulfillment of the quality of after-sales service.
- H5: Operational knowledge positively strengthen the relationship between the Functional benefits of Fulfillment with customer satisfaction.
- H6: Operational knowledge positively strengthen the relationship between the fulfilment of Operational Assurance with customer satisfaction.
- H7: Operational knowledge positively strengthen the relationship between the reliability of vehicles with customer satisfaction.
- H8: Operational discipline positively strengthen the relationship between the Functional benefits of Fulfillment with customer satisfaction.
- H9: Operational discipline positively strengthen the relationship between the fulfilment of Operational Assurance with customer satisfaction.
- H10: Operational discipline positively strengthen the relationship between the reliability of vehicles with customer satisfaction.

The questionnaire contains two major parts, the question of respondent information and related variables of user gratification motorcycles using 6 category likert scale. These are all factors (variables) are tested on research:

1. Functional Benefits Fulfillment (*Functions*): The fulfillment of customer benefits that related to functional properties of motorcycles according to Chiu et al statement [3].
2. Operational Guarantee Fulfillment (*Assurance*): The fulfillment of customer assurance that related to operational characteristic of motorcycles
3. Vehicle Reliability (*Reliability*): The size of the possibility of such a product (vehicles) will not be damaged during a specific time period according to Kotler [5].
4. The Quality of Service (*Service Quality*): Customer perception of maintenance fulfillment guarantees of vehicles as well as relational comfort with service providers according to Kotler [5].

The proposed intervening variable is:

1. Operational Knowledge: User knowledge of motorcycle-related expertise and skills necessary to take advantage of the bike properly.
2. Operational Discipline: The discipline of motorcycle users to meet the technique requirements needed to use a motorcycle properly.

#### 4. RELATIONSHIP BETWEEN VARIABLES

After a pilot test, reliable and valid questionnaire is used in collecting data process according to sample number needed. This process was undertaken from April until may 2012 and have 517 questionnaires. From 517 questionnaires, found 22 questionnaires was invalid because some of the answers are empty, so only 495 questionnaires which can be used in data processing. Following are the results of data processing using SEM:

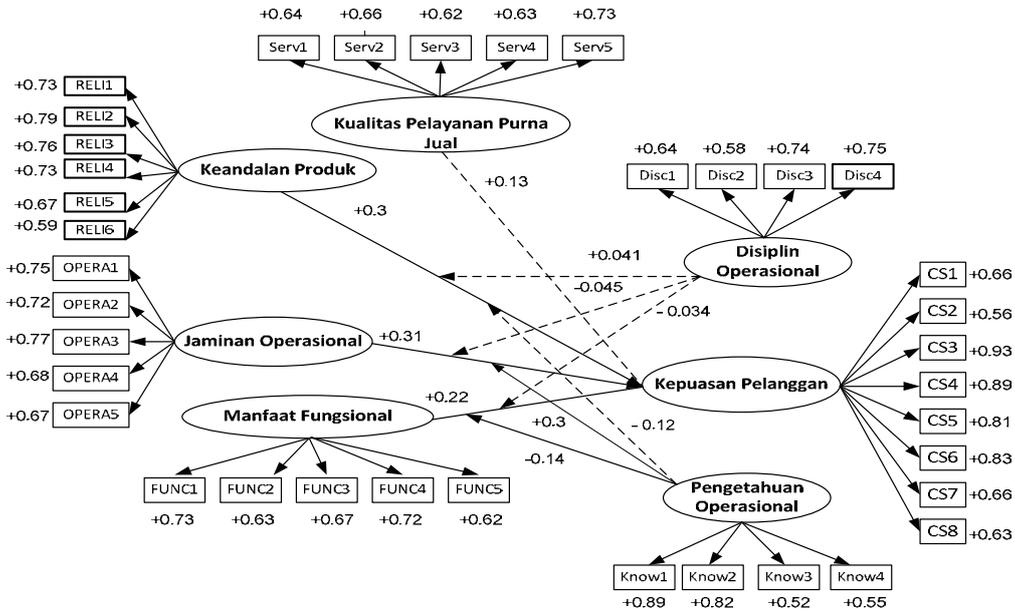


Figure 3: Relationship between variables of the motorcycle matic type users

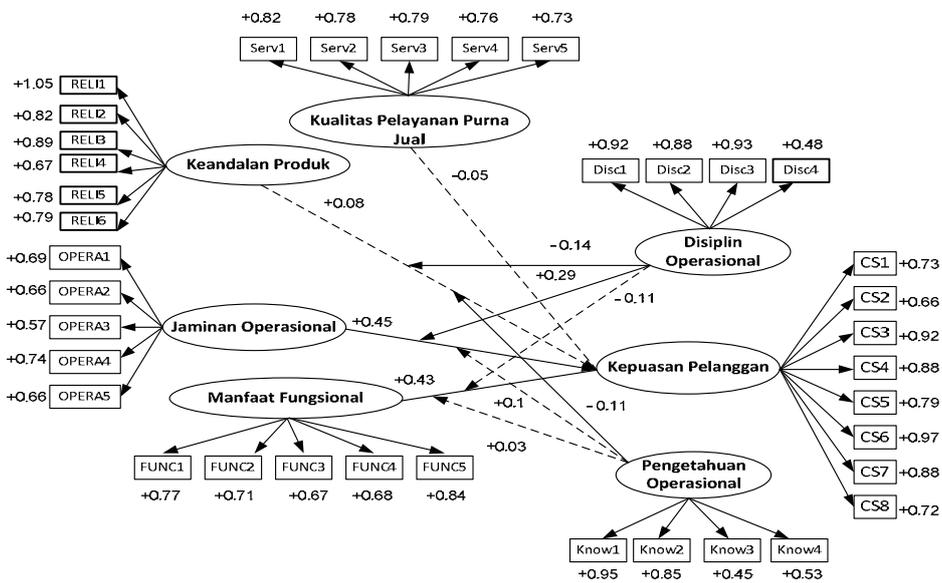


Figure 4: Relationships between variables of the motorcycle type duck users

Table 1: Comparison of variable between duck and matic motorcycle type

No	Relationship	Duck Type		Matic Type	
		Coefficient Value	Conclusion	Coefficient Value	Conclusion
1	OPERA=>CS	0.31	Significant	0.45	Significant
2	FUNC=>CS	0.22	Significant	0.43	Significant
3	RELI=>CS	0.3	Significant	0.077	Unsignificant
4	SERV=>CS	0.13	Unsignificant	-0.057	Unsignificant
5	KNOWOPERA=>CS	0.3	Significant	0.097	Unsignificant
6	KNOWFUNC=>CS	-0.14	Significant	0.092	Unsignificant
7	KNOWRELI=>CS	-0.12	Unsignificant	-0.11	Significant
8	DISCOPERA=>CS	-0.045	Unsignificant	0.29	Significant
9	DISCFUNC=>CS	-0.034	Unsignificant	-0.11	Unsignificant
10	DISCRELI=>CS	0.041	Unsignificant	-0.14	Significant

**Description:**

- FUNC: Functional Benefits Fulfillment
- OPERA: Operational Assurance Fulfillment
- RELI: Vehicle Reliability
- SERV: Quality of After Sales Service
- KNOW: Operational Knowledge
- DISC: Operational Discipline
- KNOWFUNC: Operational Knowledge\*Functional Benefits Fulfillment
- KNOWOPERA: Operational Knowledge\* Operational Assurance Fulfillment
- KNOWRELI: Operational Knowledge \*Vehicle Reliability
- DISCFUNC: Operational Discipline\*Functional Benefits Fulfillment
- DISCOPERA: Operational Discipline\*Operational Assurance Fulfillment
- DISCRELI: Operational Discipline \* Vehicle Reliability

**5. DISCUSSION AND BENEFIT OF RESEARCH RESULTS**

According to the hypothesis, on the motorcycle duck type, the role of one of the intervening variable is proven, the higher Operational Knowledge will increase the influence of Operational Guarantee Fulfillment variable against customer satisfaction.

On the contrary, intervening variable of Operational Knowledge thus weaken influence Functional Benefit Fulfillment against customer satisfaction. Contradiction of this hypothesis may caused by perception towards the low fulfillment of functional benefit on motorcycle duck type and also decrease their satisfaction. Although these allegations still needed to be tested further. On the duck type: the sequence of significant variable

The results on duck type: the sequence of significant influence variables towards customer satisfaction are Operational Assurance Fulfillment, Vehicle Reliability and Functional Benefit Fulfillment. Quality of after sales service is not significant influence towards customer satisfaction. This happen because most of them didn't use official workshop.

While on the matic type, intervening varibale of operational knowledge will decrease influence of vehicle reliability variable towards customer satisfaction. Contradiction of this hypothesis may caused by low perception of vehicle reliability and also causes low customer satisfaction. But this assumption still needed to be tested further.

Operational discipline variable can increase the influence of operational assurance variable towards customer satisfaction, according to proposed hypothesis. Thus, the sequence of significant variable are: Operational Assurance Fulfillment, Functional Benefit Fulfillment and Vehicle Reliability.

The result of this research can use by motorcycle company as consideration in order to satisfy the customers. Intervening variables of Operational Knowledge and Operational Discipline can influence relationship between independent and dependent variable. Because of that, the influence of this variable should be studied by each company and according to certain brands. On the motorcycle duck type, the company should pay attention in company efforts to increase operational knowledge of users because it significants influence relationship between operasional assurance fulfillment and customer satisfaction. While on matic type, the company should increase operational discipline of users in order to increase relationship between operasional assurance fulfillment and customer satisfaction. For intervening variable that have negative impact, the company should be vigilant, because these happens as a result of low motorcycle performance, so still need to be studied further.

This research is limited to learn some of variables that affect to customer satisfaction, and its increase or decrease by two kinds of intervening variable. Because of that, this model potentially developed by adding new variables to see its effect on customer satisfaction comprehensively. This research also have limited in responent scope that only covers some of the motorcycle users in the area of Jabodetabek.

## REFERENCES

- [1] Conklin, Michael. (2004). "Customer Satisfaction Analysis : Identification of Key Drivers". *European Journal of Operational Research*, 2004, 154/3, 819-827
- [2] Garvin, David A. "Competing on the Eight Dimensions of Quality", *Harvard Business Review*, November-December 1987, pp. 101-109.
- [3] Chiu, Shao-I, Ching-Chan Cheng, Tieh-Min Yen & Hsiu-Yuan Hu. (2011). "Preliminary Research on Customer Satisfaction Models in Taiwan : A Case Study from the Automobile Industry." *Expert System with Application* 38 (2011) 9780-9787
- [4] Wijanto, Setyo Hari. (2008). "Structural Equation Modelling dengan LISREL 8.8". Yogyakarta :Graha Ilmu
- [5] Kotler, P. (2006). *Marketing management* (12th ed.). New York, NY: Prentice Hall.

# Product Development of Cylinder Head Component using Quality Function Deployment and Value Analysis Approach

Maya Arlini Puspasari<sup>a</sup>, Erlinda Muslim<sup>b</sup>, Y. Wahyu Suryawidayat<sup>c</sup>

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : maya@ie.ui.ac.id

<sup>b</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : erlinda@eng.ui.ac.id

<sup>c</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : whygd@yahoo.com

## ABSTRACT

This research is focused on product development of Cylinder Head, an engine of motor cycle component. The product development is critically important to fulfill customer needs to apply this component in motorcycle racing event. In this case, the customer is eight Partner Teams of the manufacturer that follow Indoprix motorcycle race event. Quality Function Deployment method is used to connect customer needs with manufacturer strategy. Some tools of Value Analysis, such as Mudge Diagram, Matrix of Resources, and Comparison Matrix are implemented to analyze data. The output of this research is a specification of Cylinder Head that can be produced by the manufacturer. This research also determined production cost and the importance of customer need.

## Keywords

*QFD, Value Analysis, Mudge Diagram, Resources Matrix, Comparison Matrix*

## 1. INTRODUCTION

The business process of product development must be focused on the customer. In fact, if it is not customer-based, it will consume more time to deal with customer later [1]. The customer needs can contradict with manufacturer's capability, because customer demands maximum satisfaction, however manufacturers have limitations to fulfill customer needs. In this case, product development attempts to bridge customer needs and manufacturer's strategy. Product development is not a temporary process with haste activity, but need a systematic, measurable, dan limitable steps. Product development process is defined as sequence of steps or activities to arrange, design, and commercialize a product, giving added value to reduce gap with customer need fulfillment [2]. In this research, the product development process is based on Quality Function Deployment (QFD) and Value Analysis (VA) approach.

QFD concept is introduced by Dr. Yoji Akao in Japan in 1966. Akao defines QFD as a systematic method to define design quality to be customer expectation and translate them to be design target and critical quality point, so that can be used in production or service development phase. QFD is an effective total quality management tool based on customer need, and commonly used in product or service development in industry [3]. QFD is consist of 4 phase, are Product Planning Phase, Product Design Phase, Process Planning Phase, and Production Planning Phase. Value Analysis is an investigation method for all components of products to find and eliminate unnecessary cost without damage, disturb, or reduce performance of product [4]. The main purpose of VA study is increased the value for maintaining and increase product performance, while in same case, reduce cost entirely. Value increases if cost reduces with product performance maintaining. Value will also increase if customer wants to pay more [5].

Some of Value Analysis Tools used are Mudge Diagram, Resources Matrix, and Function & Cost Percentage Comparison Matrix. Mudge Diagram is a diagram which describes the importance level of customer needs that have passed pairs comparison before [6]. Resources Matrix is deployment of total cost to fulfill customer needs. The cost is defined to have more detail attribute and illustrated in Resources Matrix [7]. Comparison Matrix of Function and Cost Percentage is a comparison between function importance level in Mudge Diagram with cost percentage in Resources Matrix. This matrix can explain how much cost will be paid to fulfill customer need, with the importance of customer need [7].

This research takes place in a manufacturer who is a market leader in motorcycle industry in Indonesia and primary agent from one of motorcycle trademark from Japan. This manufacturer leads the market and motorcycle selling in Indonesia with

2,701,278 unit sold in 2009, and 3,416,049 unit sold in 2010. However, in 2011, market competition is harder than before. There was 80,000 unit sold difference with competitor in February 2011, and 20,000 unit sold difference in March 2011. Therefore, it is important to apply some new marketing strategies, which is giving attention and special promotion in racing segmentation. The actual marketing activity is become an official sponsorship for eight Team Partners who follow Indoprix motorcycle racing event, the most popular and highest level racing event in Indonesia. This research is based on dissatisfaction of cylinder head component that is produced by manufacturer for Indoprix event. Until now, manufacturer just provides Cylinder Head mass pro standard. It is not suitable, and need a lot of adjusting and modification for racing application.

Cylinder Head is a component motorcycle engine that stay over the Cylinder Comp. Cylinder Head close upper Cylinder Comp, forming combustion chamber. Cylinder Head is vital component that influences engine performance, because one of part of Cylinder Head named porting as intake port and exhaust port for fuel from carburetor or injector to combustion chamber. Cylinder Head is also used for Camshaft seating. Figure 1 describes cylinder head component more specifically.

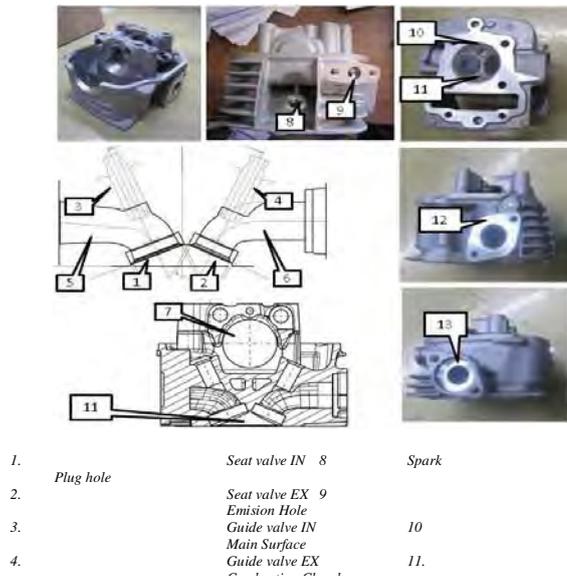


Figure 1: Cylinder Head Illustration

This Product development of Cylinder Head Component with racing specification is critically important. From the previous research, effectiveness of Cylinder Head can contribute 30% to increase Rear Wheel Power. From survey, it is known that modification cost for build Cylinder Head racing specification is the most expensive compared to other components. Besides that, longer modification time is needed, and the continuous quality and performance of Cylinder Head component can not be maintain continuously because Team Partners still use manual manufacturing system.

## 2. METHODS

Data source for this research generates from four types. The first one is observations and benchmarking Cylinder Head modification by Team Partner, by collecting Cylinder Head and comparing quality, performance, and product characteristic. The second one is customer need and complaint data collecting for Cylinder Head mass production standard. The method is collecting by survey method with some question. Third one is observation of Cylinder Head mass production standard manufacturing process, and fourth one is observation of Cylinder Head modification manufacturing process by Team Partner.

Based on data above, requirement interpretation is formed to describes customer needs. Because there are many customer needs, we can classify them into some groups, using Affinity Diagram. Not all customer needs are important, therefore, we must make priority level of customer need using Mudge Diagram tool. Mudge Diagram can be formed after pass Pairs Comparison method before. Pairs Comparison are against every customer needs and giving score for importance level. Moreover, we can start QFD Phase 1. QFD Phase 1 can be called product planning phase. QFD phase 1 can be done with focus group method involving customer, marketing staff, product engineering staff, and manufacturing engineering staff. QFD phase 1 defines customer need to be quality characteristic. In QFD phase 2, the quality characteristic in phase 1 is defined to be part characteristic that discuss product specification technically. This phase is named product desain and can be done by focus group with product engineering staff majority. QFD phase 3 wants define part characteristics to be process parameters, all of manufacturing effort to make Cylinder Head racing specification, appropriate with consideration in part characteristic in phase

2. Phase 3 finds all of detailed activities to manufacture Cylinder Head with special specification with their relative importance.

Detail of activities to manufacture Cylinder Head with racing specification is very important to determine source of cost from every customer needs. Cost calculation consists of man power cost, machining cost, material cost, and sub assembly component cost. Then, all of costs are calculated before product development until after product development. It is important to classify parts of variable cost and fixed cost (new machine investment, new cutting tools buying, desain and programming cost, dies investment). Determination of a detailed cost attributes cost is necessary to construct a Resources Matrix. Resources Matrix consists of customer needs items, and how much the cost to fulfill each consumer needs. Cost contains a detailed cost breakdown of each activity. We can construct a percentage cost of each requirement. Furthermore, we can form Comparison Matrix, a comparison between percentage of importance ratio of customer need with percentage of cost for each customer needs. This matrix is very useful for analyzing cost allocation for each customer need, to allocate higher cost in important customer needs, and allocate lower cost in unimportant customer needs.

From comparison matrix we can determined how much allocated higher cost in unimportant customer need. If that situation happens, our manufacturer will be losed out, and we have ineffective effort. In other case, we can know how much allocated lower cost in customer need. The ideal case is lower cost should be allocated in unimportant customer need, and higher cost should be allocated in a very important customer need. Determining final specification is considered by 2 suggestions which are: form Relative Importance (RI) in QFD phase 3, and from Comparison Matrix. If there are unimportant customer needs, but need higher cost, we can envisage them to be erased, so they will not affect them in final specification. In final parts, we can compare value of Cylinder Head between before and after development, by considering cost and performance.

### 3. RESULTS AND DATA ANALYSIS

From survey, there are a massive customer needs of Cylinder Head with racing specification that are determined as raw customer need. Therefore, we must filter and classify them using Afinity Diagram. The customer needs is shown in Table 1. After determined customer needs, we define relative importance level using Mudge Diagram which has passed Pairs Comparison. Relative Importance level can be seen in Table 2. Customer Needs A.3 has highest relative importance level than others. Relative Importance level will be used in Importance Ratio in QFD Phase 1. In QFD phase 1, the main activity is product planning, to define the customer needs, become quality characteristic. Result of QFD 1 are technical responses can be seen in Table 3, together with Relative Importance value (RI).

The purpose of QFD phase 2 is product design by translating quality characteristic become component characteristics. Results of QFD phase 2 are technical responses that can be viewed in Table 4. QFD phase 3 is about process planning by determining part characteristic to be process parameters. Results are technical responses that are shown in Table 5. From QFD phase 3, activity D.6 is the most importance because has highest RI than others. Activity D.1, D.2, and D.11 have smaller RI. RI percentage graphic from each technical targets. That activities can be seen in figure 2.

Table 1: Customer Needs

Number	Customer needs
A.1	Can accommodate high compression ratio
A.2	Can accommodate higher Camshaft lift
A.3	Porting modification fleksibility
A.4	Contonous manufacturing identically
A.5	Use bigger Seat Valve
A.6	Durable Seat Valve and Guide Valve
A.7	Main surface is not leak
A.8	Left out emission leakage

Table 2: Relative Importance Level

								Total	Name	Percentage	Priority
A.1	A2.2	A3.2	A4.3	A5.2	A6.1	A7.3	A1.2	2	A.1	4.08%	8
	A.2	A3.3	A4.2	A5.1	A6.2	A7.2	A8.1	2	A.2	4.08%	7
		A.3	A3.1	A3.1	A6.1	A7.2	A3.2	11	A.3	22.45%	1
			A.4	A4.2	A4.1	A7.2	A4.2	10	A.4	20.41%	2
				A.5	A6.1	A5.2	A5.1	6	A.5	12.24%	5
					A.6	A6.1	A6.2	8	A.6	16.33%	3
						A.7	A8.2	7	A.7	14.29%	4
							A.8	3	A.8	6.12%	6
TOTAL								49		100%	

Table 3: Technical Response of of QFD Phase 1

Item	Technical Response	Technical Target	RI
B.1	Reduce combustion chamber volume	Reduce to be 3.6 cm <sup>3</sup>	2.24 %
B.2	Camshaft Lift	accomodate Lift max.9,5 mm	2.98 %
B.3	Wide Area of Port IN	To be 14,2 cm <sup>2</sup>	13.54 %
B.4	Engine Power difference	± 10%	15.28 %
B.5	Air Port Flowdifference	± 2 cfm	15.28 %
B.6	Valve IN & EX size	28mm & 24mm	6.96 %
B.7	Seat valve precision	Press Fit (p6 +0,025/+0,020 )	13.42 %
B.8	Guide valve precision	Press Fit (p6 +0,020/+0,015 )	10.19 %
B.9	Chamfering Surface Roughness	Ra 0,8µm (N6)	8.94 %
B.10	Surface Leakage	Leak Test Point=0	7.83 %
B.11	Emission Hole Leakage	Leak Test Point=0	3.35 %

Table 4: Technical Response of QFD Phase 2

Item	Technical Response	Technical Target	RI
C.1	Increase combustion chamber surface	Increase thickness 1cm <sup>3</sup>	2.50 %
C.2	Decrease Camshaft Seat area	1 - 1,5 mm	3.12 %
C.3	Wide Area of Port IN	To be 14,2 cm <sup>2</sup>	11.27 %
C.5	CAD: difference Scan 3D countur Porting	± 0,1 mm	11.99 %
C.6	Using seat valve size 28 and 24	Seat valve Type Unit KWC	25.43 %
C.7	Using Guide valve Mass Pro	Guide valve Type Unit KWW	12.53 %
C.8	Chamfering 45° Surface Roughness	Ra 0,8µm (N6)	8.48 %
C.4	Weldless manufacturing	weldless	7.44 %
C.9	Surface Roughness	Ra 0,8µm (N6)	6.51 %
C.10	Surface Flatness	0,003 (standard)	7.93 %
C.11	Close Emission Hole	0 diameter	2.79 %

Table 5: Technical Response of QFD Fase 3

Item	Technical Response	Technical Target	RI
D.1	Main Mold	Make new Main Mold	1.91 %
D.2	Dies Sand Core Camshaft	Make new Dies Sand Core Camshaft	2.38 %
D.3	Add Core Camshaft material	Increase material cost	8.60 %
D.4	Dies Slide Core	Make new Dies Slide Core	14.12 %
D.5	Increase production cost	Calculating man power and machining cost	9.15 %
D.6	CAM (Computerized Aided Manufacturing)	CAM (Computerized Aided Manufacturing)	19.41 %
D.8	Valve Angle by CAD simulation	CNC Programme Editing	5.68 %
D.9	Seat valve KWC & Guide valve KWW Assembling	Seat valve KWC & Guide valve KWW Assembling	9.56 %

Item	Technical Response	Technical Target	RI
D.7	Decrease Chamfering feed	Production Cost Addition	16.03 %
D.10	CNC Programm Editing: rpm & feed	CNC 1 Programm Editting	11.02 %
D.11	CNC Programm Editing: Emission Hole	CNC 2 Programm Editting	2.13 %

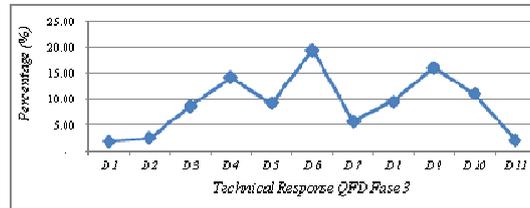


Figure 3: Relative Importance Percentage in QFD Phase 3

Furthermore, we can form resources matrix that describe all of cost in each customer needs. Cost calculation is based on man power, machining, material and sub assembly cost. The resume of resources matrix can be seen in Tabel 6. From Mudge Diagram and Resources Matrix, we can build Comparison Diagram, that can be seen in Figure 4.

Table 6: Resources Matrix Resume

Customer Need	% Function	Cost	% Cost
A.1	4.08	63,000,000.00	33.21
A.2	4.08	48,017,823.33	25.31
A.3	22.45	41,001,855.71	21.61
A.4	20.41	37,274,414.29	19.65
A.5	12.24	170,746.43	0.09
A.6	16.33	227,661.90	0.12
A.7	14.29	8,131.67	0.00
A.8	6.12	1,733.33	0.00



Figure 4: Comparison Matrix

From figure 4, we can know that customer needs A.1 and A.2 has a lower relative importance level, but has higher cost. Therefore, we can suggest to erase A.1 and A.2 in final specification determination.

From considering RI QFD 3 and comparison matrix, we can define final specifications as below:

- Port IN Cylinder Head wide area is increased to be 14,2 cm<sup>2</sup> by making new Dies Slide Core.
- Manufacturing process of porting uses CAM (Computerized Aided Manufacturing)
- Use size 28 and 24 seat valve size from KWC motorcycle.
- Seat valve surface roughness is Ra 0,8 μm (N6).
- Use Guide Valve mass production standard from KWW motorcycle.
- Erase machining process in Emission Hole.
- All of Cylinder Head modification and manufacturing can be applied in manufacturer's plant.

After obtaining final specification, we must determine comparison of cost before development and cost after development. Calculating and classifying all of cost to be variable cost and fixed cost. Modification process is moved from Team Partner Workshop into manufacturer fabrication, production cost in manufacturer become higher than before, from variable or fixed cost. But, if we look in a whole picture, Team Partner is not necessarily obtains modification again, so that modification cost in Team Partner workshop become zero. Because until now, modification cost in Team Partner is funded by manufacturer, cost

production in manufacturer is cheaper for 100 lot production, therefore, production cost of manufacture Cylinder Head with racing specification is cheaper than before. The comparison of cost can be seen in Table 7.

Table 7: Comparison of Cost before and after Development

Cost Name		Before Development	After Development
Fixed Cost	Dies Slide Core Investment	-	60,800,000
	Tool CAM Investment	-	6,000,000
	Tools Desain & Programming Cost	-	3,235,770
	Man Power Desain Investement	-	2,450,000
Variable cost (100 pcs)	Machining Cost	2,077,689	7,071,861
	Man Power Cost	315,250	2,011,946
	Material Cost	4,494,000	4,899,200
	Sub Assembly component Cost	2,338,000	2,421,000
	Total	9,224,939	16,404,007
Modification Cost by Team Partner	100 pcs x Rp 1.500.000	150,000,000	0
Total		168,449,878	105,293,784

Therefore, if we compare the value by value analysis concept, Cylinder Head component after development have higher value because decrease of modification and manufacturing cost is happened. Because value is determined as comparison between performance and cost, if cost after development decreases with the same performance, The value will increased. Moreover, performance of Cylinder Head will be increased because manufacturing system in manufacturer is more precision than manufacturing process in Team Partner workshop. The detailed comparison can be seen in Table 8 below.

Table 8: Comparison between value before with after development

	Before	After
Value	<u>Performance</u>	<u>Performance</u>
	<u>Cost</u> (Rp1,500,000/component)	<u>Cost</u> ↓ (Rp 888,898/component)

#### 4. CONCLUSION

There are some conclusions from this research:

- All of customer needs will not be applied in specification of Cylinder Head racing specification because importance ratio is low, or cost of production is too expensive
- QFD phase 1, 2, and 3 are very useful to define possibility cost to fulfill customer needs. Cost data is used to arrange Resources Matrix.
- Value of Cylinder Head after development is higher than before development, if has 100 pcs per lot production. Cost for production 100 Cylinder Head inplant PT.A is cheaper than modifying in Team partner workshop.
- Much production can reduce cost for every component, that influence price of component.
- The final specification is just suggestion and not tested yet. But, some items in Technical response have been applied in temporary specification. We suggest to take durability testing for final specification in Cylinder Head, that must be reflected into performance of component. Furthermore, manufacturer must evaluate sponsorship financial fund to Team Partner research. Because cost of development and production of Cylinder Head is expensive, manufacturer must rearrange sponsorship financial value.

#### 5. REFERENCES

- [1] Dale, Carol, Glen, Mery Besterfield. (2003). *Total Quality Management*. p. 351-360. Mc.Graw Hill.
- [2] Ulrich T. Karl & Eppinger Steven, (2001). *Perancangan dan Pengembangan Produk*. P 350. Jakarta: Salemba Teknika.
- [3] Akao Yoji.(1997). *QFD: Past, Present, dan Future, International Symposium on QFD*. Chicago.
- [4] Fasal H John.(1972). *Practical Value Analysis*, New York: Hayden.
- [5] Miles D. Lawrence.(1972). *Technique of Value Analysis and Engineering*. New York: Mc Graw Hil Manufacturer.
- [6] Bonita Alveranga Flavia, Guiseppe Dedini Franco. (2005). *Development of System of Alternative Motorization for Conventional Wheelchairs*. Campinas State University.
- [7] Ramos da Silva, Fabio (2004). *Combined Application of QFD and VA Tools in the Product Design Process, International Journal of Quality & Reliability Management*, Emerald Group Publishing Limited.

## Design of Ergonomic Stool (*Dingklik*) for Batik Crafters

Shabila Anjani<sup>a</sup>, Rachma Hidayati<sup>b</sup>, Yoke A. Adlan<sup>c</sup>,  
Amalia Suzianti<sup>d</sup>, Radita T. V. Hapsari<sup>e</sup>

Product Development and Innovation Laboratory, Industrial Engineering Department  
Faculty of Engineering, Universitas Indonesia, Depok 16424

<sup>a</sup>E-mail : shabila.anjani@ui.ac.id

<sup>b</sup>E-mail : rachma.hidayati@ui.ac.id

<sup>c</sup>E-mail : yoke.arfela@ui.ac.id

<sup>d</sup>Email : suzianti@ie.ui.ac.id

<sup>e</sup>Email : radita.tanaya@yahoo.com

### ABSTRACT

*Batik crafting is a job done in a sitting position. The design of a stool itself affects the sitting position of workers using it. This paper proposes an optimal design for batik stool (dingklik) which is tested using the task analysis toolkit in the virtual environment with the Jack™ 6.1 software. An anthropometric measurement is done to create the suitable dimension for all users of the batik stool. This research is conducted to reduce MSD found in previous research, by designing ergonomically friendly stool to support batik crafters. This improved design is proved to be ergonomically friendly due to the decreased PEI result compared to the current design.*

### Keywords

*Product design, ergonomics, batik, dingklik*

**This Paper is Published in International Journal of Technology (IJTech)**

# Indonesian Body Surface Area Database and Estimation Formula Based on Interpolation Method

Boy Nurtjahyo<sup>a</sup>, Erlinda Muslim<sup>b</sup>,  
Dwiki Drajat Gumilar<sup>c</sup>, Tegar Septyan<sup>d</sup>, Aisyah Iadha Nuraini<sup>e</sup>

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : boymoch@eng.ui.ac.id

<sup>b</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : erlinda@eng.ui.ac.id

<sup>c</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : dwiki.drajat@ui.ac.id

<sup>d</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : tegar.septyan@ui.ac.id

<sup>e</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : aisyah.iadha@ui.ac.id

## ABSTRACT

The study of human body surface area has been a concern for many experts in several research fields. Having unique anthropometry characteristics, every human race should have certain formula that fit those characteristics. Generated using strong based data taken with high accuracy 3D Anthroscan. This study obtain a new BSA formula,  $BSA = 0.0113 \times W^{0.1956} \times H^{0.8169}$  that will potentially fit Indonesian anthropometric characteristics. A geometrical interpolation model also proposed for a more personal BSA calculation.

## Keywords

*Anthropometry, Body Surface Area (BSA), Formula, Interpolation Method*

## 1. INTRODUCTION

Anthropometry is a branch of ergonomics science related to the study of human body measurements which encompass body size, shape, strength and work capacity [1]. Anthropometric become important because there is a significant difference in body size between the human races of the world, so it is necessary to categorize the anthropometry's design that fits in each characteristics. One of the most important applications of anthropometry is about Body Surface Area (BSA) study. Body Surface Area (BSA) has long been considered as an important element in the study of anthropometry. BSA is a very important parameter in several ways, such as in knowing the quality of the physiology of the body, drug dosage calculations, estimating of burns, and studying of the mechanisms of heat transfer body [2]. In many countries, there are project data collection and preparation of the BSA database for its citizens, such as 3D Body Taiwanese Bank in Taiwan, Civilian American and European Surface anthropometry Project Resource (CAESAR) for European citizens and a few other examples [3].

In the drug industry, BSA also used to determine the dose of the drug, especially in the treatment involving drugs with side effects such as chemotherapy treatment. BSA was also used for estimating burns suffered by patients [4]. These calculations are often performed by partial injured body part or as a whole if the burns occur quite severe. The results of these calculations become basis for determining the amount of replacement tissues that should be given to patients in order to reduce the impact of fatal skin loss.

Determination of the temperature of the room is also closely related to BSA calculation. In terms of air associated with this study is known as thermal comfort. Thermal comfort is a condition in which the human mind satisfied or according to the temperature of the surrounding environment (standard AHSRAE 55). In practice, determining the temperature of the room will be charged the amount of power adjustable with a maximum capacity room. The calculation is related to the area of the human body which assumed to fill the room.

The human body calculation has attracted the attention of experts from different disciplines over the years. Many researchers had been trying to formulate area of the human body calculation. In 1879, for example, a researcher named Mech noted that he had succeeded in measuring body surface area of six adults and ten children with method such as by providing certain geometrical patterns on the body was being measured. The pattern geometry is then transferred onto a transparent thin paper and the pieces of paper that are not irregular. Other researchers such as Funke, did the measurement by measured body lining with adhesive material similar to papers plastered with a square, where the paper was used as a reference to calculate the area of the human body [5].



Figure 1: Du Bois method

In 1916, Du Bois published a formula of BSA, which until now has been used with the following formulation [6].

$$\text{BSA (m}^2\text{)} = 0.007184 \times \text{Height (cm)}^{0.725} \times \text{Weight (kg)}^{0.425} \quad (1)$$

By doing a variety of improvements in the methods and sampling. Some formulas are often used in various purposes BSA including [7]:

- Monstaller (1908):
  - $\text{BSA (m}^2\text{)} = ([\text{Height (cm)} \times \text{Weight(kg)}] / 3600)^{1/2} \quad (2)$
- Haycock (1978):
  - $\text{BSA (m}^2\text{)} = 0.024265 \times \text{Height(cm)}^{0.3964} \times \text{Weight(kg)}^{0.5378} \quad (3)$
- Gehan and George (1970):
  - $\text{BSA (m}^2\text{)} = 0.024265 \times \text{Height(cm)}^{0.3964} \times \text{Weight(kg)}^{0.5378} \quad (4)$

In use, the formulas of BSA are often required to provide a high level of accuracy. High degree of accuracy would be very difficult to achieve if the formula is offered only limited empirical formula and little accuracy of technology because still using conventional method.

In this research, we develop BSA formulation based on Indonesian as a cutting-edge for national database of BSA. We want to develop the BSA formula using case studies of male students in Universitas Indonesia. This research will produce a formula that can calculate the human body in Indonesia accurately because data collection of human body size that is used to construct this formula will use the 3D Body scanner technology. So, it can generate measurement data with high accuracy. This research can also be for anthropometric ergonomic research that will further enrich our knowledge of the human body anthropometric Indonesia.

## 2. METHOD

The main tool to be used on the project anthropometric data collection Indonesia's population is 3D Body Scan or also known as Anthroscan. The results of this scanning three-dimensional objects can calculate 151 variables measuring dimensions of the human body.

In this research, we also have following boundaries of research such as:

- a. Data taken from the student (male) in Universitas Indonesia in the range of 17-25 years.
- b. The variables measured in the study of human body dimensions are variable based on 3D Body Scanner amounted to 151 variables as a basis for obtaining the interpolation of the human body surface area of Indonesia.
- c. Through pilot research project conducted only as an example to model the human body area calculation formula Indonesia with a limited number of samples. Not for human anthropometric characteristics portray Indonesia nationally.
- d. The design of the human body area calculation formula based interpolation method synthesized the literature on the sources of data that have been owned.

Table 1: Responding Category

Category	Group
Gender	Male
Age	17-25 years old
Ethnic	South East Asiatic
Location	Java Island
Posture	Standing

In order to obtain data that is constant and steady, and in accordance with the expected quality parameters, there are several stages of anthropometric data collection using Anthroscan. The stages are:

- Calibrating Anthroscan
- Setting laser
- Preparing the subject
- Scanning data using Vitus Control - Scan Wizard
- Validating data using Measurement Tools
- Improving data manually using the Ruler Tools 52

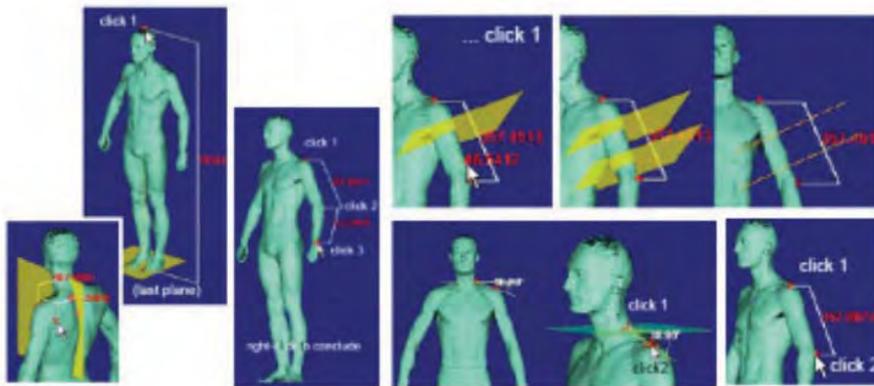


Figure 2: Interactive Body Measurement



Figure 3: Standard Posture Scanning

In this research, after performing calibration and subject preparation, we scan the data for each respondent and calculated about 151 body size points. These body size points can be seen in Table 2 and Table 3.

Table 2: Body Size Point

No	Body Dimension	No	Body Dimension
1	3D waist band	36	Crotch height
2	3D waistband back height	37	Crotch length
3	3D waistband back to vertical	38	Crotch length at waistband
4	3D waistband front height	39	Crotch length at waistband
5	3D waistband front to vertical	40	Crotch length, front

6	3D waistband left to crotch	41	Crotch length, rear
7	3D waistband right to crotch	42	Dev. waist band from waist (back)
8	Across back width	43	Dev. waist band from waist (front)
9	Across back width (armpit level)	44	Dev. waist band from waist (side)
10	Across front width	45	Distance 7CV - vertical
11	Ankle girth left	46	Distance abdomen to vertical
12	Ankle girth right	47	Distance across back width (armpit level) - waist
13	Ankle height	48	Distance back in belly height to vertical
14	Arm length left	49	Distance back in breast height to vertical
15	Arm length right	50	Distance back in hip height to vertical
16	Arm length to neck back left	51	Distance back in maximum belly height to vertical
17	Arm length to neck back right	52	Distance belly to vertical
18	Arm length to neck left	53	Distance breast to vertical
19	Arm length to neck right	54	Distance buttock to vertical
20	Belly circumference	55	Distance crotch to waistband
21	Belly circumference height	56	Distance front in hip height to vertical
22	Body height	57	Distance maximum belly to vertical
23	Breast height	58	Distance neck front to vertical
24	Bust point to neck left	59	Distance neck to hip
25	Bust point to neck right	60	Distance neck-knee
26	Bust points around neck	61	Distance scapula to vertical
27	Bust points width	62	Distance waist back to vertical
28	Bust/chest girth	63	Distance waist-knee
29	Bust/chest girth (horizontal)	64	Distance waistband - buttock
30	Buttock girth	65	Distance waistband-high hip back
31	Buttock height	66	Distance waistband-knee
32	Calf girth left	67	Elbow girth left
33	Calf girth right	68	Elbow girth right
34	Cross shoulder	69	Forearm girth left
35	Cross shoulder over neck	70	Forearm girth right

Table 3: Body Size Point

No	Body Dimension	No	Body Dimension
71	Forearm length left	106	Shoulder angle left
72	Forearm length right	107	Shoulder angle right
73	Head circumference	108	Shoulder width left
74	Head height	109	Shoulder width right
75	Height of shoulder blades	110	Side upper torso length left
76	High hip girth	111	Side upper torso length right
77	High waist girth	112	Sideseam 3D waistband left
78	High waist height	113	Sideseam 3D waistband right
79	Hip girth	114	Sideseam ankle left
80	Hip height	115	Sideseam ankle right
81	Hip/thigh girth	116	Sideseam at waist left
82	Inseam left	117	Sideseam at waist right

No	Body Dimension	No	Body Dimension
83	Inseam right	118	Sideseam left
84	Inside leg-ankle left	119	Sideseam right
85	Inside leg-ankle right	120	Thigh girth left (horizontal)
86	Knee girth left	121	Thigh girth right (horizontal)
87	Knee girth right	122	Torso width at waist
88	Knee height	123	Total torso girth
89	Maximum belly circumference	124	Underbust circumference (horizontal)
90	Maximum belly circumference height	125	Upper arm diameter left
91	Mid neck girth	126	Upper arm diameter right
92	Min. leg girth left	127	Upper arm girth left
93	Min. leg girth right	128	Upper arm girth right
94	Neck at base girth	129	Upper arm length left
95	Neck diameter	130	Upper arm length right
96	Neck front to waist	131	Upper torso torsion
97	Neck front to waist over bust line	132	Waist band
98	Neck height	133	Waist girth
99	Neck height front	134	Waist height
100	Neck left to waist back	135	Waist to buttock
101	Neck right to waist back	136	Waist to buttock height left
102	Neck right to waist over bust	137	Waist to buttock height right
103	Neck to across back width (armpit level)	138	Waist to high hip back
104	Neck to waist center back	139	Waist to hip/thigh left
105	Scapula height 2	140	Waist to hip/thigh right
No	Body Dimension	No	Body Dimension
141	Waistband back height	147	Waistband to buttock height right
142	Waistband back to vertical	148	Weight
143	Waistband front height	149	Width armpits
144	Waistband front to vertical	150	Wrist girth left
145	Waistband height	151	Wrist girth right
146	Waistband to buttock height left		

### 3. RESULTS AND DISCUSSION

By obtaining database as a result of the study, it was necessary to calculate formula that can be widely used and practical in accordance with the characteristics of human anthropometry Indonesia. After finding data based on the body size, we used the correction factor and multiplication factor instead of body proportions were not scanned. The results of calculations that have been corrected can be seen in table 4.

Table 4: Total Area after Correction

Sampling Point	Weight (kg)	Height (cm)	Total Area (m <sup>2</sup> )
92	74.40	170.80	1.769255376
93	48.60	158.50	1.503045093
94	70.2	170.8	1.738468107

Sampling Point	Weight (kg)	Height (cm)	Total Area (m <sup>2</sup> )
95	76.4	171.5	1.822068258
96	20.8	169.7	1.553469167
97	50.4	163.6	1.524337867
98	61.7	178.7	1.68033102
99	71.5	188.1	1.873812249
100	53.9	163.5	1.604937838
101	57.9	164.3	1.634514509
102	55	164.3	1.537334597
103	62.8	167.5	1.656017822
104	56.4	174.8	1.600006369
105	46.2	169	1.576737768
106	53.6	158.5	1.553214091
107	59	173.7	1.696506078
108	62.1	171.5	1.704470118
109	83.8	165	1.823780911
110	68.6	169	1.714138714
111	83.3	182	1.955456817
112	63.5	161	1.676913811
113	56	184.1	1.704696852
114	79.8	178	1.937257346
115	54.6	169.7	1.66836674
116	67	173.7	1.721608797
117	84.4	188.1	1.993572461
118	56.6	161.7	1.547918227
119	51.8	165.7	1.504336669
120	43.8	169	1.504915651
121	55.6	172.2	1.566506386
122	65.4	166.4	1.703409326
123	52.4	172.2	1.573486561
124	59	165	1.582746225
125	60.1	169.7	1.64892428
126	83.8	179.4	1.903838339
127	46.8	170.8	1.472938026
128	76.2	173.7	1.837595504
129	59.2	159.6	1.638150355
130	66.6	161.8	1.606338732
131	77.2	174.8	1.743205233
137	65.1	174.6	1.562449463
142	78.5	179.5	1.888157238
143	62.7	169	1.6791933
144	64.5	169	1.712490842

Sampling Point	Weight (kg)	Height (cm)	Total Area (m <sup>2</sup> )
145	72.2	183.4	1.830785379
146	58.6	178	1.72025244
147	64.1	172.9	1.748132653
148	53.4	163.6	1.621764758
150	94.3	182	1.982839024
151	63.6	178	1.741047208
152	63.5	168.3	1.670630034

For further calculations that aimed to determine the empirical formula connecting the wide body, weight and height of the human body, it used mathematical principle BSA which have the following basic formula:

$$L = \gamma \times W^\alpha \times H^\beta \quad (5)$$

$$\ln L = \ln \gamma + \alpha \ln W + \beta \ln H \quad (6)$$

By using the Matlab that used to solve the equations on simple geometric interpolation approach, it would result the matrix to triangle interpolation on the data format stereolytography which have following value:

$$\begin{aligned} \ln \gamma &= -4.4846 \\ \alpha &= 0.1956 \\ \beta &= 0.8169 \\ \gamma &= 0.0113 \end{aligned}$$

So, it yielded the following formulation as the potential BSA formulation in Indonesia :

$$L = 0.0113 \times W^{0.1956} \times H^{0.8169} \quad (7)$$

Based on formula above, it will give correction to previous BSA formulation which developed by Du Bois, Haycock, and Mosteller consequently about 4.38%, 4.92%, and 4.61%.

#### 4. CONCLUSION

In this research, it used interpolation body surface area method by simplifying the shape of the human body into basic geometric shapes. It can be the basis for processing anthropometric data were obtained from three-dimensional scanners high accuracy including 38 body dimensions. With the widespread use of three-dimensional scanner, it can also be opportunity to use the interpolation technique in a human body area calculation Indonesia, so it can also improve the accuracy of the empirical formula correlating vast body weight and height.

The data used in this research have stereolytography format. It is the basic form of rapid prototyping modeling language that transforms the scan object surfaces into triangles form or another simple polynomial-up based on coordinates of the point. One of the weakness of the format based on Stl, it has an opportunity emergence redundant triangles or double triangles coincide which potentially increase the area of the cumulative area of the triangle to be much larger than factual. This weakness can be overcome by testing the reliability of the measuring instrument by using the three-dimensional scanner and using factor correction.

Based on calculations using a varied tube length relationship between the results obtained with an actual scan, it found that correction factors are obtained for 2541 with the addition of constants  $-34473.2343 \text{ mm}^2$ . Therefore, any calculations used in the present study must first be divided by a correction factor of 2541 and added with a constant area of  $34473,234 \text{ mm}^2$ . It was also multiplied by a correction factor proportions which are not scanned by 1018 times, and then processed to get the empirical formula.

Based on this research, potential new BSA formula has a higher accuracy rate for Indonesian people become  $BSA = 0.0113 \times W^{0.1956} \times H^{0.8169}$ . It will provide a correction of about 4-5% when compared with the calculation formula BSA three most frequently used of Du Bois, Haycock and Mosteller.

## ACKNOWLEDGMENT

The author gratefully acknowledges the data collection using tools from ergonomic center Universitas Indonesia.

## REFERENCES

- [1] Pheasant, Steven, "Body space: anthropometry, ergonomics and the design of work," London: Taylor & Francis. 1997.
- [2] Chi-Yuan Yu, Yu-Huang Lo, and Wen-Ko Chiou, "The 3D scanner for measuring body surface area: a simplified calculation in Chinese adult," Elsevier: Applied Ergonomic. 2003.
- [3] Blackwell,S.,Robinette,K.,Daanen,H.,Boehmer,M,Fleming,S.,Kelly,S.,Brill,T.,Hoeflerlin,D.,And Burnside,D.,(2002) Civilian American and European Surface Anthropometry Resource (CAESAR),Final Report, Volume II: Descriptions, (in press)
- [4] Chun-Yi Liao, Shao-Liang Chen, Trong-Duo Chou,et al, "Use of two-dimensional projection for estimating hand surface area of Chinese adults," *Burns* vol. 34 issue 4 June, 2008.
- [5] Du Bois D, Du Bois EF, "The measurement of the surface area of man," In: archives of internal medicine, clinical calorimetry, fifth paper. 1915. p. 868–81.
- [6] Du Bois D, Du Bois EF, "A formula to estimate the approximate surface area if height and weight be known.In: Archives of internal medicine," clinical calorimetry, tenth paper. 1916. p. 863–71
- [7] Haycock GB, Schwartz GJ, Wisotsky DH, "Geometric method for measuring body surface area: a height weight formula validated in infants, children and adults," *J Pediatrics*1978; 93(1):62–6.

# Investment Feasibility Analysis of CNG Fueling Station in Central Jakarta under Acceleration Scenario

Farizal<sup>a</sup>, Indah Prihastuti<sup>b</sup>

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424E-mail : farizal@ie.ui.ac.id

<sup>b</sup>Faculty of Engineering, University of Indonesia, Depok 16424E-mail : indah.prihastuti@ui.ac.id

## ABSTRACT

To reduce the use of gasoline, the government has recently re-issued a policy about restriction of gasoline subsidy and diversion of gasoline to Compressed Natural Gas (CNG). As a result, the need for new CNG fueling station will be higher since the estimated number of vehicles powered by natural gas (NGV) will increase. However, the government is constrained by limited funding from APBN to invest in CNG fueling station. This makes investment from private investors become urgent. The fact is many investors who invest in CNG fueling station are not based on adequate understanding about its feasibility. Therefore, this study analyzes the feasibility of CNG Fueling Station investment under acceleration scenario using NPV, IRR, and Payback Period followed by sensitivity analysis. The study shows that the best location to build a CNG fueling station is on Budi Utomo Street. The feasibility analysis shows that build CNG fueling station on Budi Utomo Street under acceleration scenario is feasible even when worst case demand occur (demand only from Busway) and NPV is positive with Rp 4.929.489.648.

## Keywords

CNG Fueling Station, NPV, IRR, Payback Period, Sensitivity Analysis

## 1. INTRODUCTION

To reduce the use of gasoline, the government has recently re-issued a policy about restriction of gasoline subsidy and diversion to compressed natural gas (CNG). CNG has been found to be effective to meet the ever-growing demands of transport vehicles [1]. CNG for natural gas vehicle (NGV) is more suitable for public transportation under fixed routes. CNG was chosen because the total gas reserves are abundant as described in the master plan of the expansion and development acceleration in Indonesia. The total reserves of natural gas is currently about 165 trillion cubic feet (TCF). This policy is supported by Regulation of the Minister of Energy and Mineral Resources No. 19, 2010 about the use of natural gas for transportation and the National Energy Policy 2010-2050 which has mission to enhance the role of alternative energy. As the remainder of previous CNG policy, Jakarta has only five operating CNG fueling stations; three in East Jakarta, one in West Jakarta, and one in South Jakarta. This lack of infrastructure causes long queues at the station and many NGVs switch back to use gasoline as reluctant to queue [2]. Due to the policy to use gas and lack of infrastructure, the need for new CNG fueling station is high in order to well serve the increasing number of NGV. Jakarta has Transjakarta (busway) that uses gas as its fuel. However, one barrier to address this problem is limited funding for CNG fueling station investment, whether it is sourced from the state budget or private.

2008 state budget allocated to energy sector, including for infrastructure development was only 1.6%. Therefore, this makes investment from private investors is crucial. On the other hand, private investors who invest in this downstream oil and gas business are still not sufficient. To mention some, PT.Petross Gas, PT. T-Energy, Perum PPD, PT. Aksara Andalan Prima (AAP), PT. CNG (in Palembang) and its subsidiaries, PT. CNE (in Surabaya), are companies that have tried to set up this business. Even though demand of gas for transportation is inevitable and the government plans to rerun a conversion program from gasoline to gas, why industry does not invest their money on CNG fueling station? What is the station minimum demand in order an investment on this facility is profitable? If the government delay (or even cancel) the conversion program, is the investment still justified? Those the questions addressed on this study. This study will use company owned company operated (COCO) type of CNG Fueling Station that located in Central Jakarta under acceleration scenario using net present value, internal rate of return and and payback period methods.

## 2. METHODOLOGY

Techno-economics analysis provides a quantitative basis in the monetary unit for making a decision. Concern is emphasized on technical and economic aspects towards a problem completely [3]. Techno-economic analysis is closely related to problem-solving techniques which using indicators of economic efficiency as alternative selection criteria. The results of this analysis

will determine the feasibility of investment. Investment methods that are used are Net Present Value, Internal Rate of Return, and Payback Period.

### 2.1 Net Present Value (NPV)

Method of NPV analyzed finance by considering the changes in value of money due to the time. This method calculates the difference between the present values of cash flow with the initial investments:

$$(1) \quad NPV = \sum_{n=1}^n \frac{CFI_n}{(1+r)^n} - I_0$$

where  $CFI_n$  is the net annual cash flow from year one to year- $n$  (Rp.),  $r$  is the discount rate which is used to find the present value (%),  $n$  is duration of the project (year), and  $I_0$  is the initial investment in year-0 (Rp). Criteria for assessment of NPV are:

- i). If  $NPV > 0$  then the business investment proposal is feasible to be implemented,
- ii). If  $NPV < 0$  then the business investment proposal is not feasible to be implemented,
- iii). If  $NPV = 0$  then the value of the company is fix although business investment proposal will accept or reject.

### 2.2 Internal Rate of Return (IRR)

IRR is interest rate that makes the present value (PV) of investments and the net proceeds that are expected during the running of project or business to be equal to 0 (zero). Same as NPV, internal rate of return method or IRR is also a method that considers the value time of money. IRR can be obtained through trial and error by determining the NPV at some discount rate to obtain a negative and a positive NPV. Then, do interpolations in which NPV equal to 0 (zero). To obtain IRR by interpolation using the equation below:

$$(2) \quad IRR = P1 - \left( C_1 \times \frac{P_2 - P_1}{C_2 - C_1} \right)$$

where  $P1$  is discount rate 1 (%),  $P2$  is discount rate 2 (%),  $C1$  is Net Present Value (NPV) 1 (Rp), and  $C2$  is Net Present Value (NPV) 2 (Rp). A trial and error method could be used to find the optimal Internal Rate of Return (IRR). Criteria for assessment of IRR are;

- i). If  $IRR >$  rate of capital or MARR, then the project is feasible to be implemented and the investment will get a surplus after the payment of obligation (to return capital + interest).
- ii). If  $IRR <$  rate of capital or MARR, then the project is not feasible to be implemented.

### 2.3 Payback Period (PB)

PB is the period that is needed to cover initial cash investment by using cash flow [5]. It means the shorter of payback period, the better of investment. To obtain Payback Period using the equation below:

$$(3) \quad PP = \frac{\text{The investment Value}}{\text{Net Cash Inflow}} \times 1 \text{ year}$$

where Payback Period (PB) is the Payback Period which is sought (year), the investment value is the initial investment in year  $n$  (Rp), and Net cash inflow is the present value (PV) from cash inflow or operating cash flow (Rp). Criteria for assessment Payback Period are:

- i.) If Payback Period  $<$  the maximum time of projections, then the proposed project is accepted,
- ii.) If Payback Period  $>$  the maximum time of projections, then the proposed project is rejected.

## 3. RESULTS AND DISCUSSION

For the purpose of this study, primary and secondary data are collected. Secondary data was obtained from reading journals and previous thesis which discuss about CNG fueling station, Badan Pusat Statistik (BPS), Public Service Board of Transjakarta, Ministry of Energy and Mineral Resource, and Department of Transportation. Primary data was collected through observation and interview to the two owner of COCO CNG fueling station in Pinang Ranti, managed by PT. T-

Energy and in Perintis Kemerdekaan, managed by PT. Petross Gas. Some supporting data were collected from CNG fueling station at Jalan Pemuda. On this study, data were processed using Microsoft Excel 2007.

### 3.1 Selection of Location

CNG station location determination is conducted by inspection (qualitative in sense). Observing that none of the five existing stations is located in Central Jakarta and North Jakarta, the location candidate is between those two regions. Furthermore, Central Jakarta is selected as the candidate location because Central Jakarta is a center of trade and services. Therefore, many vehicles will pass it. In addition, travel business and hotel has minibus that potential as a consumer. Central Jakarta is passed by PT.PGN gas pipelines; At Central Jakarta, there is Harmoni Shelter which serve 3 corridors of TransJakarta and Senen Bus Station. This last reason indicates the potential of vehicles to fueling CNG.

Five alternative sites for CNG fueling station are considered that are 1) Gajah Mada Street; 2) KH. Hasyim Ashari Street; 3) Budi Utomo Street; 4) Gunung Sahari Street; and 5) Kramat Raya Street. The alternatives were scored according to the criteria listed below:

1. Proximity to gas pipeline
2. Located in commercial rather than residential areas
3. The site at least has 4000 m<sup>2</sup> area
4. Location is not far from the end of the Busway corridor
5. The vehicles pass through or close to public transportation seem like bus station, Busway's pool, or shelter.
6. Location does not cause queue when fueling CNG
7. Strategic and easy to access the location

By multiplying the weight and score from all alternative location based on criteria that are determined, the results are shown in Table 1.

Table 1: Alternative locations assessment

Criteria	Weight	Alternative Location				
		1	2	3	4	5
Proximity to gas pipeline	0.30	9	9	8	6	5
Minimum area	0.25	7	8	9	10	8
Many vehicles pass through or close to public transport terminals, pool Busway, or shelter	0.25	9	9	8	9	8
Effect to the surrounding environment (not in residential areas or doesn't cause queue)	0.15	5	8	9	6	7
Strategic and easy access location	0.05	8	5	9	8	8
Total Score	100%	7.85	8.40	8.45	7.85	6.95

From the total results that were obtained by multiplying the weight and score (0-10) above, then the selected location with the highest total score is considered as the best location for the construction of CNG fueling station. And the best location is on Budi Utomo Street with the total score are 8.45.

### 3.2 Estimation of Investment Cost under Acceleration Scenario

Acceleration was made by reducing the duration of construction CNG fueling station. This causes the increase in number of construction workers and their working hours. If there is no acceleration, the construction will conduct during 10 months by 13 construction workers. However, under acceleration, the construction will conduct during 4 months by 23 construction workers. Presence the acceleration has an impact on expenditure, i.e., for machineries, equipments, and construction materials. It happens because there is the force to make the procurement process quickly, especially for the machines which order from abroad (import). The funds that will use to invest in CNG Fueling Station is 50% own equity: 50% equity loan. The loans were obtained from the Local Government Bank that is followed by interest rates for the investment (investment loans) is 12%.

Selected location on Budi Utomo Street has a distance 1966 meters from the nearest gas pipeline. Percent of rising prices under acceleration scenario is assumed to appropriate under difference percentage in the construction costs by 15%. Working capitals are for the preparation of gas by PT PGN, the budget for the employees and the cost of machining operations. The preparations of gas for the first 3 months appropriate with the capacity of CNG Fueling Station. For the pipe's installation, the amounts are Rp 800,407 per meter and for the telephone's installation are Rp 500,000. Electric insatallation is assumed as the

tariff class B3 based on interviews with the owners of Pemuda CNG Fueling Station. And for its calculations are based on the Regulation of the President Republic of Indonesia No. 8, 2011 regarding tariff which is provided by PT. PLN. Table 2 shows the estimation of CNG Fueling Station investment costs under acceleration scenario The table shows that the total investment costs under acceleration scenario are Rp 16,296,834,369.

Table 2: Investment costs of CNG fueling station under acceleration scenario

Assets	Amount	Unit	Per Unit (Rp)	Cost (Rp)	Cost + 15% (Rp)
<b>Fixed Assets</b>					
<b>Building and Licensing</b>					
Construction				403.315.706	403.315.706
Canopy Building	2	unit	393.000.000	786.000.000	903.900.000
Office Building, Toilet, and Security Post	1	unit	199.900.463	199.900.463	229.885.532
Engine Room Building	1	unit	481.241.855	481.241.855	553.428.133
Pavement	1	unit	222.111.625	222.111.625	255.428.369
Fence	1	unit	81.440.929	81.440.929	93.657.068
Licensing	1		45.000.000	45.000.000	45.000.000
<b>Machinery and Equipments</b>					
CNG Gas Compressor	2	set	785.130.451	1.570.260.902	1.805.800.037
Dispenser (2 Nozzle)	2	unit	85.000.000	170.000.000	195.500.000
Boster Compressor	1	unit	745.272.902	745.272.902	857.063.837
Storage Cylinder (Low Bank)	1	unit	933.805.436	933.805.436	1.073.876.251
Storage Cylinder (Medium/High Bank)	1	unit	1.098.296.908	1.098.296.908	1.263.041.444
Dryer	1	unit	201.944.915	201.944.915	232.236.652
Piping Installation	1966	meter	800.407	1.573.600.000	1.809.640.000
Electrical Installation	1	unit	232.306.000	232.306.000	232.306.000
Telephone Installation	1	unit	500.000	500.000	500.000
Office Equipments	22	unit	23.889.800	23.889.800	27.473.270
<b>Working Capital</b>					6.314.782.068
Total					16.296.834.369

### 3.3 Costs and Expenses

Costs and expenses of CNG Fueling Station consists of gas purchase costs, electricity costs, employee salaries, land rent, promotion, administration and office needs, maintenance, insurance, telephone and water, investor interest, and incentives. Total costs and expenses that CNG Fueling Station should spend in the first year is Rp. 977.810.062.

### 3.4 Demand Projection

Project analysis will be conducted for the next 10 years. The cases are distinguished in two ways:

1. Worst Case, where the revenue only by the sale of gas to Busway. This case assumes that there is no conversion of fuel to gas by mikrolet.
2. Best Case, where the revenue by the sale of gas to Busway and mikrolet. Percent conversion of public transportation based on the target conversion by Pertamina, which is 100%.

Based on data from the Public Service Board of TransJakarta, currently the corridors that stills operate is corridor 1-11. And corridor 1 is still using biodiesel fuel. The new CNG Fueling Station will be built on Budi Utomo Street, where is not far from the shelter Harmony. Therefore, the potential corridors that will pass it are corridor 1, 2, 3, 5, and 8. From the entire corridor, the amounts of potential Busway are 280 buses. However, in the case of fueling gas, the capacity of each CNG Fueling Station should consider. In addition, the entire number of busway has been divided into 5 CNG Fueling Station that still operates.

The data from *Bina Sarana Transportasi Perkotaan* (BSTP) shows that the number of Busway will be increase in the future. Based on these data, we did the forecast demand for the worst case until 2022. The assumptions that were used are any additions Busway will be distributed evenly across the corridors and every year there will always be the addition of two CNG Fueling Stations in Central Jakarta. These will affect the number of demand for CNG Fueling Station that will be built. The addition of CNG Fueling Station has impact to amount of demand significantly. It is because there is currently no CNG Fueling Station in Central Jakarta. In one day, Busway do fueling as much as 125 lsp (liter premium equivalent). The forecast demand in 2021 and 2022 shows that the stagnancy due to the limit of its capacity

On the other hand, the best case scenario also calculated the potential number of mikrolet. It was known that total of mikrolet at Senen Bus Station are 1180 units, whereas mikrolet in Jakarta are 8046 units. From that data, we know that mikrolet at Senen Bus Station take 15% from the total of mikrolet in Jakarta. It means that the potential of mikrolet that will do fueling CNG in this CNG Fueling Station are 15% from the total mikrolet in Jakarta. After that, the demand projection is made based on planning to increase the number of mikrolet in Jakarta (source: BSTP). The assumption is from the potential amount of mikrolet that was obtained, there are only 80% mikrolet will be operated. The data of mikrolet was added with the previous demand projection of Busway. Total demand projection results for worst case and best case scenario are shown in Table 3.

Table 3: The demand projections for worst and best case

Type of Case	Demand Projection									
Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Worst Case										
Busway	41	41	54	93	127	150	175	199	200	200
Best Case										
Busway	41	41	54	93	127	150	175	199	200	200
Mikrolet	38	458	462	404	369	345	329	316	307	299

### 3.5 Cash Flow

Cash flow can provide information about the number of cash which are required to start a business, investment planning, and ensure compliance cash to expenditures that will spend in the future. Indirect method is the method that is used in this cash flow. This includes depreciation and amortization as non-operating expenses. Cash flow is divided into two, there are cash inflow and cash outflow. Cash inflow includes profit after tax, depreciation, and amortization while cash outflow just include debt principal repayments. The difference between both of them is the net cash flow.

Cash flow's percentages that increase in the price of CNG are 4% with reference to the historical data since 1986. Tax which is considered here are PPN and PPKB. They are deposited into the country in which the amounts are 5% for PPKB and 10% for PPN. And the percentages that increase the costs and expenses are 6.42% refers to the average inflation rate over the last 5 years.

Table 4 : The net cash flow for worst and best case

Type of Case	Net Cash Flow				
Year	2013	2014	2015	2016	2017
Best Case	(Rp 1.176.369.268)	(Rp 1.188.572.014)	(Rp 230.093.399)	Rp 923.311.612	Rp 6.050.042.908
Worst Case	(Rp 1.916.283.850)	(Rp 1.188.654.995)	(Rp 168.878.775)	Rp 1.062.086.573	Rp 5.833.426.982
Year	2018	2019	2020	2021	2022
Best Case	Rp 10.388.931.303	Rp 10.792.622.413	Rp 13.490.929.545	Rp 14.059.859.578	Rp 14.537.856.908
Worst Case	Rp 6.126.486.700	Rp 10.756.784.010	Rp 13.576.832.549	Rp 14.293.458.937	Rp 14.949.606.571

### 3.6 Investment Feasibility Analysis

To analyze the feasibility this CNG Fueling Station investment NPV, IRR, and Payback Period using the equation (1) - (3) are used. The specified amount of MARR at 14% is derived from the Government Bank Local Investment Interest Rate at 12% plus 2% (from risk). MARR is used to compare the benefits that can be given from the Interest Rate of Bank in CNG fueling station investment and period is analyzed from the first year to the ten years. The calculation results for best case and worst case scenario are shown in Table 5.

Table 5: The calculation results of NPV, IRR, and Payback Period

Investment Criteria	Best Case Demand	Worst Case Demand
NPV	Rp. 7.310.840.986	Rp. 4.929.489.648
IRR	19.5%	17.7%
Payback period	7.2	7.8

From the calculation results for best case demand, the NPV is Rp 7.310.840.986. Because NPV value is greater than zero or positive, it can be concluded under acceleration scenario and best case demand (the demand from Busway and mikrolet), CNG fueling station is feasible to build. Similarly, IRR with 19.5% means the IRR is greater than the MARR, set as 14% by the company. This IRR value consistent with the NPV. And the last investment criteria are payback periods. The results show payback periods are 7 years 3 months that show the return on investment from the business of CNG Fueling Station investment relatively less than the project analysis which was done for 10 years. It also shows that CNG Fueling Station investment is feasible to build. The second calculation is investment criteria for worst case demand. It was obtained NPV with Rp 4.929.489.648. Even though the NPV is smaller than the best case demand scenario but NPV is still greater than zero or positive, it can be concluded that CNG Fueling Station investment under this scenario still feasible to build. This result is consistent with IRR. The IRR is 17.7% is which greater than MARR of 14%. And payback periods are 7 years 10 months that less than the project analysis duration of 10 years.

### 3.7 Sensitivity Analysis

Sensitivity analysis was conducted to determine how sensitive a decision on the change of the variables or parameters that influence it. The sensitivity analysis was performed only on the worst case demand scenario. Variable was changed to see the level of sensitivity including the bank interest rate, life years, operations and maintenance (O & M) costs, investment costs, and demand. Sensitivity analysis in this study only considers to the impact by changing variables on NPV worst case demand scenario that would be base case NPV.

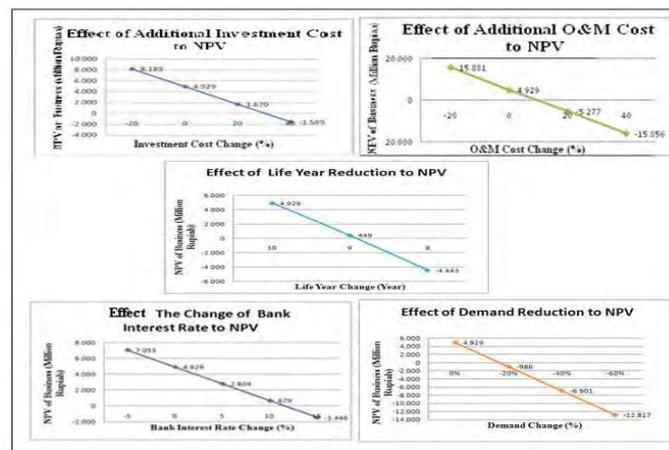


Figure 1 : Sensitivity analysis

The increase of investment cost is possible due to the rising price of machines, raw materials, and others. Based on the graph in Figure 1, it can be seen that the project can match the increase of investment cost at the level of 30.25% (point between 20% and 40%). After that point, the NPV begins to be negative. Thus, if the investment costs increase up to 30.25% or Rp. 21.226.626.765, CNG Fueling Station project under acceleration scenario and the demand from Busway (worst case) is still feasible and able to attract investors to invest.

O & M cost is possible to increase for example because of the increase of rent land, the increase of electricity costs, maintenance costs, etc. (excluding depreciation and amortization). Based on the graph in Figure 1, it can be seen that the Station can match the increase of O&M cost to the level of 10% (point between 0% and 20%) Thus, if the O&M costs increase up to 10%, CNG Fueling Station projects under acceleration scenario and only consider the demand from Busway (worst case) is still feasible and able to attract investors to invest.

Demand is possible to change when BSTP Policy as reference for demand projection do not proceed according to plan or the user communities that interest to switch to CNG fuel are lacking, thus the number of demand not in accordance under previous estimates. Based on the graph in Figure 1, it can be seen that the business or project CNG Fueling Station can match the demand reduction at the level of 17% (point between 0% and -20%) because at that point the NPV begin to be negative. Thus, if the demand decreases up to 17%, this CNG Fueling Station project is still feasible and able to attract investors to invest.

Life year could be decrease from the projection or expectation early. This may be happen due to CNG Fueling Station where is located in Central Jakarta area close to Tanjung Priok. It makes the water is salty. The water might be causing the machines break down quickly or damaged easily then should be making the new investments. Based on the graph in Figure 1, it can be seen that the business or project CNG Fueling Station can match the life year reduction only 2 years, specifically 1 year 8 months. It's because at that point the NPV begin to be negative.

The change of Bank interest rate may be happen. The changes are fluctuating. It is influenced by inflation because basically a bank determines the interest rate with reference by the inflation rate. Based on the graph in Figure 1, it can be seen that the business or project CNG Fueling Station can match Bank Interest Rate at 24% or increase in interest rates by twice from the base case because at that point the NPV begin to be negative. That means, when interest rate more than 24% or increase in interest rates by twice, CNG Fueling Station is not feasible to build.

### 3.7.1 Two-Dimensional Sensitivity Analysis

Investment and O & M costs are two parameters that are regarded as the most described the outflow (cash out). Based on the graph in Figure 1, O&M costs parameter line is more slope than other to decline NPV. The increase of 10% has made the NPV is negative while the investment cost is less critical because it can touch negative NPV when the increase reaches about 30%. After know that O&M cost is the most critical as cash out then comparison to the cash in variable, i.e., demand. Three-dimensional sensitivity analysis that is taken between the demand and O & M cost can be seen in figure below:

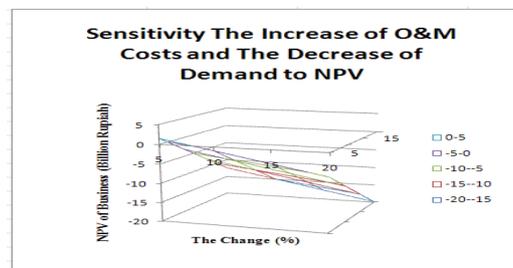


Figure 2: Three-dimensional sensitivity analysis

From the graph in Figure 2 can be analyzed that NPV is positive, or the business is still considered to be feasible along with the increase of O & M costs and the decrease of demand only by 5%. It indicates that when the decrease of demand is more than 5% and at the same time there was also the increase of O & M cost, the business or project of CNG fueling station is not feasible to run because the NPV value is negative.

## 4 CONCLUSION

There are some conclusions that can be concluded from this research. The best location to build CNG fueling station is on Budi Utomo Street, Central Jakarta. Feasibility analysis showed that building CNG fueling station on Budi Utomo Street under acceleration scenario is feasible even when worst case demand occur (demand only from Busway) and NPV is positive with Rp 4.929.489.648, IRR with 17.7% and Payback period for 7 years 10 months. Results of two-dimensional sensitivity analysis show that the most sensitive factor is the change in NPV because of the increase in O&M cost which the increase can not exceed 10%. And results from three-dimensional sensitivity analysis show that the NPV value is quite sensitive because it still considered regarded to be feasible along with the increase of O & M cost and decrease of demand only by 5%. It indicates that when the decrease of demand is more than 5% and at the same time there was also the increase of O & M cost, the business or project of CNG fueling station is not feasible to run anymore.

## REFERENCES

- [1] T. R. Kolanu and U. B. Kondury, "Market driven model for promotion of CNG as transportation fuel in developing countries: learning from a successful initiative in India," *As. J. Energy Env.*, vol. 08, no. 04, pp. 618-626, 2007.
- [2] S. Vita, A. Hartanto, R. A. Subekti, H. M. Saputra, "Program konversi dari BBM ke BBG untuk kendaraan," in *Centre of Mechatronics, Electrical Power, and Vehicular Technology*, R. Estiko, A. Hapid, Jakarta: LIPI Press, 2011.
- [3] Wright, J. C., *Technoeconomics: Concept and Cases*, Hongkong : Asian Productivity Organization, 1987.
- [4] Gray, C.,P. Simanjuntak, L. K. Sabu, P. F. L. Maspaitella, and R. O. G. Varley, *Pengantar Evaluasi Proyek*, Jakarta : Gramedia Pustaka Utama, 1993.
- [5] H. Umar., *Studi Kelayakan Bisnis, Manajemen, Metoda, dan Kasus*. Jakarta : PT. Gramedia Pustaka Utama, 2001.

# Analysis Cellular Phone Design based on User-Centered Design for College Student

Nabilla Nur Anisah<sup>a</sup>, Rachma Hidayati<sup>b</sup>, Septy Aprilliandary<sup>c</sup>, Amalia Oktaviani Paera<sup>d</sup>

Faculty of Engineering University of Indonesia, Depok 16424

E-mail : <sup>a</sup>nabilla.nur@ui.ac.id, <sup>b</sup>rachma.hidayati@ui.ac.id, <sup>c</sup>septy.aprilliandary01@ui.ac.id, <sup>d</sup>amalia.oktaviani@ui.ac.id

## ABSTRACT

This study aim to analyze cellular phone design based on user-centered design for college student. Method of user-centered design that used is usability testing, which is exploring the emotional usability through conjoint analysis to determine the combination of mobile phone design that desired by college student and behavior usability through usability assessment QWERTY keypad. Through this study showed that mobile phone design that are desired by the students is candy bar model (4 cm x 10 cm), QWERTY keypad design, touch screen navigation system, and screen sizes 2-3 inch width. The value of efficiency, performance, feedback, and satisfaction of QWERTY keypad design is higher than 12 button keypad and it also produces high mental workload, effort, and the frustration level.

## Keywords

Cellphone, user-centered design, usability, QWERTY keypad, college student

## 1. INTRODUCTION

There is no any other technology that is more distinctively developed and more influential in humanity's life than technology of communication. Paisley stated that technology transformation has put communication in the frontline of civilization's revolution [1]. The development of technology communication is mostly seen in electronica inventions. For example, cellphone is developed really advanced and rapidly, far beyond other technology inventions.

As a result, there are many variance of cell phone in order to fulfill market's demand and there are also various trends for example in its physical appearance. The most noticeable difference in cell phone evolution from times to times is the combination of its design. Cell phone's design aspect varies from its model, keypad, and navigation system. Those aspects are affecting the usability of the cell phone. Across the world, mobile phones are mostly used for the SMS and social media features within it. According to the survey named Global Attitudes Project that is held on 21<sup>st</sup> of March to 15<sup>st</sup> of May 2011 and made by Pew Research Centre, generally 85 percent of mobile phone users in the word send at least one text message every day. Based on the survey conducted by Vlingo Corporation, teenagers (13-19 years old) and adults (20-29 years old) tend to use short message service feature more often than any other age group.

## 2. LITERATURE REVIEW

### 2.1. Cellular Phone Design

In order to comprehend the usability of cellular phone, there should be an understanding in the main area of cellular phone design that affects user experience. The main areas are industrial design, mechanical concept, hardware, software, type of user interface. Industrial design has exceptional impact on product success. For example, watches and shoes are often sold based on design instead of their function. A cellular phone is identified and distinguished through its industrial design. Keinonen stated that the size of cellular phone keeps shrinking, the new model always lighter, more flat, and shorter. The small size and simple appearance have been a major challenge for industrial designer (Keinonen, 2000). Mechanical concept of product is an implementation of industrial design in detail. Mechanical design initially defined as physical product implementation, such as material, dimension, and position of product component. Hence, industrial design along with mechanical design is decision key for ergonomic design. Hardware defines the main performance of cellular phone, such as screen resolution, battery consumption, memory capacity, and processor efficiency. Hardware supports a specific software performance. Therefore, software functionality depends on hardware. The development of cellular phone starts as design focused on hardware. However, the increasing importance of software and software function convincemanufacturer to develop cellular phone, especially smart phone, with extensive software design. Software design defines all possible software to be implemented with reasonable effort, and software architecture defines how flexible this design, particularly with complex product that rapidly undergoes technological change. The function of software design and user interface style depends on each other. Selection of software design, for example Symbian design, determines the principals of user interface style for product, selection of user interface style is used to guide company in selecting software design, for example Microsoft CE. User interface style is a

framework that portrays interaction style and object, including look and behavior (Hix and Hartson, 1993). In computer termination, user interface style has same meaning with user interface software (display). For cellular phone, user interface style is translated as appearance, button, and key needed on a device. Some companies have many different user interface style.

### 2.1.1. Cellular Phone Component

Previous studies indicated that cellular phone interfaces consist of four components: hardware user interface, software user interface, external interface, and service interface [2]. Hardware user interface includes ergonomics hardware, input method, and communication method, while software user interface focuses on menu design such as phone size, color, and navigation menu logic. External interface involve feature that help on using device, but not physically part of the device itself, such as user support elements, accessories, and supporting software. Lastly, service interface is a component that facilitate the usage of phone service that provided by service provider or carrier, such as special calling plan services, text messaging services, and business practices including calling plan agreement, sales communication, other information resources, and phone bill.

### 2.1.2. User Centered Design

User centered design term has a tight relation with product, service, and experience design to match the need and capability of user. Donald Norman in *The Design of Everyday Things* stated that many designers have lost user touch that resulted on devices that unfriendly, inconvenient, and unsafe for user. Norman suggested user centered design which utilizes the nature of human so that user can operate the device without instruction. Nonetheless, for the fully user centered design, further studies are needed to adapt product with physical and cognitive needs along with user ability. Using user centered design approach can optimize usability. Four main principals in user centered design are (ISO, 1997p.7): (1) User active involvement, (2) Function allocation between user and system, (3) Iteration of design solution, (4) Multidisciplinary design team. Meanwhile, four major activities of user centered design are (ISO, 1997p.10): (1) Understand and determine usage context, (2) Determine user and organization needs, (3) Produce design solution (prototype), (4) Design evaluation with user towards requirements.

There are several methods of user centered design. These methods along with the sub-technique and output can be seen in the figure below:

Method	Sub-Technique	Output
Laddered Grid Method	One-to-one interview Think aloud Expert Review	Navigation flow diagrams
Focus Group	Consensus Usability heuristics	Selection and modification of navigation flow diagrams Final design mock-up Mid-to-high fidelity Flash prototype
Usability Testing	Performance Testing Retrospective think aloud (RTA) Questionnaire	Navigation diagram Critical incidents Usability problem list High fidelity Flash prototype
Expert Review	Heuristic analysis Usability walkthrough Questionnaire	Usability problem list Design recommendations Final Flash prototype

Figure 1: User centered design methods (Source: Young Sam Ryu, 2006)

### 2.1.3. Usability

According to ISO 9241-11 (ISO, 1998), the definition of usability is how far a product can be used by particular user to reach particular objective with effectiveness, efficiency, and satisfaction in particular usage context. Effectiveness is described as rate of accuracy and completeness of user objectives is satisfied. Efficiency refers to system usage effectiveness related to cost of effort or time. Satisfaction relates to user convenience and their acceptance in working with their system. Logan revealed that usability is divided into behavioral usability, which means ability to finish some functions, or objectives that directly related into tasks with reasonable time and emotional usability, which means how far the desired product can fulfill and serve other needs outside functional objectives [3]. Hassenzahl, Platz, et al. suggested and tested research model related to ergonomic (usability and hedonic aspect) as key factor to make attractive and satisfying product. It consists of three separated layers: (a) product quality objective (determined by designer), (b) perception and evaluation of subjective quality (cognitive assessment by user), (c) consequences of behavior and emotional (for user) [4].

## 2.2. Conjoint Analysis

Conjoint analysis is a statistic technique used in Multivariate Analysis that specifically used to understand how respondent build preferences towards a product. This technique is based on simple premise that consumer evaluate value from a product/service/idea through combining separated value that are contributed by each attribute. In conjoint analysis, there

should be a product (item or service) made before, either real or hypothetic by combining selected levels from each attributed. These combinations then revealed to respondents that will give evaluations towards each combination. In order to get good results, the product that will be valued should be described completely with its attributes and all relevant values for each specific attributes of a product. Meanwhile, possible values from each factor are defined as levels. In conjoint analysis, a product is described into levels from factors that form it. There are seven steps in doing conjoint analysis: (1) Objectives selection, (2) Conjoint analysis experiment design, (3) Conjoint analysis assumption, (4) Model estimation and accuracy assessment, (5) Interpreting the result, (6) Validating the result, and (7) Applying the conjoint result.

### 2.3. Quality Function Deployment

Yoji Akao defined Quality Function Deployment (QFD) as a method used to develop design quality in order to satisfy consumers and translate consumers' needs into target design and quality assurance. Voice of customer is used to explain this term and state customer needs or requirements. Voice of customer is obtained through several ways such as direct discussion or interview, survey, focus group discussion, customer specification, observations, and field study. This understanding then being summarized into product plan matrix or House of Quality (HOQ). The main objective of QFD is to assure product quality from the development stage. Furthermore, QFD is a method that enables establishment and development of consumer needs into quality characteristics in order to create a product which can fulfill all the customer needs.

### 2.4. Type of Keypad

There are two types of cellular phone keypad:

#### 2.4.1. Alphanumeric keypad

Alphanumeric keypad consists of numeric button (0-9) and two additional buttons (\* and #). A to Z characters spread on button 2 until 9 alphabetically. Character layout is identical in every cellular phone and becomes international standard (Grover, King, and Kuschler 1998).

#### 2.4.2. QWERTY keypad

This kind of keypad places its characters similar with a computer keyboard. This keypad can be found in Blackberry phones or Nokia Communicator Series.

### 2.5. Keypad Usability Study

Usability that is measured using both qualitative and quantitative technique relied mainly on user experience level with the interface. Direct usability from the interface for beginner user is important because their initial reactions will determine their needs to invest time and effort needed to expertise it (Scheidermann, 1998). Previous evaluation focused on collecting quantitative indicator especially text entry speed measurement (words per minute) and accuracy (failure rate), rather than the qualitative one (James & Reischel 2001, Mackenzie et al. 1999). However, accurate interpretation from quantitative measurements needs subjective response from participants for an interface, which can only be caught up by qualitative test.

### 2.6. Factorial Design

Factorial design is the most efficient method to analyze effect from two or more factors. Through factorial design, we interpret that in every replication, all combination from each level of factors are applied. For example, if there are  $a$  levels for A factors and  $b$  levels for B factors, then every replication consists of  $ab$  treatment combinations. The effect from experiment factors can be seen from response change that created by level change from these factors. This effect is called main effect.

## 3. METHODOLOGY

### 3.1. Students Preference Survey

In the early stage of research, a student's preference survey was conducted by spreading questionnaire into bachelor degree students of Universitas Indonesia using random sampling. The desired information from this questionnaire is respondent profile, reasons in having cellular phone, frequently used application, determining factors in choosing cellular phone, cellular phone specifications preference.

### 3.2. Conjoint Analysis

In the first step of the conjoint analysis, factors determination from a product that will be studied is specified. Previous studies show that cellular phone interface consists of four components: hardware user interface, software user interface, external interface, and service interface. After determining the factors, the next step is specifying level from each factor. In order to do that, an observation of cellular phone sales in Indonesia was conducted to perceive cellular phone specification in the market.

The selected level is the one that mostly chosen by student in order to balance the number of each factor, since more levels required more combination. Besides, so as to be carried a fractional factorial design to produce an optimal stimuli so that the resulted stimuli is not excessive and disconcerting other respondents.

The assumption of conjoint analysis is determining composition rule and model shape that are used to estimate conjoint result. In this research, the model shape used is additive model. Part-worth estimation and importance level measurement is conducted aggregately for respondent. Estimation is done through using MONANOVA (Monotomic Analysis of Variance) method, which is an ANOVA model used in ordinal data. Meanwhile, goodness-of-fit analysis model is done using Kendall's tau correlation coefficient to measure accuracy and respondent consistency in value giving. All these estimation and measurement is done by using SPSS software. An observation towards part-worth estimation for each factor is commonly done to interpret the conjoint results. As the part-worth increases (positive or negative), the effect it gives to utilities in general are increasing. Therefore, this part-worth value is usually converted into general scale in order to identify the pattern of the results and contribution of each factor in total utility.

### 3.3. Quality Function Deployment

In this research, the QFD method will be combined with Conjoint Analysis. The stages that will be done in QFD-Conjoint Analysis method combination are: (1) Conjoint Analysis is used as conceptual bridge for discrepancy between consumers and designers, and also to balance the variety of consumer needs level. Conjoint analysis is also applied to enable consumer needs prioritization; (2) Market segmentation approach with consumer grouping into homogeneity segment; (3) Conjoint analysis is done on every segment accurately with the similar procedure in the first stage; (4) A traditional HOQ process to prioritize technical requirements for every consumer segment; (5) Result and integration of conjoint analysis-HOQ analysis.

The first three stages in QFD-conjoint analysis combination have been done in conjoint analysis stage. The remaining stages are HOQ making process, the steps in making HOQ are: (1) Determining customer requirement factor. For this step, the determination of importance factors is taken from factors used on previous conjoint analysis; (2) Determining priority of customer requirement factor based on importance level; (3) Determining technical response. Technical response is activity development planning that is usually done by company in developing cellular phone product.

### 3.4. Usability Study QWERTY keypad

In reviewing behavioral usability, this research focuses on ergonomic quality value on cellular phone. Based on previous survey, teenagers in age 13-19 and adults in age 20-29 are using their cellular phone for SMS more. Therefore, behavioral usability that will be conducted is about usability study QWERTY keypad. Through factorial design method, this research aims to answer the following questions: how the effect of keypad type differences in typing effectiveness and efficiency? Are the factors interacted in impacting the typing effectiveness and efficiency? Are respondent difference factors that are used as blocking affect one typing effectiveness and efficiency?

Linear statistic model for factorial design with blocking is stated on equation below:

$$X_{ijk} = \mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \delta_k + \epsilon_{ijk} \begin{cases} i = 1, 2, \\ j = 1, 2, 3, 4 \\ k = 1, 2, \dots, n \end{cases} \quad (1)$$

$\tau_i$  = effect of keypad type

$\beta_j$  = effect of typing type

$(\tau\beta)_{ij}$  = effect of interaction between two factors

$\delta_k$  = effect of k-th block. K refers to number of replication used in this research. Since 1 replication is done by 1 respondent, k = number of respondent

Then, hypotheses submissions for this case are:

- $H_0 : \tau_1 = \tau_2 = \tau_3 = 0$   
 $H_1 : \text{at least one } \tau_i \text{ is not zero}$
- $H_0 : \beta_1 = \beta_2 = \beta_3 = 0$   
 $H_1 : \text{at least one } \beta_i \text{ is not zero}$
- $H_0 : (\tau\beta)_{ij} = 0 \text{ for all } i \text{ and } j \text{ value}$   
 $H_1 : \text{at least one } (\tau\beta)_{ij} \text{ is not zero}$
- $H_0 : \delta_k = 0 \text{ for all } k \text{ value}$   
 $H_1 : \text{at least one } \delta_k \text{ is not zero}$

If p value less than 0.05, researcher has sufficient proof to accept  $H_1$  that keypad type, typing type, and/or blocking factors are significant toward typing effectiveness and efficiency.

#### 4. DISCUSSION

##### 4.1. Students Preference Survey

The number of respondent that participated in the questionnaire consists of 63% female and 37% male. Questionnaire deployment into every faculty is spread evenly with majority of respondents come from engineering faculty (20%). Respondents consist of 57% of 2006 batch, 18% of 2008 batch, 15% of 2007 batch, and the remaining percentage from 2009 batch. Respondent's age range from 18-24 years old. The first information obtained is about the reason for students to have a cellular phone. The common reason is the main function of cellular function itself, to communicate. This reason is followed by the needs to save important data, either file, music, or photo, and also for entertainment. Therefore, the desired cellular phone is the one that has sufficient memory capacity, and many features for their entertainment. For the most used application, it is found sequentially as followed: short message service, phone call, alarm, internet, Bluetooth, calendar, camera, music, notes, and dictionary. Based on the survey, in choosing cellular phone students consider factors, such as price, brand, hardware and software.

##### 4.2. Conjoint Analysis

Based on the conjoint analysis calculation, it is found that utility value for each level in each factor: (1) Cellular phone model that has high utility value is candy bar model. This means students prefers candy bar model over slide model phone; (2) For dimension factor, dimension with highest utility value is 4 cm x 10 cm, 6 cm x 11 cm, and 5 cm x 10 cm; (3) Keypad design that is most preferred by students is QWERTY; (4) Utility value for navigation button, from the highest sequentially is touch screen, track ball, button; (5) Screen size that is preferred by students is in range 2-3 inch

The most preferred cellular phone combination is cellular phone with candy bar model, in size of 4 cm x 10 cm, with QWERTY keypad, screen size around 2-3 inch, and using touch screen as its navigation system.

Result obtained from part worth estimation in conjoint analysis is importance level from every factor. Here is the value of importance level for every factor

From the view of importance factor, it is found that students' preference towards cellular phone is mostly affected by its model with 27.601%. From the most important, design factors that mostly affecting students in selecting cellular phone are: model, navigation button, dimension, keypad design, and screen size.

The next step is market segmentation based on gender to find the preferences for each segment. It is shown the result of conjoint analysis in Table 1, where red font color indicate highest utility value for each level.

Table 1: Utility value for each segment

Utility			
Factor	Level	Male	Female
Model	Candy bar	0,6736	0,6491
	Slide	-0,6736	-0,6491
Dimension	4 cm x 10 cm	0,0722	0,1004
	5 cm x 10 cm	-0,1986	-0,0502
	6 cm x 11 cm	0,1264	-0,0502
Keypad Design	QWERTY	0,1111	0,3223
	non QWERTY	-0,1111	-0,3223
Navigation Button	Button	-0,4407	-0,1667
	Touchscreen	0,6398	0,2987
	Trackball	-0,1991	-0,132
Screen Size	> 3 inch	-0,2319	-0,1762
	2-3 inch	0,2319	0,1762
(Constant)		8,2226852	8,5737952

Based on utility table for each existing level, the combination for each segment is not really different, which is cellular phone candy bar model with QWERTY keypad design, touch screen navigation system, and screen size about 2-3 inch. However, there is a difference in dimension factor, where female prefers smaller dimension (4 cm x 10 cm), while male prefers wider dimension (6 cm x 11 cm)

##### 4.3. Quality Function Deployment

Based on HOQ above, company is able to know what action should be done for every market segment and what factors should be put into consideration and prioritized to implement the existing strategy.

Table 2: House of Quality

Consumers' Needs	Technical Response			Relative Importance Level			Importance Ranking		
	Product Diversification	Making user-friendly product	New Technology Development	All	Male	Female	All	Male	Female
Dimension	9	1	3	19,493	19,008	19,88	3	3	3
Model	9	3	1	27,601	30,332	24,497	1	1	2
Keypad Design	9	9	9	14,58	14,355	14,643	4	4	4
Navigation Button	9	9	9	27,304	25,94	29,15	2	2	1
Screen Size	9	3	3	11,021	10,365	11,83	5	5	5
Absolute Importance	Male	558,72	311,5						
	Female	531,11	424,42						
Relative Importance	Male	47,04%	26,23%						
	Female	32,31%	25,82%						
Male Ranking	1		3						
Female Ranking	2		3						
All Absolute Importance	539,33		300,37						
All Relative Importance	46,94%		26,14%						
All Ranking	1		3						

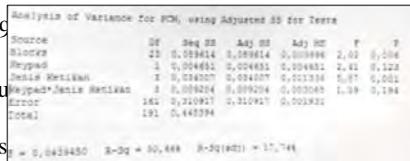
#### 4.4. Usability QWERTY Keypad

Factorial design statistic model results an analysis in a form of ANOVA table below

##### 4.4.1. Effectiveness

Table 3: ANOVA Effectiveness

Based on Table 8, using level of confidence 9



```

Analysis of Variance for WCH, using Adjusted SS for Tests
Source          DF    Seq SS    Adj SS    Adj MS    F      P
Keypad          2    0,009614   0,009614   0,004807   2,02   0,128
Keypad*Jenis    2    0,004612   0,004612   0,002306   0,91   0,402
Keypad*Jenis*  2    0,008204   0,008204   0,004102   1,69   0,194
Error          162   0,210917   0,210917   0,001302
Total          166   0,443394

R-sq = 0,0428450    R-sq (adj) = 0,04488    R-sq (pred) = 17,746
  
```

- On hypothetic test (a), researcher has sufficient proof to accept  $H_0$ , which means keypad type does not affect significantly towards typing effectiveness.
- On hypothetical test (b), researcher has sufficient proof to accept  $H_0$ , which means typing style affects significantly on effectiveness
- On hypothetical test (c), researcher has sufficient proof to accept  $H_0$ , which means the interaction between keypad type and typing style does not affect significantly toward typing effectiveness.
- On hypothetical test (d), researcher has sufficient proof to decline  $H_0$ , which means blocking between respondent affects significantly on typing effectiveness.

Model assumption about residual normality (error) is fulfilled to make the model accurate enough to be used as baseline. The other thing that should be put in consideration is R-square value about 30.66% which means 30.66% of existing variability in typing effectiveness can be explained by the model. The correlation level is medium, showed by correlation degree (R)  $=\sqrt{0.3066}=0.5537$

##### 4.4.2. Efficiency

Table 4: ANOVA Efficiency

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Blocks	23	213,53	213,53	9,28	1,29	0,183
Keypad	1	144,92	144,92	144,92	20,37	0,000
Stimulus	5	3872,28	3872,28	2840,74	400,87	0,000
Keypad*Stimulus	5	149,98	149,98	54,65	7,66	0,000
Error	141	1241,00	1241,00	8,80		
Total	171	10282,69				

Based on Table 9, using level of confidence 95%, researcher concludes that:

- On hypothetic test (a), researcher has sufficient proof to decline  $H_0$ , which means keypad type affect significantly towards typing time needed.
- On hypothetical test (b), researcher has sufficient proof to decline  $H_0$ , which means typing style affects significantly on typing time needed
- On hypothetical test (c), researcher has sufficient proof to decline  $H_0$ , which means the interaction between keypad type and typing style affect significantly toward typing time needed.
- On hypothetical test (d), researcher has sufficient proof to accept  $H_0$ , which means blocking between respondent does not affects significantly on typing time needed.

Model assumption about residual normality (error) is fulfilled to make the model accurate enough to be used as baseline. The other thing that should be put in consideration is R-square value about 88.80% which means 88.80% of existing variability in typing effectiveness can be explained by the model. The correlation level is medium, showed by correlation degree (R)  $=\sqrt{0.8888}=0.942762$

#### 4.4.3. Satisfaction

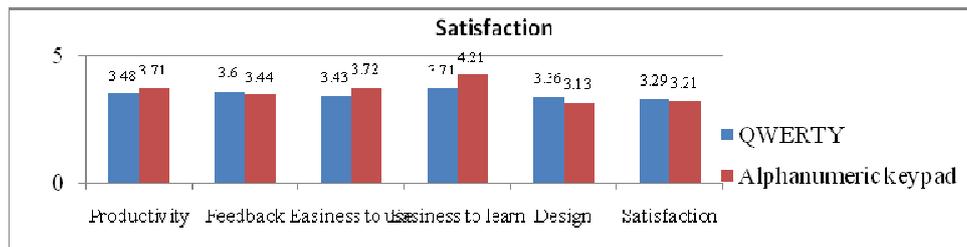


Figure 2: Satisfaction

Through the assessment of 6 satisfaction factors it is found that QWERTY keypad has feedback, design, and satisfaction value higher than alphanumeric keypad. This indicates that esthetical value of QWERTY makes satisfaction level assessment of user considerably high. For alphanumeric keypad, it has productivity, easiness to use, and easiness to learn value higher than QWERTY keypad. This indicates that satisfaction value of alphanumeric keypad comes from its simplicity that makes its user can be more productive.

## 5. CONCLUSION

Based on conjoint analysis result, the combination of cellular phone factor for students is a cellular phone with candy bar model (4 cm x 10 cm), QWERTY keypad design, touch screen navigation system, and screen size about 2-3 inch. The main consideration factors for students in selecting their cellular phone are model, navigation button, dimension, keypad design, and screen size. Considering market segmentation, there is difference in female and male preference when selecting cellular phone, which lay in the cellular phone dimension. Based on usability keypad, it is resulted that the keypad type, either QWERTY or alphanumeric do not affect significantly on typing effectiveness. However, QWERTY keypad has higher efficiency value than alphanumeric keypad in typing sentence and symbol. While in typing number, alphanumeric keypad is much more efficient. Aesthetical value of QWERTY keypad makes satisfaction assessment of user is higher because of its feedback and design factor rather than alphanumeric keypad. On the other hand, the satisfaction value of alphanumeric keypad is high in productivity, easiness to use, and easiness to learn value which makes the user can be more productive.

## 6. REFERENCES

- [1] Rogers, Everett, "Communication Technology: The New Media in Society", USA: Free Press, 1986
- [2] Ketola, P, "Integrating usability with concurrent engineering in mobile phone development," 44-48, 2002.
- [3] Logan, R, "Behavioral and emotional usability: Thomson consumer electronics," In M. E. Wiklund Usability in practice, New York: AP Professional.
- [4] Hassenzahl, M, "The effect of perceived hedonic quality on product appeal," *International Journal of Human-Computer Interaction*, pp.481-499, 2001.
- [5] Lee, Young Seok, "Older adults' user experiences with mobile phones: identification of user clusters and user requirements," unpublished, p. 18, 2007

# Application of Two-Dimensional Image in Digital Anthropometric Measurement System Design

Herianto<sup>a</sup>, Ardiyanto<sup>b</sup>, Dito Januar<sup>c</sup>

<sup>a</sup> Industrial Engineering Program, Department of Mechanical and Industrial Engineering,  
Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta 55281  
e-mail: herianto@ugm.ac.id

<sup>b</sup> Industrial Engineering Program, Department of Mechanical and Industrial Engineering,  
Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta 55281  
e-mail: ardiyanto@mail.ugm.ac.id

<sup>c</sup> Industrial Engineering Program, Department of Mechanical and Industrial Engineering,  
Faculty of Engineering, Universitas Gadjah Mada, Yogyakarta 55281  
e-mail: ditojanuar28@yahoo.co.id

## ABSTRACT

Due to several advantages of conventional anthropometry methods, conventional anthropometry methods used tools such as measuring sticks or calipers have endured to the present day and they are also still widely used in many researches. However, the conventional methods are clumsy and time consuming. As the one of the solutions, utilizing two-dimensional images offers an opportunity for covering the shortcoming of the conventional anthropometry methods. According to this explanation, a digital anthropometric measurement system using two-dimensional images will be designed in this research. As the results of the design process, hardware setting and customized software will be established. The hardware will be used for producing the two-dimensional image that will be the input of the system, while the software will be used for processing the two-dimensional image. By processing the image, several anthropometric dimensions can be determined. After that, for answering whether the proposed system fulfills the requirements of the measurement system, accuracy and reliability test will be conducted. By using this design, the proposed system can be used for measuring sixty anthropometric dimensions. Afterwards, according the results of the accuracy and reliability test, the proposed system seems accurate and reliable. In addition, for increasing the accuracy of several variables, it is better if when measuring using the proposed system, the measuring object wear special clothes such as swimming head gear and swimwear.

## Keywords

*Anthropometry, two-dimensional images, accuracy and reliability tests*

## 1. INTRODUCTION

Anthropometry can be defined as a science of human body dimension measurements [1]. The term of anthropometry comes from two Greek words, *anthropos* that means human and *metron* that means measure [2]. Anthropometry is widely used by ergonomic experts as the basis of product or layout dimensions [1] which is purposed for increasing the human well-being in a system.

There are a variety of methods available for anthropometry measurements which range from highly sophisticated equipment such as 3-D scanners to traditional tools [3]. Traditional or conventional anthropometry methods and tools use tools such as measuring sticks or calipers [2]. Due to several advantages of this method, these conventional methods and tools have endured to the present day and they are also still widely used in many researches [4], [3], [5], [6]. In addition, these conventional methods are the golden standard of anthropometry measurement because they are accurate and relatively cheaper than the other advance tools like 3-D scanner [3].

Although the conventional ones seem very beneficial, the conventional methods have several disadvantages too. Kroemer *et. al.* [7] stated that the traditional method is clumsy and time consuming. Not only that, measuring human dimensions using conventional tools also makes part of the human body directly contacted with the measurement tools. According to that, Hung *et. al.* [8] stated that the conventional methods are invasive methods.

As the one of the solutions, utilizing two-dimensional images offers an opportunity for covering the shortcoming of the conventional anthropometry methods. By using a two-dimensional image, the measuring objects do not need directly contacted with the measurement tools. In addition, producing the two-dimensional image of human body do not also need expensive and sophisticated technology like 3-D scanner. It only needs a standard digital camera that may be one of the daily gadgets nowadays.

According to the previous explanations, a digital anthropometric measurement system using two-dimensional images will be proposed in this research. As the results of the development process, hardware setting and software will be established. The hardware following certain setting will be used for producing the two-dimensional image that will be the input of the system, while the software will be used for processing the two-dimensional image. By processing the image, several anthropometric dimensions can be determined. After that, for answering whether the proposed system fulfills the requirements of the measurement system, validation and reliability test will be conducted. If the proposed system fulfills the requirements, it can be stated that the proposed system is valid and reliable, so it can be used as an alternative for anthropometric measurement.

## 2. MATERIALS AND METHODS

### 2.1. Anthropometric Dimensions

Sixty human body dimensions, both in standing and sitting posture will be accommodated in the proposed system. Several body dimensions and measurement definitions, such as popliteal height and span, were adopted from Pheasant [9]. The sixty body dimensions accommodated in the proposed system can be seen in Figure 1 and Table 1.

### 2.2. System Design

There are two main parts of the system design in this research: set the supporting hardware and create the system software. Several hardware such as digital camera and tripod will be set up using a specific setting thus it can be used for capturing the two-dimensional image of the objects. The two-dimensional images captured will be used as the input in the proposed system. The hardware used in this research are Canon EOS 1000D digital DLSR camera, calibration board, tripod, and a computer with a Pentium Core 2 Duo processor 1.83 GHz with 2 GB of RAM. The calibration board used in this research is a board that has a length of 15 cm.

After that, if the hardware is used for producing the input, a customized software is needed for processing the input. The software built in this research accommodates several functions that can be used to transform the two-dimensional images into several anthropometric dimensions. The software will be built using Matlab R2009a software.

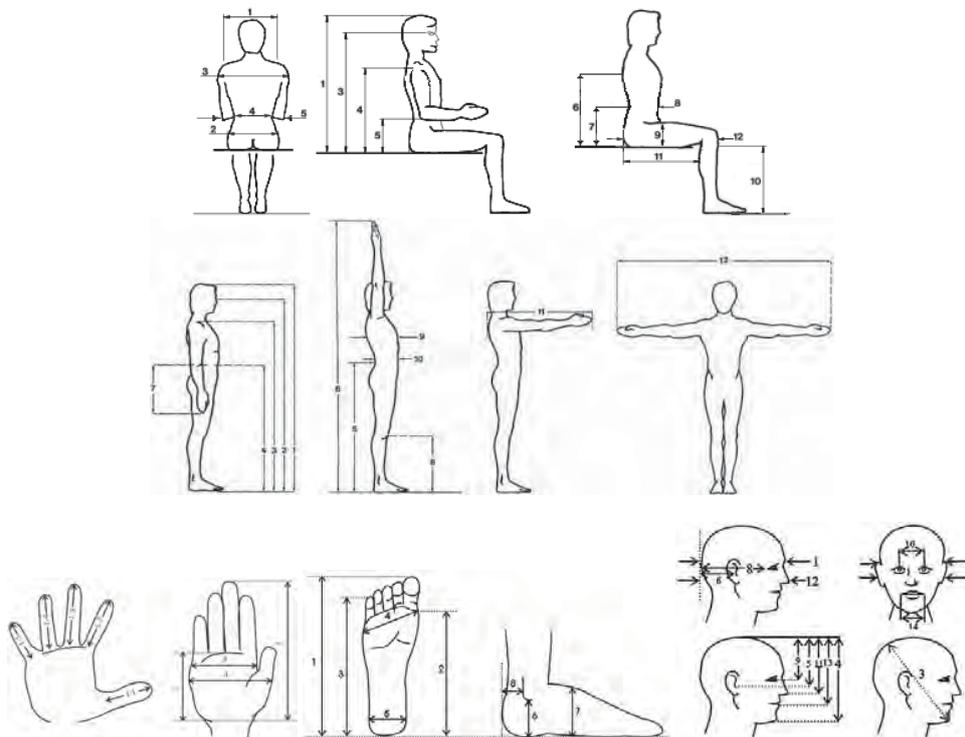


Figure : Anthropometric Dimensions

Table 1: Name of the Anthropometric Dimensions

No	Name	No	Name	No	Name
<b>Sitting position (from the back)</b>					
1	Shoulder Breadth (Biacromial)	3	Shoulder Height	2	Foot breadth
2	Hip Breadth	4	Elbow Height	3	Sole length (up to little toe)
		5	Hip Height	4	Sole breadth

3	Shoulder Breadth (Bideltoid)
4	Waist Breadth
5	Elbow to elbow Breadth
<b>Sitting position (from the rear)</b>	
1	Erectly sitting Height
2	Normal sitting height
3	Eye height (sitting)
4	Shoulder height (sitting)
5	Elbow height (sitting)
6	Backrest height
7	Waist height (sitting)
8	Abdominal depth (sitting)
9	Thigh breadth
10	Popliteal height
11	Upper limb length
12	Buttock knee length
<b>Standing position</b>	
1	Stature
2	Eye Height
6	Vertical grip reach (Standing)
7	Lower hand length
8	Knee height
9	Chest Depth
10	Abdominal Depth (Sitting)
11	Forward reach
12	Span
<b>Hand</b>	
1.1	Thumb length
1.2	Index finger length
1.3	Middle finger length
1.4	Ring Finger length
1.5	Little finger length
2	Palm width
3	Total finger breadth
4	Hand breadth
5	Hand length
<b>Foot</b>	
1	Foot Length
5	Hind foot breadth
6	Ankle height
7	Foot center height
8	Ankle length
<b>Head</b>	
1	Head length
2	Head breadth
3	Maximum diameter of head
4	Chin to top of head length
5	Ear to top of head length
6	Ear to back of head length
7	Distance between ears
8	Eye to back of head length
9	Eye to top of head length
10	Distance between pupils
11	Nose to top of head length
12	Nose to back of head length
13	Mouth to top of head length
14	Mouth breadth

### 2.3. Accuracy and Reliability Test

Accuracy and reliability test on the system is intended to answer whether the proposed system fulfill the system requirements or not. The first test carried out on the accuracy of the system measurement. Accuracy test aims to determine how close the anthropometric measurements results from the proposed system compared with the conventional anthropometric measurement results. Slightly different with the accuracy test, the reliability test aims to determine how consistence the anthropometric measurements result using the proposed system.

To determine the accuracy level of the proposed system measurement, paired t-test or Wilcoxon signed rank test will be performed. Paired t-test will be performed if the data are normally distributed, while Wilcoxon signed rank test will be performed if the data are not normally distributed. If the value of the p-value is more than the confidence interval (in this case we use 5%), it can be concluded that the proposed system is accurate.

After that, to determine the reliability of the proposed test-retest reliability will be used. Test-retest reliability will be done by comparing two sets of measurement data using the proposed system. The data used for comparison must come from same system operator. The proposed system can be reliable if there is no significance differences between the measurement results on the first measurement compared with the second measurement. The differences between the first and the second measurement will be established by performing paired t-test or Wilcoxon signed rank test.

Data used on the accuracy and reliability tests taken from measurement data from 12 objects. Each of objects will be measured using the traditional tools and the proposed system. Due to the needs of reliability tests, measurement using the proposed system will be done twice. Objects were 12 men with age range 21-23 years old (median = 22 years old). It consists of 9 Javanese, 2 Chinese, and 1 Sundanese.

## 3. RESULTS AND DISCUSSION

### 3.1. System Design Results

#### 3.1.1. Hardware Setting

As mentioned before, several hardware such as digital camera and calibration board will be set up using specific setting, so they can be used for producing the two-dimensional images. Several setting attempted in this proposed system are: (1) locating the calibration board in the same line with the measuring object; (2) locating the camera attached in the tripod in front of the measuring object. Illustration of the hardware setting can be seen in Figure 2. This setting will be used for capturing several images representing the sixty anthropometrics dimensions.

#### 3.1.2. Software Design

Each image captured will be inserted in the software. Illustration of the software interface can be seen in Figure 3. For determining an anthropometric dimension, four landmarks need to be determined by the software operator. Two landmarks are the end to end of the body landmarks representing the anthropometric dimension, while the rest of the two landmarks are the end to end of the calibration board landmarks representing the calibration dimension. Both of the dimension units are pixel. Illustration of these landmarks is shown in Figure 4.

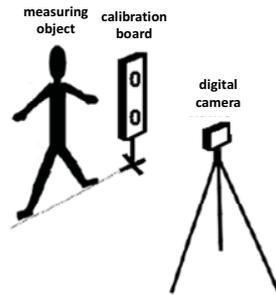


Figure 2 : Hardware Setting

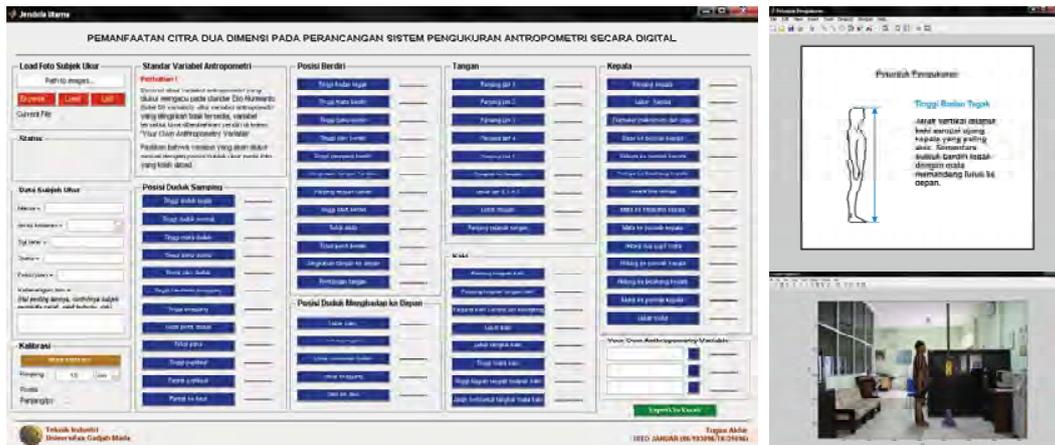


Figure 3 : Software Interfaces (in Bahasa Indonesia)

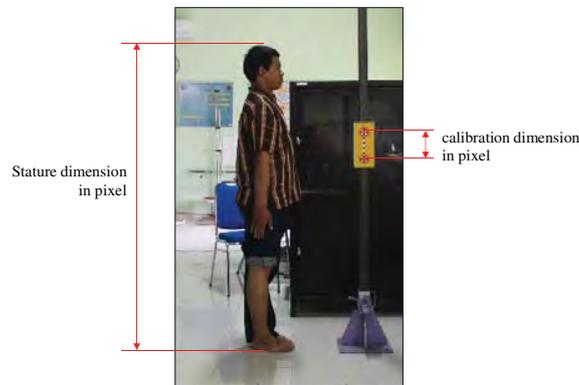


Figure 3 : Four Landmarks representing the anthropometric and calibration dimension

After both of the anthropometric and calibration dimensions can be determined, by adding the actual dimension of the calibration in millimeters, the actual anthropometric dimension in millimeters can be also determined. Illustration of this equation is shown in Equation 1.

$$\frac{\text{Calibration Dimension in mms}}{\text{Calibration Dimension in pixel}} = \frac{\text{Anthropometric Dimension in mms}}{\text{Anthropometric Dimension in pixel}} \quad (1)$$

### 3.2. Accuracy and Reliability Test Result

#### 3.2.1 Accuracy Test Results

Complete accuracy test results expressed using p-value of the paired t-test or Wilcoxon signed rank test are shown in Table 2.

Table 2. Accuracy Test Results

Name of Variable	p-value	Name of Variable	p-value
Erectly sitting Height	0.026*	Index finger length	0.033*
Normal sitting height	0.108	Middle finger length	0.074
Eye height (sitting)	0.755	Ring Finger length	0.223
Shoulder height (sitting)	0.477	Little finger length	0.705
Elbow height (sitting)	0.057	Palm width	0.059
Backrest height	0.583	Total finger breadth	0.365
Waist height (sitting)	0.350	Hand breadth	0.136
Abdominal depth (sitting)	0.476	Hand length	0.036*
Thigh breadth	0.609	Foot length	0.782
Popliteal height	0.782	Foot breadth	0.467
Upper limb length	0.220	Sole length (up to little toe)	0.717
Buttock knee length	0.421	Sole breadth	0.257
Shoulder Breadth (Biacromial)	0.181	Hind foot breadth	0.046*
Hip Breadth	0.037*	Ankle height	0.091
Shoulder Breadth (Bideltoid)	0.530	Foot center height	0.572
Waist Breadth	0.814	Ankle length	0.411
Elbow to elbow Breadth	0.084	Head length	0.474
Stature	0.088	Head breadth	0.341
Eye Height	0.010*	Maximum diameter of head	0.003*
Shoulder Height	0.609	Chin to top of head length	0.020*
Elbow Height	0.081	Ear to top of head	0.665
Hip Height	0.014*	Ear to back of head	0.141
Vertical grip reach (Standing)	0.138	Distance between ears	0.928
Lower hand length	0.539	Eye to back of head	1.000
Knee height	0.682	Eye to top of head	0.008*
Chest Depth	0.646	Distance between pupils	0.089
Abdominal Depth (Sitting)	0.695	Nose to top of head	0.755
Forward reach	0.059	Nose to back of head	0.029*
Span	0.504	Mouth to top of head	0.969
Thumb length	0.145	Mouth Breadth	0.073
<b>Mean</b>	0.353		
<b>Minimum</b>	0.003		
<b>Maximum</b>	1.000		

\*Significant at  $p < 0.05$

According to Table 2, the p-value of the 49 dimensions is more than 0.05, while the rest of the p-value is less than 0.05. The mean of p-value is 0.353, while the minimum and the maximum value of the p-value are 0.003 and 1.000.

### 3.2.2 Reliability Test Results

Complete reliability test results expressed using pearson's or spearman's correlation coefficient are shown in Table 3.

Table 3. Test-retest Reliability

Name of Variable	Correlation Coefficient (r)	Name of Variable	Correlation Coefficient (r)
Shoulder Breadth (Biacromial)	0.988	Index finger length	0.924
Hip Breadth	0.986	Middle finger length	0.978
Shoulder Breadth (Bideltoid)	0.990	Ring Finger length	0.857
Waist Breadth	0.972	Little finger length	0.956
Elbow to elbow Breadth	0.964	Palm width	0.943
Erectly Sitting Height	0.904	Total finger breadth	0.913
Normal sitting height	0.855	Hand breadth	0.945
Eye height (sitting)	0.921	Hand length	0.982
Shoulder height (sitting)	0.846	Foot length	0.981
Elbow height (sitting)	0.950	Foot breadth	0.942
Backrest height	0.612	Sole length (up to little toe)	0.946
Waist height (sitting)	0.682	Sole breadth	0.728
Abdominal depth (sitting)	0.978	Hind foot breadth	0.854
Thigh breadth	0.826	Ankle height	0.705
Popliteal height	0.597	Foot center height	0.832
Upper limb length	0.926	Ankle length	0.895
Buttock knee length	0.951	Head length	0.900

Name of Variable	Correlation Coefficient (r)	Name of Variable	Correlation Coefficient (r)
Stature	0.998	Head breadth	0.723
Eye Height	0.999	Maximum diameter of head	0.761
Shoulder Height	0.997	Chin to top of head length	0.948
Elbow Height	0.993	Ear to top of head	0.914
Hip Height	0.966	Ear to back of head	0.862
Vertical grip reach (Standing)	0.996	Distance between ears	0.875
Lower hand length	0.983	Eye to back of head	0.873
Knee height	0.979	Eye to top of head	0.924
Chest Depth	0.937	Distance between pupils	0.878
Abdominal Depth (Sitting)	0.964	Nose to top of head	0.888
Forward reach	0.996	Nose to back of head	0.876
Span	0.995	Mouth to top of head	0.909
Thumb Length	0.941	Mouth Breadth	0.456
<b>Mean</b>	<b>0.898</b>		
<b>Minimum</b>	<b>0.456</b>		
<b>Maximum</b>	<b>0.999</b>		

According to Table 3, the correlation coefficients of the 59 dimensions are more than 0.500. The mean of the correlation coefficient is 0.898, while the minimum and the maximum value of the correlation coefficient are 0.456 and 0.999.

### 3.3. Discussion

Based on the previous explanation, by using a specific hardware setting and a customized software, the proposed system has been established for measuring the anthropometric dimensions. The proposed system can be used for measuring sixty anthropometric dimensions as explained in the Figure 1 and Table 1.

After that, according to the results of accuracy and reliability tests, generally, the proposed system is accurate and reliable. However, when it was used for measuring several dimensions such as erectly sitting height, hip breadth, eye height, hip height, index finger length, hand length, hind foot breadth, maximum diameter of head, chin to top of head length, and nose to back of head length, significant differences between the measurement results using the proposed system and the conventional methods happen.

For several dimensions such as erectly sitting height, maximum diameter of head, chin to top of head length, and nose to back of head length, the differences can occur because of the measuring object's hair. When it measured using the traditional tools, the caliper or the anthropometer can push the hair. However when captured using the digital camera the hair cannot be pushed. After that, for the other dimensions such as hip breadth and hip height, the differences happen due to measuring object's cloths. The cloths of the objects make the body landmarks are difficult to find.

Slightly different with the result of the accuracy test, according to the results of the reliability test, the significant differences between the two measurements only occurs in the mouth breadth dimension. It can occur because when the objects captured for the first and the second image, the objects may change their mouth position.

## 4. CONCLUSION

By using the two-dimensional images as the input on the proposed system, a digital anthropometrics measurement system has been established. The proposed system consists of the supporting hardware setting which is utilizing digital camera, calibration board, and tripod and a customized software. By using this design, the proposed system can be used for measuring sixty anthropometric dimensions. After that, according the results of the accuracy and reliability test, the proposed system seems accurate and reliable. In addition, for increasing the accuracy of several variables, it is better if when measuring using the proposed system, the measuring object wear special clothes such as swimming head gear and swimwear.

## REFERENCES

- [1] Pulat, B. M., 1992. *Fundamentals of Industrial Ergonomics*, Prentice-Hall, New Jersey.
- [2] Karwowski, W. (Ed.), 2006. Anthropometry : Definition, Uses, and Methods Measurement, *International Encyclopedia of Ergonomics and Human Factors*, 2<sup>nd</sup> edition, pp. 879-882.
- [3] Karmegam, K., Sapuan, S.M., Ismail, M.Y., Ismail, N., Bahri, S., Shulb, S., Mohana, G.K., Seetha, P., Tamimoli, P., Hanapi, M.J., 2011. Anthropometric study among adults of Different Ethnicity in Malaysia, *International Journal of the Physical Sciences* 6(4), pp. 747-788.
- [4] Ismaila, O. S., 2009, Anthropometric Data of Hand, Foot and Ear of University Students in Nigeria, *Leonardo Journal of Sciences*, pp. 15-20
- [5] Tan, K. C., Hartono, M., Kumar, N., 2010. Anthropometry of the Singaporean and Indonesian populations, *International Journal of Industrial Ergonomics*, 40, pp. 757-766.

- [6] Mirmohammadi, S. J., Mehrparvar, A.H., Jafari, S., Mostaghaci, M. 2011. An Assesment of the Anthropometric Data of Iranian University Students, *International Journal of Occupational Hygiene*, 3, 85-89
- [7] Kroemer, K.H.E., Kroemer, H.J., and Kroemer-Elbert, K.E., 1997, *Engineering Physiology*, Springer, New York
- [8] Hung, P. C., Witana, C. P., and Goonetilleke, R. S., 2004, Anthropometric Measurements from Photographic Images, *Work with Computing Systems* (2004), pp 764-769
- [9] Pheasant, S., 2003. *Body Space : Anthropometry, Ergonomics, and the Design of Work*, 2<sup>nd</sup> edition, Taylor & Francis, Philadelphia.

## Design Alternatives for Elementary School Desk and Chair As an Effort in Optimize Learning Process; Anthropometrical and Aesthetical Approaches

Silfia Mona Aryani<sup>a</sup>, Lu'lu' Purwaningrum<sup>b</sup>, Mulyadi<sup>c</sup>

<sup>a</sup>Faculty of Letters and Visual Arts, University of Sebelas Maret, Surakarta 57126  
E-mail : Silfia.aryani@uns.ac.id

<sup>b</sup>Faculty of Letters and Visual Arts, University of Sebelas Maret, Surakarta 57126  
E-mail : lulupurwaningrum@gmail.com

<sup>c</sup>Faculty of Letters and Visual Arts, University of Sebelas Maret, Surakarta 57126  
E-mail : mulyadiuns@yahoo.com

### ABSTRACT

Well designed elementary school desk and chair might accommodate in-classroom-learning process. How well designed a school furniture can be assessed on its comfort, usability and aesthetic. On the previous research with 2000 elementary school pupils in Surakarta as the sample, it had been concluded that those three requirements are not well considered in desk and chair design. This research is purposed to optimize the function of elementary school desk and chair as one of education facilities by proposing design alternatives. The alternatives that are designed ergonomically and aesthetically could be appropriate in reaching learning goal. The research was conducted in several steps. It was started by reviewing anthropometric data from the previous research. The data was used as basic reference in dimension for designing the furniture set. The next step was evaluating the existing elementary school desk and chair in ergonomic and aesthetic aspects. The result shall support in creating the more detail and applicative design. The design was made in 1:5 scale model. In three-dimensional model, it was easier to assess its proportion and aesthetic. The assessment led to final design recommendation as the result of this research.

### Keywords

*Elementary school desk and chair, anthropometry, aesthetic.*

### 1. INTRODUCTION

Elementary school desk and chair that are well designed might accommodate in-classroom-learning process. How well designed a school furniture can be assessed on its comfort, usability and aesthetic. On the previous research [1], it had been concluded that there has been a little attention of those three qualities requirement on current desk and chair design used in Indonesia with schools in Surakarta as the sample.

The lack of anthropometric aspect considerations has been found on the unsuitable furniture dimension and pupil dimension. The finding was tested with mannequin software compared with furniture used currently by the students. Similar research [2] recommends desk and chair design; however it has not related to dimension and anthropometric issue. This in-appropriateness has been discussed by some researches [3-13]. It may lead to student un-comfort sitting position during classroom activities [14-16]. Another research results design prototype for desk and chair [17-20]. However, the design has not been tested in laboratory or direct user assessment.

On the previous research [1], it has been found that the inappropriateness of desk and chair design with their function especially related to student-centered in moving class learning method curricula. The furniture is presented in heavy and static hence represents un-moveable design. Similar result has been presented [2] so it becomes one factor why student active learning is hard to be applied [21] beside interior and building lay out [22]. Moreover, the additional facility for bag storage seems not to be considered [23].

The last point of the research founding [1] is the appearance of the desk and chair that is less considering aesthetic aspect. They are made in conventional design with small modification in color variation. There are some design improvement with aesthetical variable but still do not fit with student anthropometry. The main result has recommended desk and chair dimension based on pupil anthropometry.

Based on the results, the next research was conducted to further explore in desk and chair function related to learning activity. The function includes personal function to accommodate variation student body dimension and also moveable class learning method. The result from previous research was re-assessed to find out the final data with considering functionality and possibility for mass-producing. The second term research results prototype model for elementary school desk and chair that can be a reference in making better school furniture.

## 2. RESEARCH METHOD

The first step of the second term research was begun with assessing anthropometry data gained from previous term. The data was re-analyzed and re-classify in simple variation hence it might be more economical to be applied. The second step was reviewing design recommendation from the first year with supervision from research partner team purposed to acquire more ideal design recommendation. The third step was collecting and evaluating existing school desk and chair design in ergonomic and aesthetic aspects. This evaluation will be compared to the design proposed by this research for creating more detail and applicable design. The fourth step was conducting design workshop several times for creating design alternatives to be discussed and developed. The recommended dimension was then used in the designs based on pupil anthropometry. Those designs then were made in 1:5 scale models for easier visual evaluation. Some improvements are added before making it in 1:1 scale prototype. This prototype will be tested directly by the user in the next term research.

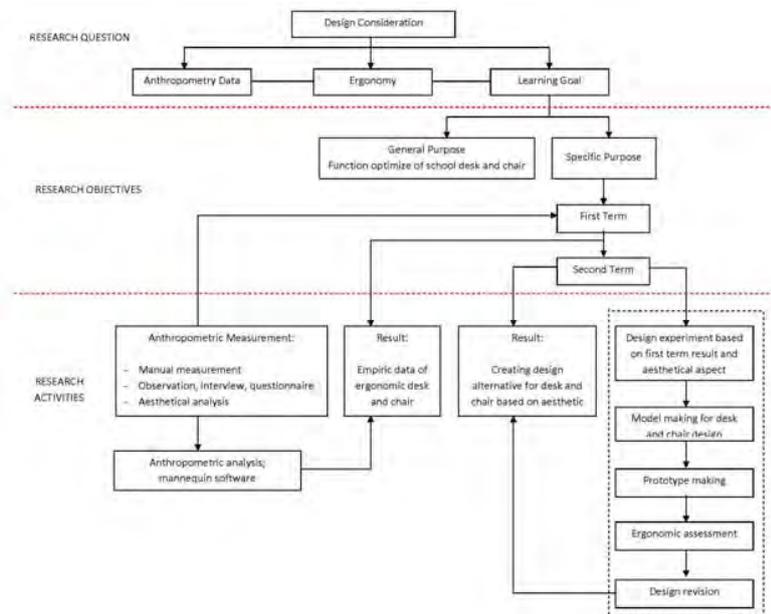


Figure 1: Reseach method

## 3. DISCUSSION

The discussion below is the report of the workshop session and design experimental process. Some possible design sketches were assessed in their aesthetic approach. Assessment focused on material and finishing used in the relation with learning process and goal to be achieved. Analysis concerned on how aesthetic approach can support functionality achievement. The furniture should be moveable but in anthropometric and function consideration. This requirement was based on the need of active learning activities for changeable classroom lay out.

### 3.1. Desk Design Alternatives

First and second desk designs combine two types of materials. The table clearance and drawer surface are made from wood. The desk legs are made from iron in 1/2inch diameter. It will be covered by duco paint in grey color.



Figure 2: Desk design model; first alternative (2 images on the left) and second alternative (2 images on the right)

The desk surface has an additional element for rubber for avoiding injuries in direct contact with sharp corner of the surface. The second alternative has an additional leg cover that is made from wood. However, this component then is cancelled in prototype model since it will raise the budget and not support attitude lesson for having polite sitting position.

In prototype model, the first design alternative is presented in half sliding surface of the top table proposed for writing and other activities that might need wider clearance. The adjustable surface might be suitable with student hand reach. It makes the student does not have to move the chair when needed [when need to stand for example] and might also minimize the lordosis effect. When needed to be moved, the sliding surface can be totally pushed hence appropriate with child hand and easier to be moved. Under the table drawer area can be made bigger that it used for the sliding surface works in solving minimal free space need for knee height.



Figure 3: Desk design improvement; first alternative (left) and second alternative (right)

On the second desk, the design has static work surface. The storage is placed on the right side of under table area. Therefore, the standing drawer must have enough width to put bag with books without disadvantage the need of free leg space under the table. Side storage might be more accessible. Its static work surface might seem more realistic to deliver, easy maintenance and simple construction system to be used in public facilities in such as public schools.

Table : Recommended dimension of desk design alternatives based on anthropometry data

Desk Dimension	Grade 1,2,3		Grade 4,5,6	
	Recommendation Range	Final Dimension	Recommendation Range	Final Dimension
Desk Length	minimum 37 cm	50 cm	minimum 42 cm	60 cm
Desk Width	45 - 62 cm	50 cm	54 - 71 cm	60 cm
Desk Height	maximum 57 cm	52.5 cm	maximum 77 cm	60 cm
Drawer Height (alternative 1)	10-15 cm	12 cm	10-15 cm	12 cm
Drawer Width (alternative 2)	10-15 cm	12 cm	10-15 cm	12 cm
Footrest height		10 cm		10 cm

## 2.1 Chair Design Alternatives

Chair design with two separated back support is purposed to accommodate a variety range of lumbar height with economical consideration. This budget limitation might lead to inflexibility lumbar support in moving and dimension. It needs aesthetic improvement as well.

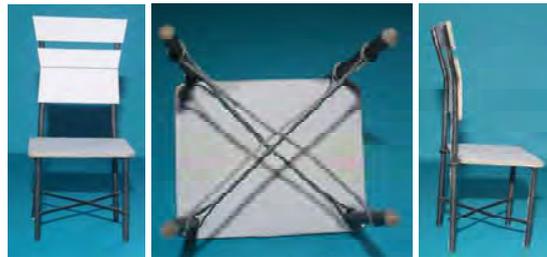


Figure 4: Chair design model; first alternative

In prototype model, the first design looks like conventional existing chair. The research result improve the design by giving comfort in appropriateness with child anthropometry. This chair is the pair of the table with sliding work surface. Adjustable requirement of the furniture has been represented by the table so the chair can be designed in static performance. Over adjustment might not beneficial as pupil mobility has to be limited for learning process effectiveness.



Figure 5: Chair design improvement; first alternative (left) and second alternative (right)

The second design offers mobility advantage as it is paired with static work surface table. This chair can be moved forward or backward so it is possible for the user to adjust his sitting position while studying. Wheels are placed on the back of chair legs so it will easier to be moved. The wheels can be locked for safety purpose. The user only needs to stand, elevate the front part of the sitting surface and pull it forward or push it backward. There are no wheels on the front chair legs. It is an effort to limit the mobility that may disturb the learning process and endanger the user.

Table 2: Recommended dimension of chair design alternatives based on anthropometry data

Chair Dimension	Grade 1,2,3		Grade 4,5,6	
	Recommendation Range	Final Dimension	Recommendation Range	Final Dimension
Seat Height	maximum 27 cm	25 cm	maximum 31cm	30 cm
Back Support Height	13 - 26 cm	22 cm	17 - 26 cm	24 cm
Seat Width	minimum 28 cm	30 cm	minimum 32 cm	35 cm
Seat Depth	maximum 32 cm	30 cm	maximum 37 cm	35 cm

#### 4. CONCLUSION

Desk and chair redesigning for Indonesia elementary school of this research has considered function, comfort, dimension, and aesthetic aspect. The result can be alternatives to be applied although it still needs to be redeveloped. The crucial problem of the design process is the difficulty of fulfilling ergonomic requirement with low production budget. Therefore, it can be a further research to explore potential local material that might be affordable and applicable to accommodate active learning method.

#### ACKNOWLEDGMENT

This paper is based on research funded by Directorate of Higher Education on Universities Research Collaboration scheme [PEKERTI]. Therefore we thank Yassierli Ph.D as the research partner for assisting and supervising during the research.

#### REFERENCES

- [1] L. Purwaningrum, S.M. Aryani, and Mulyadi, "Redesain meja dan kursi sekolah dasar sebagai upaya optimalisasi proses pembelajaran dengan pendekatan ergonomi dan estetika," *Laporan Penelitian Tahun Pertama Hibah Penelitian Kerja Sama antar Perguruan Tinggi*, Universitas Sebelas Maret, Surakarta, 2011.
- [2] Martadi, "Konsep desain bangku dan kursi sekolah dasar di Surabaya," *Dimensi Interior*, vol.4, no. 2, pp. 72-79, December 2006.
- [3] P.C. Dhara, G. Khaspuri, and S.K. Sau, "Complaints arising from a mismatch between school furniture and anthropometric measurements of rural secondary school children during classwork," *Environ Health Prev Med*, vol. 14, no. 1, Januari 2009.
- [4] D. Domljan, I. Grbac, and J. Halina, "Classroom furniture design correlation of pupil and chair dimensions (Original scientific paper)," *Coll. Antropol.*, 32, pp. 257-265, 2008.
- [5] M.K. Gouvali, and K. Boudolos, "Match between school furniture dimensions and children's anthropometry," *Applied Ergonomic*, vol 37, pp. 765-773, November 2006.
- [6] G. Panagiotopoulou, K., Christoulas, A. Papanicolaou, and K. Mandroukas, 2004. "Classroom furniture Dimensions and Anthropometric Measures in Primary School," *Applied Ergonomic*, vol 35, pp. 121-128, March 2004.
- [7] C. Parcels, M. Stommel, and R.P. Hubbard, "Mismatch of classroom furniture and student body dimensions," *Journal of Adolescent Health*, vol 24, no 4, pp. 265-273, 1999.
- [8] R. A. Salah, "School furniture match to students' anthropometry in the Gaza Strip," *Ergonomics*, vol 53, issue 3, pp: 344-354, March 2010.
- [9] N.A. Adewole, B. Isedowo, "Excel interface utilization in automation of design process of ergonomic classroom furniture for primary school pupils in Nigeria," *International Journal of Scientific & Engineering Research*, vol. 3, issue 9, September 2012.
- [10] M. Tunay, and K. Melemez, "An analysis of biomechanical and anthropometric parameters on classroom furniture design," *African Journal of Biotechnology*, vol. 7, no. 8, pp: 1081-1086, April 2008.
- [11] J.W.Y. Chung, and T.K.S. Wong, "Anthropometric evaluation for primary school furniture design," *Ergonomics*, vol. 50, no. 3, pp: 323-334, March 2007.
- [12] L. Saarni, C.H. Nygard, A. Kaukiainen, and A. Rimpela, "Are the desks and chairs at school appropriate?," *Ergonomics*, vol 50, no. 10, pp: 1561-1570, September 2007.
- [13] S. A. Oyewole, J. M. Haight, and A. Freivalds, "The ergonomics design of classroom furniture/computer work station for first graders in the elementary school," *Industrial Ergonomics*, vol 40, issue 4, pp: 437-447, July 2010
- [14] F. Balague, M.L. Skovron, M. Nordin, G. Dutoit, L.R. Pol, and M. Waldburger, "Low back pain in schoolchildren: A study of familial and psychological factors," *Spine*, vol 20, issue 11, pp:1265-1270, June 1995.
- [15] K. Grimmer, and M. Williams, "Gender-age environmental associates of adolescent low back pain," *Applied Ergonomics*, vol 31, no. 4, pp: 343-360, August 2000.
- [16] S. Murphy, P. Buckle, and D. Stubbs, "Classroom posture and self-reported back and neck pain in schoolchildren," *Applied Ergonomics*, vol. 35, pp:113-120, June 2004.
- [17] R. Lin, and Y.Y. Kang, *Ergonomic design of desk and chair for primary school students in Taiwan*, [http://www.idemployee.id.tue.nl/g.w.m.rauterberg/conferences/cd\\_donotopen/adc/final\\_paper/616.pdf](http://www.idemployee.id.tue.nl/g.w.m.rauterberg/conferences/cd_donotopen/adc/final_paper/616.pdf), retrieved on December 2012.
- [18] H.S. Jung, "A prototype of an adjustable table and an adjustable chair for schools," *International Journal of Industrial Ergonomics*, vol. 35, issue 10, pp: 955-969, October 2005.
- [19] R. Lin, S. Yang, W.Siao, H. Lin, and Y. Kang, "Designing height into daily used products – A case study of universal design," in *Universal Access in Human Computer Interaction. Coping with Diversity*, Berlin: Springer, 2007, pp: 207-216.
- [20] P.K. Kartika, "Perancangan meja dan kursi sekolah ergonomis untuk siswa kelas 3, 4, dan 5 Sekolah Dasar Negeri Banjarsari Bandung," *Laporan Tugas Akhir SI*, Bandung: ITB, 2011, pp:1-117.
- [21] Pardjono, S. Groves, J. Gough, "Constructing teaching models of student active learning from classroom observation," *Paper of Deakin University*, Australia, 1999.
- [22] L. Yosita, "Preliminary study to primary education facilities : A comparison study between Indonesia and development contries," *Dimensi Teknik Arsitektur*, vol.34, no 2, pp:122-132, December 2006.
- [23] L. Purwaningrum, S. M. Aryani, Mulyadi, "Redesain Meja dan Kursi Sekolah Dasar sebagai Upaya Optimalisasi Proses Pembelajaran dengan Pendekatan Ergonomi dan Estetika", *Laporan Penelitian Tahun Pertama Hibah Penelitian Kerja Sama antar Perguruan Tinggi*, Universitas Sebelas Maret, Surakarta, 2012, pp: 1-60.

# Usability Testing of UPH Library Website based on WEBUSE Indicator

Agustina Christiani<sup>a</sup>, Helena J. Kristina<sup>b</sup>, Frenkie<sup>c</sup>

<sup>a</sup> Industrial Engineering Department Faculty of Industrial Technology Universitas Pelita Harapan, Tangerang 15811  
E-mail : agustina.christiani@uph.edu

<sup>b</sup> Industrial Engineering Department Faculty of Industrial Technology Universitas Pelita Harapan, Tangerang 15811  
E-mail : helena.kristina@uph.edu

<sup>c</sup> Industrial Engineering Department Faculty of Industrial Technology Universitas Pelita Harapan, Tangerang 15811  
E-mail : frenk.xu@gmail.com

## ABSTRACT

UPH library website is one of the supporting media for teaching and learning process at UPH. Therefore, the content of library website should be designed in such a way for ease of use by students. Over the past, the usability of UPH library website was not known. Therefore, this study is conducted to evaluate the usability of UPH library website based on WEBUSE indicator. In addition, experimentation is conducted to test the ease of use of several website features. A questionnaire is used to determine the usability level of library website. Based on the results of the questionnaires, it is known that the usability of library website for three categories, which are: content, organization and readability; Navigation and links; as well as Performance and Effectiveness are moderate. With each usability point respectively are 0.60; 0.59 and 0.58. For user interface category, UPH library website is assessed to have good usability level (0.640). Experiments are carried out to determine the usability problems directly, by observing respondents when they are doing several tasks using UPH library website. Based on the experimental results, it is known that the respondents are still facing difficulties to use some features available on the UPH library website. This can be known from the low effectiveness (average task score = 51.67 out of 100) and low efficiency (the average completion time is 5 times longer than expert time and the average number of clicks required is 2-3 times more than the expert click). Some of the problems found are the search function that does not work, the location for important information is on the bottom side and there are some uncommon names of menus or less likely to represent the content.

## Keywords

*usability, website library, WEBUSE indicator*

## 1. INTRODUCTION

Internet is widely used in education since it makes it easy for students to access any information without the need to travel long distances. One way to know whether a website is easy to use is by doing usability testing. Usability is closely related to the interaction between the user and the computer (human-computer interaction). UPH library website is supposed to be useful for students to get any information regarding learning media, such as books and journals. UPH library website is often used by students who do their thesis. Over the past, the usability level of UPH website library has not been known. Therefore this research is conducted to measure the usability level of UPH library website from different aspects, such as navigation, content and website structure. By conducting usability test, it is known which functions or features are not user-friendly enough so that they could be improved. The improvements are expected to increase the utilization of UPH website library. There were some previous researches about website usability test. Jumeno and Putri [1] studied the usability testing of website by using 9 variables, which were accessibility; feedback mechanism; navigation link; update information; simplicity; user freedom, control and help; consistency and visibility of website structure; readability and aesthetics of website; and learnability and memorability. Nawangpalupi [2] studied website car sharing by using 3 variables, which were effectiveness, efficiency and user satisfaction. Meanwhile Chiew and Salim [3] used a combination of methods to develop Website Usability Evaluation Tool (WEBUSE). WEBUSE is chosen as a tool to measure the usability level of UPH website library.

## 2. RESEARCH METHOD

The research method consists of six steps as follows:

### 2.1 Problem identification and formulation

One of the supporting facilities for learning process in higher education is library website. Students can use this website to find any information needed. Website should be designed properly so that the users are able to gather the needed information easily. Therefore, it is important to measure the usability level of UPH library website so that it could be known which features need improvement and how the students could find any information easier.

**2.2 Research objective determination**

This research aims to measure the usability level of UPH library website by using WEBUSE indicator. From the result, any problems related to the website usability will be identified so that improvement could be proposed. The website usability will be classified into 4 categories, which are: content, organization and readability; navigation and link; user interface design; performance and effectiveness [3]. The description of each category is as follows [4]:

1. Content, Organization, and Readability describes website material contents, organization and updating, and defines how much these contents are clear, easy to find and read.
2. Navigation and link defines how clear and consistent is the navigation mechanisms used in the website.
3. User Interface defines different interface issues such as the availability and helpfulness commands, menus design, and the use of Graphical User Interface (GUI) designs.
4. Performance and Effectiveness defines how much time, and how many steps, are required for people to complete online basic tasks?

From all categories, it can be determined which category is less optimal. Furthermore, an experiment will be conducted to identify any problems happen during the usage of UPH library website.

**2.3 Data collection method**

Data are collected by distributing questionnaires using purposive random sampling. Questionnaires are distributed to respondents, UPH active students from third semester onwards, who have used UPH library website before. The target students are chosen from UPH Business School, Faculty of Social and Political Science, Faculty of Design and Planning as well as Faculty of Industrial Technology, because the total number of active students from those four faculties reaches 63% of total UPH students. The questionnaire consists of two parts. The first part consists of 7 questions to know the characteristics of UPH library website users as well as their purpose in using the website. The second part is the WEBUSE questionnaire. The questionnaire consists of 24 questions with possible answer from “strongly disagree” to “strongly agree”. All of the 24 questions are classified into 4 main categories, which are Content, Organization and Readability; Navigation and Links; User Interface Design; Performance and Effectiveness. The minimum number of sample required is calculated using a formula,

below:  $n = \frac{1}{\alpha^2}$ .....(1)

With significance level ( $\alpha = 0.1$ ), the minimum number of sample was 100.

**2.4 Questionnaire data processing**

Each answer from respondent is converted to usability merit according to the matrix shown in Table 1.

*Table 1: Options for WEBUSE Questionnaires and Corresponding Merits [3]*

Option	Strongly disagree	Disagree	Fair	Agree	Strongly agree
Merit	0.00	0.25	0.50	0.75	1.00

The merits are then accumulated based on the four usability categories. Mean value for each category is considered as the usability point for that category. Overall website usability point is the mean value of usability points for the four categories.

Usability point for a category,  $x$ , is defined as [3]:

$x = [ \sum(\text{Merit for each question of the category}) ] / [ \text{number of questions} ]$ .....(2)

Usability level is determined by the usability points (as shown in Table 2)

*Table 2: Usability Points and Corresponding Usability Levels [3]*

Point, $x$	0 ≤ $x$ ≤ 0.2	0.2 < $x$ ≤ 0.4	0.4 < $x$ ≤ 0.6	0.6 < $x$ ≤ 0.8	0.8 < $x$ ≤ 1.0
Level Usability	Bad	Poor	Moderate	Good	Excellent

The last step is calculating *Cronbach alpha coefficient*,  $\alpha$ . This coefficient is used to test the reliability of WEBUSE. The greater the coefficient means the more reliable the measurement. When the questionnaire is found reliable, then the result of usability level for each category will be used as a based to develop some tasks for the experiment. Tasks are developed according to the category that has the lowest usability level, so that the experiment can be conducted toward the right direction.

**2.5 Experiment**

Experiment is conducted by using laptop, CamStudio software (to record all screen activity), question sheet, questionnaire and internet connection (to access UPH library website). The respondents are students who have used UPH library website before. In this experiment, the chosen respondents are students from industrial engineering class of 2008 and 2009. Respondents are asked to complete some tasks by using UPH library website. After they completed the task, they need to fill the questionnaire

regarding the problems faced during the experiment. Evaluation of website usability is based on three parameters, which are: score, time of completion, and the number of clicks to complete the tasks. These three parameters are used to measure two aspects, which are effectiveness and efficiency.

### 2.6 Analysis of experiment's result

The result of the experiment is presented by using descriptive statistics. Analysis of the result is based on the three parameters used in the experiment. Based on the questionnaire distributed among the respondents, some usability problems can be identified, and the suggested improvement can be determined. After doing the analysis, the conclusion can be drawn regarding the usability level of UPH library website.

## 3. RESULT AND DISCUSSION

### 3.1 Analysis of Questionnaire

The total number of distributed questionnaire is 244, but only 234 questionnaires are completely filled in so that they can be processed further. The first part of the questionnaire shows the characteristics of the respondents. Majority of the respondents are female (63%). Most of the respondents access the UPH library website from their own laptop (86%). About 53% of the respondents are students in 7<sup>th</sup> semester. Majority of the respondents have accessed the library website to search for and read the journal. Most of them only use library website once or twice in a semester.

The second part of the questionnaire is WEBUSE questionnaire. The 234-participant response for 24-question showed that the Cronbach's alpha coefficient took value that was greater than 0.6 (0.9288). This implies that the evaluation is reliable. The usability point is calculated for each category by using formula 2 and the usability level is determined according to table 2. The result of usability point and level for each category can be seen in table 3.

Table 3: Usability Level for UPH website library

Category	Usability Criteria	Point	Usability Level	Usability level for category
Content, Organization and Readability	This website contains most of my interest material and topics and they are up-to-date.	0.59	Moderate	Moderate (0.60)
	I can easily find what I want at this website	0.55	Moderate	
	The content of this website is well organized	0.61	Good	
	Reading content at this website is easy.	0.60	Moderate	
	I am comfortable and familiar with the language used	0.61	Good	
	I need not scroll left and right when reading at this website	0.63	Good	
Navigation and links	I can easily know where I am at this website	0.55	Moderate	Moderate (0.59)
	This website provides useful cues and links for me to get the desired information	0.58	Moderate	
	It is easy to move around at this website by using the links or back button of the browser	0.65	Good	
	The links at this website are well maintained and updated.	0.65	Good	
	The website does not open too many new browser windows when I am moving around.	0.65	Good	
	Placement of links or menu is standard throughout the website and I can easily recognize them	0.48	Moderate	
User Interface	I am comfortable with the colors used at this website.	0.58	Moderate	Good (0.64)
	This website contains no feature that irritates me such as scrolling or blinking text and looping animations.	0.70	Good	
	This website has a consistent feel and look.	0.68	Good	
	This website does not contain too many Web advertisements.	0.73	Good	
	The design of the website makes sense and it is easy to learn how to use it	0.64	Good	
	This website's interface design is attractive.	0.52	Moderate	
Performance and effectiveness	I can easily distinguish between visited and not-visited links.	0.59	Moderate	Moderate (0.58)
	I can access this website most of the time.	0.59	Moderate	
	This website responds to my actions as expected.	0.59	Moderate	
	It is efficient to use this website.	0.59	Moderate	
	This website always provides clear and useful messages when I don't know how to proceed.	0.53	Moderate	
	I need not wait too long to download a file or open a page.	0.58	Moderate	

From table 3, it is known that the usability level for three categories, which are content, organization and readability; navigation and links; as well as performance and effectiveness are moderate with each usability point respectively are 0.60, 0.59, and 0.58. Meanwhile the usability level for user interface category is good (0.64). For content, organization and readability category, the usability criteria that has the lowest point is "I can easily find what I want in this website" (0.55). The lowest usability point for navigation and links category is for "Placement of links or menu is standard throughout the website and I can easily recognize them" (0.48). For user interface category, the lowest usability point is 0.52 for criteria: "This website's interface design is attractive." For the last category, performance and effectiveness, the criteria that has the lowest

point is “This website always provides clear and useful messages when I don’t know how to proceed.” Based on the above result, none of the four categories have excellent usability level (usability point > 0.8). Therefore improvement is needed to increase the usability point for each category.

### 3.2 Analysis of experiment’s result

Based on the result of WEBUSE questionnaire, 6 tasks are developed to be included in the experiment. All tasks represent the functions which are often used by student when they access the library website. The six tasks are as follows:

1. Find out the information regarding the operational time of the UPH Central Library.  
(Category: navigation and links; criteria: “This website provides useful cues and links for me to get the desired information”)
2. Download an article that has been determined from a specified journal.  
(Category: performance and effectiveness; criteria: ”This website responds to my actions as expected.”)
3. Search for the information regarding the number of room types provided in the library, then go back to the front page and find out the title of book of the month.  
(Category: navigation and links; criteria:” I can easily know where I am at this website.”)
4. Search for and record the status of a book, including call number, published year, and loan status.  
(Category: performance and effectiveness; criteria:” This website always provides clear and useful messages when I don’t know how to proceed.”)
5. Find out the information regarding the total amount of borrowed books and loan duration for undergraduate student  
(Category: content, organization and readability; criteria:” Reading content at this website is easy.”)
6. Search for the main steps required to top-up smart card in order to pay the loan penalty  
(Category: content, organization, and readability; criteria:” I can easily find what I want at this website.”)

The time allocated for completing each task is 3 minutes, based on the previous experiment conducted by Augustine and Greene [5].

In this experiment, there are 3 parameters to be measured, which are the number of task correctly done, time of completion, and the number of clicks needed. According to Nielsen [6], usability test with at least 15 users is needed to discover all the usability problems in the design. The chosen respondents are 20 undergraduate students (5<sup>th</sup> and 7<sup>th</sup> semester) from Industrial Engineering Department. The completion time is measured in second. The number of clicks is observed through CamStudio software.

Based on ISO 9241-11:1998 [7], there are three aspects to be measured in usability testing, which are: effectiveness, efficiency, and satisfaction. In this experiments two aspects are chosen, which are: effectiveness and efficiency.

#### 3.2.1 Effectiveness aspect

In this experiment, effectiveness is measured by giving score for each correct answer (accuracy and completeness). The maximum score for all six tasks is 100, so each correctly answered task is given 16.67 point. From all of the respondents, none has got 100 points. The minimum score is 16.67 (only 1 correct answer) and the maximum score is 83.33. The average score is 51.67 with standard deviation of 17.85. This result shows that the effectiveness of UPH library website is quite low. The number of respondents (in percent) who have completed the task correctly is shown in table 4.

*Table 4: The number of respondents (%) who have completed the task correctly*

Task no.	% respondents that answer correctly
1	95%
2	25%
3	60%
4	30%
5	85%
6	15%

From table 4, it is known that three tasks (number 6, 2 and 4) have very low percentage of correct answers. Based on the observation during the experiment, there are some usability problems faced by the respondents when they tried to do those tasks, as follows:

1. For task number 6 (how to top-up smart card):
  - The location of information regarding top-up smart card is on the bottom side of the home page.
  - The term used in the library website is “cash-card”, whereas students are more familiar with the term “smart-card”
  - Search engine is not functioning well.
2. For task number 2 (download a journal article):
  - There are two sub-menus under the menu “resources”, which are: e-resources and periodicals. E-Resources consist of digital library, online database (for e-journal) and recommended links. Meanwhile the sub-menu periodicals consist of journal (for local and UPH published journal only) and magazine. The term “journal” used only for local and UPH published journal lead to ambiguity.

- The usage of patron barcode as login password to access e-journal. Students are not familiar with their own patron barcodes and the option for getting the password through phone is not practical (see figure 1).

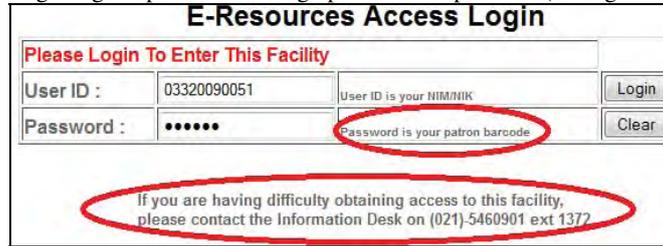


Figure 1: E-Resources Access Login

3. For task number 3 (record for the status of a book):

- Menu “search” at the top right corner of the home page is not functioning.
- The keyword used for searching menu UPH catalog is less sensitive. For example: if the student types the first word of the book title “Goldratt’s”, the result is “sorry no match found.” The result will be different if he types” Goldratt” as the keyword for title.
- Menu “search by subject” is not functioning.

### 3.2.2 Efficiency aspect

In this experiment, efficiency is measured by recording the completion time and the number of clicks required for completing the task. The result of average time as well as expert time for completing each task correctly is shown in figure 2. Expert time is the minimum time needed by the researcher (the person who creates the task) to complete the task.

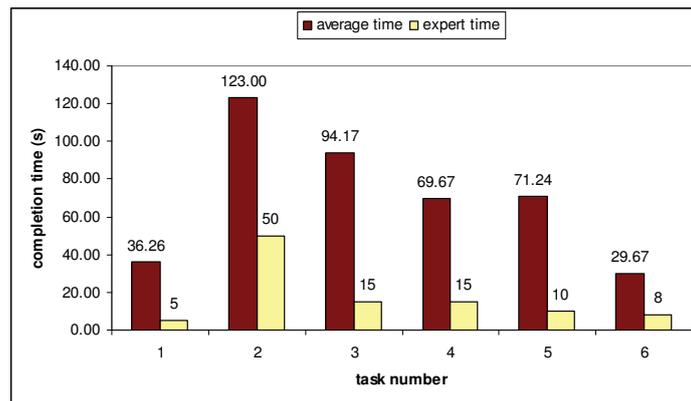


Figure 2: Completion time for each task

According to figure 2, it is known that the average completion time is significantly longer than expert time. The ratio of average time to expert time is about 5: 1. Another measurement for efficiency aspect is the number of clicks required to complete the task. The comparison between the average click and the expert click can be seen in figure 3.

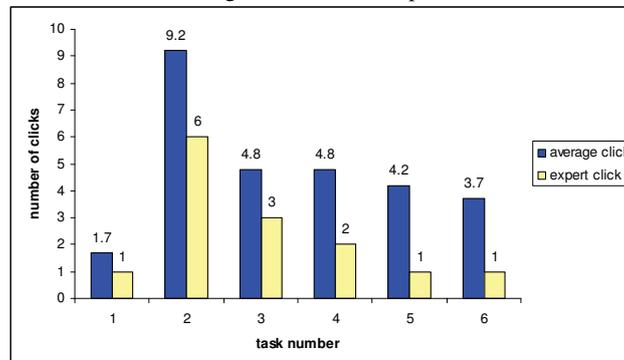


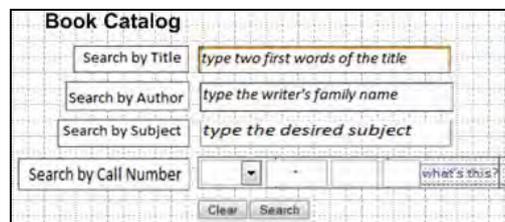
Figure 3: Number of clicks required to complete the task

Figure 3 shows that the largest amount of clicks is for completing task number 2. If figure 3 is compared with the previous one (figure 2), they will show similar trend. It means that the results are consistent. The more the number of clicks it takes, the longer the time of its completion. Based on figure 3, it is also known that there are significant differences between average click and the expert click. The average number of clicks required by the respondents to complete the task is about 2-3 times more than the expert clicks. Both results show that the UPH library website is less efficient.

### 3.3 Suggested improvements

Based on all the problems faced during the experiment, here are some suggestions for improvement:

1. Put the important information such as “how to top-up smart card” on the *navigation bar*. It is better to use more familiar term, such as “smart-card” rather than unfamiliar one (“cash-card”).
2. Make the search engine available on the library website properly functioned. Students usually try to find any information by using search engine.
3. Do not use ambiguous term, such as “journal” for local published journal only, since the published international journal is called “journal” as well. It is better to use the term “periodicals” for all paper- based journals, to differentiate them from e-journal (electronic journal).
4. If possible, use more familiar password for accessing the e-resources (such as: birth date) instead of patron barcode. If it is not possible to use another password, provide any other means for obtaining the password, for example through e-mail.
5. Add some hints to use the catalog search. An example of catalog search hints can be seen in figure 4. Besides adding hints, make sure that all the search option is functioning properly.



The image shows a search interface titled "Book Catalog". It features four search options, each with a text input field and a hint: "Search by Title" with the hint "type two first words of the title", "Search by Author" with the hint "type the writer's family name", "Search by Subject" with the hint "type the desired subject", and "Search by Call Number" with a dropdown menu and a "what's this?" link. At the bottom, there are "Clear" and "Search" buttons.

Figure 4: An example of catalog search hints

## 4. CONCLUSION

Based on the results of processing the WEBUSE questionnaires for 234 respondents, it is known that the usability level of UPH library website for category: content, organization and readability (0.60); Navigation and links (0.59); as well as Performance and Effectiveness (0.58) is moderate. For user interface category, UPH library website is assessed to have good usability level (0.640). Experiments are carried out to determine the usability problems directly, by observing 20 respondents completed six tasks using UPH library website. Based on the experimental results, it is known that the respondents are still facing difficulties to use some features available on the UPH library website. This can be known from the low effectiveness of UPH library website, since the average task score is 51.67 out of 100. The experiment results also showed that the average completion time is 5 times longer than the expert time and the average number of clicks required is 2-3 times more than the expert click. These measurements indicate that some functions in UPH library website have low efficiency. Some of the problems found are the search function that does not work, the location for important information is on the bottom side and there are some uncommon names of menus or less likely to represent the content.

## REFERENCES

- [1] D. Jumeno and D.H. Putri. "Analisis Usability Website Universitas Andalas." *National Conference on Applied Ergonomics*, 2010, pp. 245-250
- [2] C.B. Nawangpalupi, "Evaluasi Web Usability dalam Penilaian Efektivitas dan Efisiensi Akses Informasi Situs Car Sharing." *National Conference on Applied Ergonomics*, 2010, pp. 233-238M.
- [3] T.K. Chiew and S.S. Salim. "WEBUSE: Website Usability Evaluation Tool." *Malaysian Journal of Computer Science* Vol. 16 No. 1 (June 2003): pp. 47-57.
- [4] Q.A. Al-Radaideh, E. Abu-Shanab, S. Hamam, and H. Abu-Salem "Usability Evaluation of Online News Websites: A User Perspective Approach." *International Journal of human and Social Sciences* 6:2 (2011): 114-122
- [5] S. Augustine and C. Greene. "Discovering How Students Search a Library Web Site: A Usability Case Study." *College & Research Libraries* (2002): pp.354-365
- [6] J. Nielsen 2000. "Why You Only Need to Test with 5 Users." *Useit Online*. Home page on-line. Available from [www.useit.com/alertbox/20000319](http://www.useit.com/alertbox/20000319); Internet accessed on 14 November 2011.
- [7] International Organization for Standardization "ISO 9241-11: Ergonomic Requirements for Office Work with Visual Display Terminal (VDTs)-Part 11: Guidance on Usability", Geneve: ISO, 1998.

# Neuro Strategy, Industrial and Systems Engineering: Malcolm Baldrige Criteria toward Performance Excellence, Innovation and Sustainability Perspectives

**Khristian Edi Nugroho Soebandrija**

*Industrial Engineering Department, Faculty of Engineering  
 Kampus Syahdan, Jl. K.H. Syahdan No. 9, Palmerah, Jakarta Barat  
 Bina Nusantara University, Jakarta 11480  
 Tel : (021) 5345830. Fax : (021) 5300244  
 E-mail : Knugroho@binus.edu and KhristianEdi@yahoo.com*

## ABSTRACT

As Introduction, Brain research has reached and contributed to Engineering, and Social Sciences in term of Strategic Management. This paper limits its research discussion in term of i. Neuro Strategy, and ii. Industrial and Systems Engineering for enhancement of Human Life and Environment. Furthermore, as Problem, there is the need to balance between the Systems and the Human Consideration, specially form Neuro Strategy. Then, as methodology through Malcolm Baldrige Criteria and Strategic Choice, this paper relates the concept, theoretical aspects and managerial implications of Neuro Strategy, Industrial and Systems Engineering that refers to Malcolm Baldrige Criteria 2011-2012 toward Performance Excellence, Innovation and Sustainability Perspectives. As the Result of analysis and calculation of equations, this paper emphasize on the importance of Sustainability, and refer to the Future Research of Decision Making Implementation through Neuro Strategy. In term of Neuro Strategy, Powel, T.C (2011) in his paper examines the potential fit pertaining between Neuro Strategy in term of Neuroscience and Strategic Management. Both executive judgment and decision making are indispensable to i. Proceed to Performance Excellence, Innovation and Sustainability; ii. Revisit Psychological foundations of dynamic capabilities, Hodgkinson and Healey (2011), iii. Elaborate Unit of Analysis according to Rumelt, Schendel, and Teece, 1994 as scholars in term of the question in strategic management whether processes within the individual brain can really inform research that take the firm and industry as its primary unity of analysis. In term of Systems Engineering, the paper of Smartt and Ferreira (2011) indicated that The strategic application of systems engineering can lead to sustained competitive advantage for an organization.

### Keywords

*Neuro Strategy, Industrial and Systems Engineering, Malcolm Baldrige, Performance Excellence*

### 1. INTRODUCTION

The philosophy of Strategy can be related to the Brain Research. Furthermore, it is indispensable to relate Psychological Foundations of Strategic Management toward the mentioned Brain Research. Brain research has reached and contributed to Engineering, and Social Sciences in term of Strategic Management. This paper limits its research discussion in term of i. Neuro Strategy, and ii. Industrial and Systems Engineering for enhancement of Human Life and Environment. This paper relates the concept, theoretical aspects and managerial implications of Neuro Strategy (NS), Industrial and Systems Engineering (ISyE) that eventually refers to Malcolm Baldrige Criteria 2011-2012 (MBC 2011-2012) toward Performance Excellence (PE), Innovation (INNO) and Sustainability (SUST) Perspectives, that is abbreviated as Performance-Innovation-Sustainability (PIS).

NS and ISyE constitutes the building block for MBC and its PIS. First, In term of NS, Other than MBC and its PIS, The highlighted discussion refers to the Decision Making and Approximate Decision Programming to make better Decision Making, according to Powell, W. B. (2009, p.239) as relate to available approaches using Operations Research solving the a. Simulation Optimization, b. Rolling Horizon Procedures, and c. Dynamic programming. The focus on this paper pertaining the Decision Making and Approximate Decision Programming (ADP). In term of Dynamic Programming, the equation (1) refers to the Markov Decision Processes using standard form of Bellman's Equation of

$$V_t(S_t) = \max_{x_t} \left( C(S_t, x_t) + \gamma \sum_{s' \in S} p(s'|S_t, x_t) V_{t+1}(s') \right) \quad (1)$$

and Equation (2) of its expectation form of Bellman's Equation of

$$V_t(s) = \max_{x_t} (C(S_t, x_t) + \gamma \mathbb{E}\{V_{t+1}(S_{t+1}) | S_t = s\}) \quad (2)$$

, where where  $S_{t+1} = SM(S_t, x_t, W_{t+1})$ , and the expectation is over the random variable  $W_{t+1}$ .  $V_t(S_t)$  is the value function (in control theory this is represented by  $J$  and is called the cost-to-go function) which gives the expected value of being in state  $S_t$  at time  $t$  and following an optimal policy forward, according to Powell, W.B (2009, p. 240). Second, In term of ISyE, Other than MBC and its PIS, The highlighted discussion refers to discussion of Industrial and Systems Engineering and Its Analysis by Blanchard and Fabrycky (2011) and General Framework for Systems Engineering Strategy by Smartt and Ferreira (2011).

## 2. LITERATURE REVIEW

### Neuro Strategy

In term of Neuro Strategy, Powell, T.C (2011) in his paper examines the potential fit pertaining between Neuro Strategy in term of Neuroscience and Strategic Management. The mentioned Strategy Management is about the strategic management interest in executive judgment and decision making and in the psychological foundations of strategy practice according to Hodgkinson and Healey (2011). Both executive judgment and decision making are indispensable to i. Proceed to Performance Excellence, Innovation and Sustainability; ii. Revisit Psychological foundations of dynamic capabilities, Hodgkinson and Healey (2011), iii. Elaborate Unit of Analysis according to Rumelt, Schendel, and Teece, 1994 as scholars in term of the question in strategic management whether processes within the individual brain can really inform research that take the firm and industry as its primary unity of analysis.

### Industrial and Systems Engineering

In term of Systems Engineering, the paper of Smartt(2011) indicated that The strategic application of systems engineering can lead to sustained competitive advantage for an organization. Furthermore Smartt and Ferreira (2011) refers to the framework that defines a state-based model for systems engineering strategy. States are grouped by organization, environment, product or service, and systems engineering process characteristics. These characteristics provide an extensive set of considerations for making a strategic decision related to systems engineering. Smartt and Ferreira (2011) explicitly mentions that decision makers are able to apply the framework to make more informed choices that ultimately will lead to an organization's long-term survival, which is known in this paper as Sustainability.

## 3. METHODOLOGY

Several steps of the Methodology in this paper comprises the 1. Clarifying the Research Questions; 2. Research Design Strategy ( Data Collection Design and Sampling Design); 3. Data Analysis and Interpretation, 4. Research Findings and 5. Decision. Methodology and Discussion through several steps in this paper emphasize on generalized concept and scope of the problem, this paper has research questions toward the Antecedent, Behavior and Consequences of all discussion about Neuro Strategy, Industrial and Systems Engineering, Performance Excellence, Innovation and Sustainability. As scope of objectives, this Methodology and Discussion in this paper emphasize on generalized concept of Neuro Strategy, Industrial and Systems Engineering to support the Malcolm Baldrige Criteria 2011-2012 to reach the goals. The mentioned goals refer to the Performance Excellence, Innovation and Sustainability Perspectives of its unit of analysis. In this paper, Confirmatory Factor Analysis (CFA) was utilized to investigate constructs' reliability and validity, while Structural Equation Modeling (SEM) were utilize to examine relationship among constructs that relate the effect of Neuro Strategy, Industrial and Systems Engineering. Second, the mentioned effect refers to the Malcolm Baldrige Criteria toward Performance, Innovation and Sustainability.

## 4. DISCUSSION AND ANALYSIS

### Neuro Strategy

In term of Neuro Strategy, Powell, T.C (2011) in his paper examines the potential fit pertaining between Neuro Strategy in term of Neuroscience and Strategic Management. The mentioned Strategy Management is about the strategic management interest in executive judgment and decision making and in the psychological foundations of strategy practice according to Hodgkinson and Healey (2011). Brain research has reached and contributed to Engineering, and Social Sciences in term of Strategic Management. It is indispensable to relate Psychological Foundations of Strategic Management toward the mentioned Brain Research and the following Dynamic Capabilities in Table 1.

### Industrial and Systems Engineering

In term of Systems Engineering, the paper of Smartt and Ferreira (2011) indicated that The strategic application of systems engineering can lead to sustained competitive advantage for an organization. In Figure 1, Smartt and Ferreira (2011) refers to the framework that defines a state-based model for systems engineering strategy. Subsequently, various references enriched the mentioned Smartt's Framework in Table2, pertaining the Systems Engineering Process Characteristics.

Table 1: Psychological Foundations of Dynamic Capabilities Revisited

Capability	Extant psychological foundations	Indicative supporting literature(s)†	Revised psychological foundations	Indicative supporting literature(s)
<b>Sensing and shaping</b>	Opportunity discovery and creation originate from the cognitive and creative ('right brain') capacities of individuals, requiring access to information and the ability to recognize, sense, and shape developments	Entrepreneurship literature; organizational search (e.g., March and Simon, 1958; Nelson and Winter, 1982)	Identifying and creating opportunities through searching, synthesizing, and filtering information stems from the interaction between reflexive (e.g., intuition, implicit association) and reflective (e.g., explicit reasoning) cognitive and emotional capabilities	Social cognitive neuroscience research on the interaction between reflexive and reflective systems (Lieberman, 2007)
	Recognizing, scanning, and shaping depend on individuals' cognitive capabilities and extant knowledge	Knowledge-based view of the firm (e.g., Grant, 1996); organizational learning (e.g., Levinthal and March, 1993)	Recognizing, scanning, and shaping depend on the capability to harness emotion to update mental representations (e.g., dissonance recognition) and skilled utilization of intuitive processes to synthesize information and form expert judgments	Cognition and capabilities literature (Gavetti, 2005); affective processes in learning (Lieberman, 2000)
<b>Seizing</b>	Seizing innovative investment choices requires managers to override 'dysfunctions of decision making'	Classical behavioral decision theory (e.g., Kahneman and Tversky, 1979)	Seizing opportunities requires the fostering of appropriate emotional reactions to new directions	Neuroeconomics: immediate emotions shape choice (Loewenstein <i>et al.</i> , 2008)
	Overcoming biases requires a cognitively sophisticated and disciplined approach to decision making	Classical behavioral decision theory (e.g., Kahneman and Tversky, 1979)	Cognitively effortful processes can exacerbate bias—alleviating bias and inertia requires both cognitive and emotional capabilities	Self-regulation (e.g., Ochsner <i>et al.</i> , 2002) and affective routes to de-escalation of commitment (e.g., Sivanathan <i>et al.</i> , 2008)
<b>Reconfiguring</b>	Top management ability to coordinate and execute strategic renewal and corporate change	Organizational structure and design and strategy and performance literatures (e.g., Bartlett and Ghoshal, 1993; Chandler, 1962)	Reconfiguration requires management of the transition and repeated redefinition of social identities by alleviating implicit bias and self-regulating emotional responses to identity threats caused by major change	Research on the neural basis of self and social identity processes (e.g., Derks <i>et al.</i> , 2008)

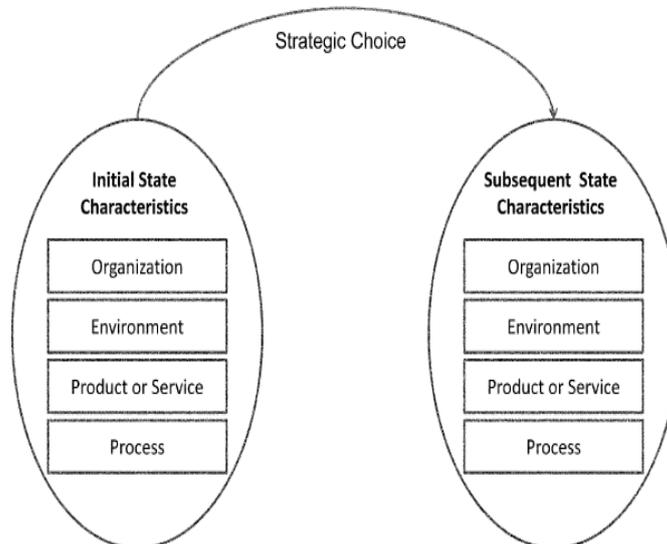


Figure 1: Overview of Framework for Systems Engineering Strategy

Table 2: Systems Engineering Process Characteristic

Characteristic	Definition	Sources
Level of quantification in control	The degree to which quantitative schemes are employed to monitor performance and exert control over a particular systems engineering process.	[Boehm and Turner, 2004]
Level of documentation generated	Overall level of documentation generated related to a specific systems engineering process.	[Agile Manifesto, 2001]
Portion of process completed	Portion of a specific systems engineering process completed before subsequent processes can begin. For example, how much of the architecture definition must be completed before developers begin writing software or creating hardware?	[Boehm and Turner, 2004]
Maturity of process	The maturity of a particular process that is being applied.	
Level of usage of information technology	Degree to which an organization utilizes information technology (databases, formal requirements management tools, formal system architecture tools, etc.) in support of a specific systems engineering process in engineering a system or service.	[Hansen et al., 1999]
Formalization of policies and procedures	Degree to which policies and procedures are formalized for a specific systems engineering process within the organization.	[Lai and Guynes, 1997]

**Malcolm Baldrige and Performance Excellence**

Generalized concepts of Malcolm Baldrige and its seven criteria, in Figure 2, are referring to three pillars in Business, Health Care and Higher Education. Furthermore, posterior to the mentioned generalized concept, specifically the result of this paper conveys discussion on the Malcolm Baldrige Criteria for Business that generates beneficial aspects for theoretical development and managerial implication in Indonesia. Data collection pertaining Company’s Malcolm Baldrige Criteria and its Performance Excellence, is conducted using both Primary and Secondary Method. For Primary Method, the interview process is conducted, along with the survey that relate to the Management of The Company. For Secondary Method, the analysis is referring to the Annual Report from the listed company in Jakarta Stock Exchange ( www.idx.co.id ). Other information is originated from the Indonesian Quality Award Foundation ( IQA ) www.indonesianqualityaward.org that since 2006 has conducted and provided the Indonesian Quality Award.



Figure 2: Malcolm Baldrige 2011 – 2012 Criteria

**Innovation and Sustainability Perspectives**

Prahalad, Nidumolu and Rangaswami (2009) raise question and discuss why sustainability is now the key driver of innovation.

The same question and discussion constitute the ground for this paper, incorporating the Innovation and Sustainability, with the holistic discussion of NS and ISyE toward MBC and its PIS. The further focus of discussion refers to Decision Making and Approximate Dynamic Programming.

### Decision Making and Approximate Dynamic Programming

Decision making constitutes important elements in the discussion of this paper, as previously the discussion refers to NS and ISyE that are related to the MBC and its PIS. Precisely, in term of Strategic Choice in Figure 1, as refer to the Innovation and Sustainability. In term of that Strategic Choice; It is deemed indispensable to be aware of the Initial State Characteristics prior to move forward to Subsequent State Characteristics that require careful assessment in term of Decision Making and its Systems Engineering Process Characteristics, as illustrated in Table 2. Malcolm Baldrige and Performance Excellence are deemed as holistic approach as this MB and PE, not only refer to the Results but also refer and carefully assess the Process that lead to the intended Results. The state does not stop to any result, but also proceed subsequent level that lead to the Innovation and Sustainability.

Prior Equations (1) and (2) respectively constitute the baseline for further discussion on the Decision Making. The first equation refers the Markov Decision Processes using standard form of Bellman's Equation and the latter equation refers expectation form of Bellman's Equation. Both Equations are beneficial to tackle Decision Making that involves Uncertainty. Powell, W.B (2009, p. 239) indicates that there is a wide range of problems that involve making decisions over time, usually in the presence of different forms of Uncertainty. By Analogy in operations research, the consideration is that system as being in a state  $S_t$ , from which take an action  $x_t$  and observation of new information  $W_{t+1}$  lead to a new state  $S_{t+1}$ . The Policy Representation for making a decision is using the function  $X^\pi(S_t)$ . The assumption is that there is a transition function  $S^M$ , known as the "system model" or merely "model" which describes how a system evolves from  $S_t$  to  $S_{t+1}$ . Powell, W.B (2009, p. 239) mentioned that The dynamics of problem can then be described using

$$x_t = X^\pi(S_t), \tag{3}$$

$$S_{t+1} = S^M(S_t, x_t, W_{t+1}). \tag{4}$$

Powell, W.B (2009, p. 239) assumes that there is a choice of decision functions  $X^\pi$  where  $\pi \in \Pi$  designates a particular function or policy and use decision function and policy interchangeably. Posterior to making a decision  $x_t$ , it is assumed cost is given by  $C(S_t, x_t)$  which usually depends on the state. Several contribution about  $W_{t+1}$ , in which case it would be written  $C(S_t, x_t, W_{t+1})$ . The ultimate goal is to find the best policy  $\pi \in \Pi$  that solves

$$\sup_{\pi \in \Pi} \mathbb{E} \sum_{t=0}^T \gamma^t C(S_t, x_t) \tag{5}$$

where  $\gamma$  is a discount factor. The form of an expectation is needed, because the information variable  $W_t$  is random, at times before time  $t$ .

Further elaboration in term of theoretical approach and managerial implication on Decision Making pertaining Approximate Dynamic Programming (ADP) approximate dynamic programming (ADP). Powell, W.B (2009, p. 240) refer to the available references in form of book that are represented by three dedicated topics. First, *Neuro-Dynamic Programming* is a primarily theoretical treatment of the field using the language of control theory; Second, *Reinforcement Learning* describes the field from the perspective of artificial intelligence/computer science; and Third, *Approximate Dynamic Programming* uses the language of operations research, emphasizing on the high dimensional problems that typically characterize the problems in this community. Judd (1989) provides a nice discussion of approximations for continuous dynamic programming problems that arise in economics, and Haykin is an in-depth treatment of neural networks, with a chapter devoted to their use in dynamic programming.

### 5. CONCLUSION

The philosophy of Strategy can be related to the Brain Research. Furthermore, it is indispensable to relate Psychological Foundations of Strategic Management toward the mentioned Brain Research. Brain research has reached and contributed to Engineering, and Social Sciences in term of Strategic Management. This paper limits its research discussion in term of i. Neuro

Strategy, and ii. Industrial and Systems Engineering for enhancement of Human Life and Environment. This paper relates the concept, theoretical aspects and managerial implications of Neuro Strategy (NS), Industrial and Systems Engineering (ISyE) that eventually refers to Malcolm Baldrige Criteria 2011-2012 (MBC 2011-2012) toward Performance Excellence (PE), Innovation (INNO) and Sustainability (SUST) Perspectives, that is abbreviated as Performance-Innovation-Sustainability (PIS).

In term of NS and ISyE, further discussion pertaining Decision Making need to be elaborated toward Decision Making Uncertainty and Decision Making Biases. The first, has been discussed by Powell, W.B (2009, p. 239) as relate to the Approximate Dynamic Programming. The latter, has been discussed by Smith and Bahill (2009, p. 130 ) pertaining attributes substitution in Systems Engineering. Furthermore Smith and Bahill (2009, p. 130) mentioned that Cognitive biases affect decision making in systems engineering (SE). Daniel Kahneman, 2002 Nobel laureate for his pioneering studies of cognitive biases in economic decision making, describes many disparate cognitive biases as abstractly belonging to one higher-level bias, that of attribute substitution.

Other than NS and ISyE, as relate to PIS and other than Decision Making Uncertainty and Decision Making Biases; it is indispensable to highlight the discussion on Sustainability. According to Smith and Bahill (2009, p. 136) Sustainability refers to the potential for a system to be supported materially and technologically over an extended period of time. Yet, in this paper the Sustainability need to be viewed in wider thinking, across the Systems Engineering and include all aspects of Cognitive Thinking in NS and ISyE that relate to Strategic Management.

As Future Research, Prior to have Sustainability, It is indispensable to consider the Decision Making Implementation. Not many existed paper discussed this Implementation, along with the NS and ISyE that relate to PIS and eventually Strategic Management. Thus, It is indispensable to elaborate in more thorough discussion and consideration this aspect of Implementation. Yet, it is important to differentiate the implementation in Neuroscience in experiments versus in firms, according to Powell, T.C (2011, p.1498). Precisely, Powell indicated that In Neuroscience experiments, the choices are often difficult, but implementation is trivial; In firms, implementation is usually more difficult than decision making, requiring motivation, resource mobilization, and major project implementation. Strategic decisions are often implemented partially, unsuccessfully, or not at all.

## REFERENCES

- [1] Powell, T.C (2011). Neurostrategy. *Strategic Management Journal*. Vol. 32. No. 13 p. 1484-1499.
- [2] Hodgkinson and Healey , G.P and Healey, M.P (2011). Psychological Foundations of Dynamic Capabilities: Reflexion and Reflection in Strategic Management. *Strategic Management Journal*. Vol. 32. No. 13 p. 1500-1516.
- [3] Smartt, C., Ferreira, S. (2011). Constructing a General Framework for Systems Engineering Strategy. *Systems Engineering* Vol. 15, No. 2 p. 140-152.
- [4] Powell, W.B (2009). What You Should Know About Approximate Dynamic Programming. Wiley Periodical Inc.
- [5] Blanchard, B.S and Fabrycky, W.J (2011). *Systems Engineering and Analysis*. 5<sup>th</sup> Edition. New Jersey. Prentice Hall International Series in Industrial and Systems Engineering.
- [6] Lieberman, M.D (2007). Social cognitive neuroscience: a review of core processes. *Annual Review of Psychology* Vol. 58, p. 259–289
- [7] Gavetti G, Levinthal DA, Rivkin JW (2005). Strategy making in novel and complex worlds: the power of analogy. *Strategic Management Journal* Vol. 26, No. 8, p.691–712.
- [8] Lieberman, M.D ( 2000). Intuition: a social cognitive neuroscience approach. *Psychological Bulletin* Vol. 126, No.1, p.109–137
- [9] Loewenstein G, Rick S, Cohen JD. (2008). Neuroeconomics. *Annual Review of Psychology* Vol. 59, p. 647–672.
- [10] Ochsner KN, Bunge SA, Gross JJ, Gabrieli JDE. (2002) Rethinking feelings: an fMRI study of the cognitive regulation of emotion. *Journal of Cognitive Neuroscience* Vol. 14, No.8, p. 1215–1229.
- [11] Sivanathan N, Molden DC, Galinsky AD, Ku G. (2008) The promise and peril of self-affirmation in deescalation of commitment. *Organizational Behavior and Human Decision Processes* Vol. 107, No.1, p. 1–14.
- [12] Derks B, Inzlicht M, Kang S. (2008). *The neuroscience of stigma and stereotype threat*. *Group Processes and Intergroup Relations* Vol. 11, No.2, p. 163–181
- [13] Boehm, B., and Turner, R. (2004) *Balancing strength and agility*, Pearson Education, Boston, MA.
- [14] Agile Manifesto (2001). Agile Manifesto, <http://agilemanifesto.org/>
- [15] Hansen et al (1999) M.T. Hansen, N. Nohria and T. Tierney, What’s your strategy for managing knowledge? *Harvard Bus Rev* 77, 2, p. 106–116.
- [16] Lai, V.S and Guynes, J.L (1997) An assessment of the influence of organizational characteristics on information technology adoption decision: A discriminative approach, *IEEE Trans Eng Management*, Vol.44, No.2, p. 146–157
- [17] Prahalad, C.K, Nidumolu, R. and Rangaswami, M.R (2009). Why Sustainability is Now the Key Driver of Innovation. *Harvard Business Review*.
- [18] Judd, K. (1989) *Numerical methods in economics*, MIT Press, Cambridge
- [19] Smith, E.D and Bahill, A.T (2009). Attribute Substitution in Systems Engineering. *Systems Engineering* Vol. 13, No. 2, p. 130-148.
- [20] Kahneman, D. and Frederick, S (2002) Representativeness revisited: Attribute substitution in intuitive judgment,” *Heuristics and biases*, Cambridge University Press, New York, p. 49–81.
- [21] [www.idx.co.id](http://www.idx.co.id) accessed on 10th September 2012
- [22] [www.indonesianqualityaward.org](http://www.indonesianqualityaward.org) accessed on 15th September 2012

## Defining Comprehensive Ergonomics in Engineering Design and Construction Processes

Sudajeng, L.<sup>a</sup>, Kristinayanti, W.S.<sup>b</sup>, Oesman, T. I.<sup>c</sup>

<sup>a</sup> Civil Engineering Department  
Bali State Polytechnic, Kuta Utara Badung Bali 80363  
Tel : (0361) 701981. Fax : (0361) 701128  
E-mail : diajenglik@yahoo.com

<sup>b</sup> Civil Engineering Department  
Bali State Polytechnic, Kuta Utara Badung Bali 80363  
Tel : (0361) 701981. Fax : (0361) 701128  
E-mail : yantie\_5977@yahoo.com

<sup>c</sup> Faculty of Industrial Engineering  
University of AKPRIND, Yogyakarta 55222  
Tel : (074)563029. Fax : (074)563847  
E-mail : ti\_oesman@yahoo.com

### ABSTRACT

*Ergonomics interest is more focuses on the human quality of life; therefore, it is very important to apply it in any kind activities, included in production process. But unfortunately, industries put on ergonomics mostly for product design or the product user only and forgot about the designer or the workers during the engineering design and construction processes. The main objective of this paper is to define how important is comprehensive ergonomics for all workers during engineering design and construction process. The proposed framework and data processing approach comprised of three major stages: 1) literature gathering and screening (textbooks, articles-journals, and the previous researches), 2) data analyzing, and 3) writing the literature review by providing an arguments. Data analyzing divided into four main aspects: a) workers characters (age, gender, and fitness), b) task (work load, man-machine interaction, and work station), c) physical environment (microclimate, noise, dust, vibrator, and lighting), and d) organization (work-rest schedule, nutrition, and information system), both for design and construction process. Result showed that for engineering design process, the ergonomics problems are mostly about work station especially human computer interface, lighting, work-rest schedule, nutrition, and working behavior. Furthermore, the most problem for construction process are physical work load, man-machine interaction, working posture, physical environment (heat stress, noise, vibrator, and dust), and work-rest schedule. This paper provides the basic ergonomics concept that should be considered in design and construction processes to protect the workers from ergonomics hazards, especially in the developing countries where ergonomics has not well known yet, such as Indonesia. It is also emphasize that applying ergonomics could provide safety, healthy, comfort, efficient and productive work condition that finally increase the welfare and quality of life, both for the workers and management.*

Keywords: *Comprehensive ergonomics, design, construction, processes.*

### 1. INTRODUCTION

Nowadays, Industry becomes the most important sector of economy in the world. Many strategic plans were obtain and all efforts were focused to support this sector. High technology has been imported and applied to meets it goal, but unfortunately, the consideration in building the program, including the system, mostly about economics and technology only, and less consideration about human factors or ergonomics point of view, especially in developing countries such as Indonesia. However, it has become more and more popular. Many products have been designed with ergonomics consideration, but industries put on ergonomics mostly for product design or the product user only and forgot about the designer or the workers during the design and construction processes.

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well being and overall system [1]. It means that ergonomics interest is more focuses on all aspect of human activities. Furthermore, Marras and Allread [2] reported that application of ergonomics in an occupational environment can have a positive impact on the safety and health experience of the facility, the production process, as well as the quality of the product or process engaged in. Therefore, it is very important to apply ergonomics in any kind activities, included in

engineering design and production processes. The main objective of this paper is to define how important is comprehensive ergonomics for all workers during engineering design and construction process.

## **2. THEORETICAL BACKGROUND**

### **2.1 Domain of Ergonomics**

The International Ergonomics Association (IEA) council describes the domain of ergonomics including physical, cognitive, and organization ergonomics [1].

#### **2.1.1 Physical Ergonomics**

Physical ergonomics is concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they relate to physical activity. The relevant topics include working postures, materials handling, repetitive movements, work-related musculoskeletal disorders, workplace lay out, safety and health.

#### **2.1.2 Cognitive Ergonomics**

Cognitive ergonomics is concerned with mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system. The relevant topics include mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system design.

#### **2.1.3 Organizational Ergonomics**

Organizational ergonomics is concerned with the optimization of socio-technical systems, including their organizational structures, policies, and processes. The relevant topics include communication, crew resource management, and work-design, design of working times, teamwork, participatory design, community ergonomics, cooperative work, new work paradigms, organizational culture, virtual organizations, tele work, and quality management.

### **2.2 Total Ergonomics Approach**

Total Ergonomics approach which is consists of SHIP approach (Systemic, Holistic, Interdisciplinary, and Participatory) and applies appropriate technology promotes the whole disciplines, opens participation, respects and gathers the new technology systematically and holistically with long-term gains and sustainable development [3][4]. A Systemic means that the plan should be analyzed through a system. Holistic means that every team works always interrelates with other team works, so it is analyzed through existence system and non- system holistically. Interdisciplinary means that analyzes should be utilized with all related and significant disciplines as tools; Participatory means that all relevant and significant parties take apart on it [5] [6]. The main goal of total ergonomics approach is to attain human and sustainable work system [7] [8].

There are four aspects that should be considered in ergonomics observation, evaluation, and problem analyses: 1) subject characters, including age, gender, fitness, and experience; 2) Task, including work load, man-machine interaction, and work station; 3) physical environment, including microclimate, noise, dust, vibrator, and lighting; and 4) organization, including work-rest schedule, nutrition, and information system.

### **2.3 Engineering Design and Construction Process**

It is important to recognize the close relationship between design and construction as an integrated system. Design is a process of creating the description of a new facility, usually represented by detailed plans and specifications, while construction is a process of identifying activities and resources required to make the design a physical reality or the implementation of a design envisioned by architects and engineers. Ertas and Jones describe the engineering design process as a multi-step process including the research, conceptualization, feasibility assessment, establishing design requirements, preliminary design, detailed design, production planning and tool design, and finally production [9].

Based on the theoretical background, the design and construction processes could be described as Figure 2. For engineering design process which is consist of basic concept, two and three dimension visualizes, the ergonomics consideration is more focuses on cognitive and organizational, while for construction process, it is more focuses on physical and organizational process. In engineering design process, the ergonomics problems are mostly about mental workload, decision-making, skilled performance, human-computer interaction, human reliability, work stress and training as these may relate to human-system design. Furthermore, the most problem for construction process are working postures, materials handling, repetitive movements, physical workload, work-related musculoskeletal disorders, workplace lay out, safety and health.

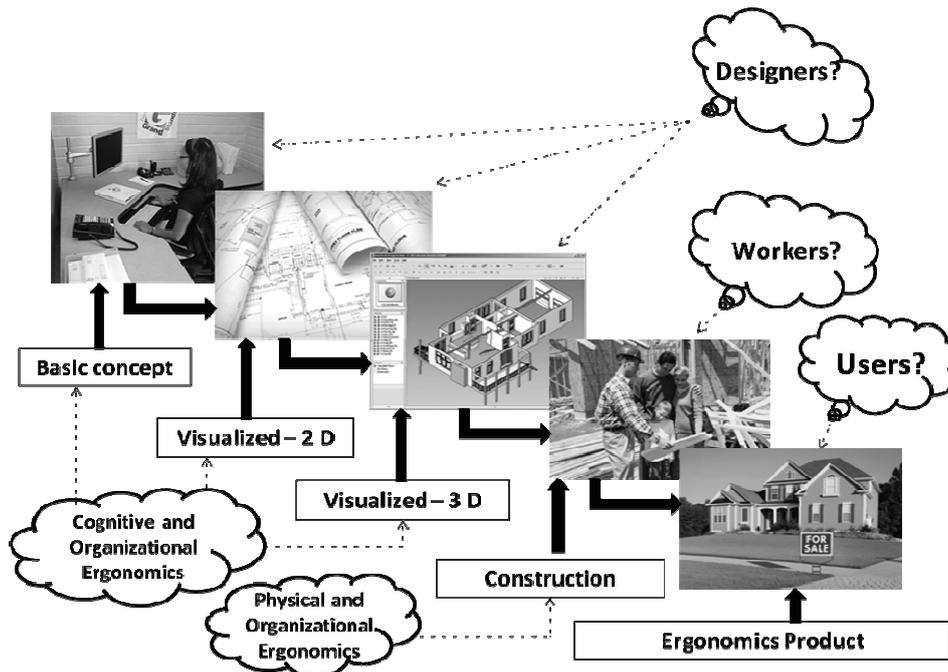


Figure 1: Ergonomics Focuses on Engineering Design and Construction Processes

### 3. RESEARCH METHOD

This paper is literature study with framework and data processing approach comprised of three major stages: 1) literature gathering and screening (textbooks, articles-journals, and the previous researches), 2) data analyzing, and 3) writing the literature review by providing an arguments. Data analyzing divided into four main aspects: a) workers characters (age, gender, and fitness), b) task (work load, man-machine interaction, and work station), c) physical environment (microclimate, noise, dust, vibrator, and lighting), and d) organization (work-rest schedule, nutrition, and information system), both for engineering design and construction process.

### 4. RESULT AND DISCUSSION

#### 4.1 Workers Characters

##### 4.1.1 Age

Many studies Show a positive relationship between age and physical activity, cognitive function, and productivity. Huxhold et al reported that in single and dual-task conditions, older adults showed lower postural control performance and lower cognitive performance than young adults [10]. In addition, Gelderblom reported that the pattern of the relationship of age and productivity is increase at younger age, but decrease at older ages. He also reported that the pattern of age with wages is rather different, namely rising wages with increasing age. At older ages, wages stabilize more [11]. Moreover, Avolio et al and Skirbec stated that the relative capability and productivity level increase gradually and reached the maximum value between the early 20s and the end of 30s [12] [13]. Patrick Aubert and Bruno Crépon found out that productivity increases with age until 40 to 45 and then remains stable after this age. Workers aged 40 and more are roughly 5% more productive than workers aged 35-39, while workers below 30 are 15% to 20% less productive [14]. Furthermore, Aubert dan Crepon [15] reported that the maximum productive age for physical work such as in manufacturing was 35 to 39, and 45 to 50 for services work.

Refers to the overview of age, engineering design workers which tent to do cognitive work have wider range of productive age start from 20 to the maximum productive age between 45 to 50, while the maximum age for construction processes is between 35 to 39 years old.

#### 4.1.2 Gender

Discussing about the gender differences has become not popular already, but however, there are biologically differences between male and female that influent both physical and psychological performance. There were many studies of gender and endurance performance reported by North West Runner Magazine in 2001 as follows:

- 1) The average VO<sub>2</sub>max is about 33 milliliters of oxygen per kilogram of body mass per minute for sedentary young women and around 42 ml/kg/min for sedentary young men [16].
- 2) Elite female distance runners can sometimes reach VO<sub>2</sub>max readings of 70+ ml/kg/min, whereas elite men can attain values in the 80s [17] [18]
- 3) men to be significantly more economical than women [19] [20]

Refers to the research above, men have more capacity for physical activities, however, another researches reported that women seem to score slightly better on tasks that involve cognitive task including visual memory, word and landmark recall and math calculations [21] [22]

Based on the overview of gender, women better than men in engineering design task, while men have more capacity in construction process.

#### 4.1.3 Fitness

A study commissioned by Medibank Private reported that healthy employees are nearly three times more productive than unhealthy employees; unhealthy employees take up to nine times more sick leave than their healthy colleagues; poor employee health and absenteeism is costing Australian business \$7 billion annually [20]. Another research identified higher levels of independent components of fitness may positively influence employees' productivity, job satisfaction and absenteeism [23]. Some indicators that influent the individual fitness level including body weight that performed by Body Mass Index (BMI), hemoglobin levels and blood pressure. Widiastuti reported that BMI and hemoglobin levels have significant correlation with productivity [24]. In line with this research, Wattles and Harris reported that the fitness level has strong correlation with productivity [25].

Refers to the overview of empirical studies on the workers characters (age, gender, and fitness), in designing and construction processes, it is importance to promote it as one of the consideration in designing humane and sustainable work system that meets the potencies and limitation of the workers.

## 4.2 Task

#### 4.2.1 Workload

Workload defines as the amount of work assigned to or expected from a worker in a specified time period. The level of workload is depending on the task demand. Workers mostly employ muscle power such as during construction process tend to exposure by physical workload, while workers use brain power such as in engineering design process tend to exposure by mental workload. Most people stress because of an overload at work, but some job demand too little effort also causes work stress. A very simple method to assess the workload level is by counting the heart rate during work. Heavier workload needs higher the energy requirements and the more blood flow. To attain more blood flow, the heart must produce higher output which is achieves by increasing number of heart beats per minute. Based on the variety of heart rate, the level of workload differentiate into light work (< 90 beats/minute), moderate work (90-110 beats/minute), heavy work (110-130 beats/minute), very heavy work (130-150 beats/minute), and extremely heavy work (150-170 beats/minute). Both overloaded and under loaded caused work stress. Overloaded caused early fatigue; decreases the work endurance, vigilant, and consistency. Under loaded leaves workers idle, bored and their capabilities underuse. Both over and under load finally decrease the productivity [4][26]. In engineering design process, the workload level tend to under load and lead the workers exposed to mental workload, while in the construction process, the workload level tend to heavy, even up to extremely workload that lead the workers exposed to physical workload.

#### 4.2.2 Man-machine/tools Interaction and Work Station

Ergonomics design of man-machine interaction and workstation depends on proper and comprehensive consideration of several aspect, including work task, work movements, and work activities. It must be designed based on the dimension of body size of the workers (the height, width, maximum reach limit, and the clearance). Unsuitable man-machine interaction to the body size of the workers forces awkward postures that caused overexertion, musculoskeletal complain, early fatigue, increase the workload and finally decrease the productivity [26] [27]. Some research showed that ergonomics intervention on man-machine interaction and work station increased the productivity up to 20 %, decreased the score of musculoskeletal complain and fatigue up to 15 % [28] [29] [30].

In this information technology era, the main problem for engineering designers is human-computer interface, while for the workers in construction process is human-machine/tools interface. The ergonomics aspects in human-computes interface focuses in sitting work posture, requirements of eye on the screen and hand on the keyboard. The best way to set up a computer

work station is by understanding the concept of natural body positioning. Working with the body in a neutral position reduces stress and strain on the muscles, tendons, and skeletal system and reduces the risk of developing a musculoskeletal disorders (MSDs). The following are important considerations when attempting to maintain neutral body postures while working at the computer workstation [31] [32].

- 1) Monitor should be set at a height that keep a straight neck
- 2) Hands, wrists, and forearms are straight, in-line and roughly parallel to the floor.
- 3) Head is level or bent slightly forward, forward facing, and balanced. Generally it is in-line with the torso.
- 4) Shoulders are relaxed and upper arms hang normally at the side of the body.
- 5) Elbows stay in close to the body and are bent between 90 and 120 degrees.
- 6) Feet are fully supported by the floor or a footrest may be used if the desk height is not adjustable.
- 7) Back is fully supported with appropriate lumbar support when sitting vertical or leaning back slightly.
- 8) Thighs and hips are supported by a well-padded seat and generally parallel to the floor.
- 9) Knees are about the same height as the hips with the feet slightly forward.

Sedentary sitting posture for prolonged periods is not healthy. Therefore, changing the working position frequently throughout the day is recommended. The best way avoiding the static sitting posture could be done as follows:

- 1) Make small adjustments to the chair or backrest.
- 2) Stretch the fingers, hands, arms, and torso.
- 3) Stand up and walk around for a few minutes periodically.

Following the engineering design process, the ergonomics aspect of man-machine interface in construction process is more complicated. Construction for one product uses many kinds of machine and tools, start from the very simple and manual to the high technology. Regarding to the product characters and the production system, workers should perform the task in sitting, standing, even both sitting and standing postures. Recommended sitting and standing posture perform at Fig.2 [33]

Standing posture is more tiring. Standing requires ~20% more energy than sitting. Prolonged standing at work causes the additional load and also increases the risks of varicose veins and accounts for more than one fifth of all cases of working age. So standing all day is unhealthy. The performance of many fine motor skills also is less good when people stand rather than sit. Different task needs different level working space. Precision work, such as writing or electronic assembly – 2 inches above elbow height; elbow support is needed. Light work, such as assembly-line or repetitive movement is about 2-4 inches below elbow height [34]. Standing puts greater strain on the circulatory system and on the legs and feet. Consequently, in industry we provide employees with ergonomic anti-fatigue to stand on, with anti-fatigue footwear, and with chairs to allow them to sit down during rest breaks [35].

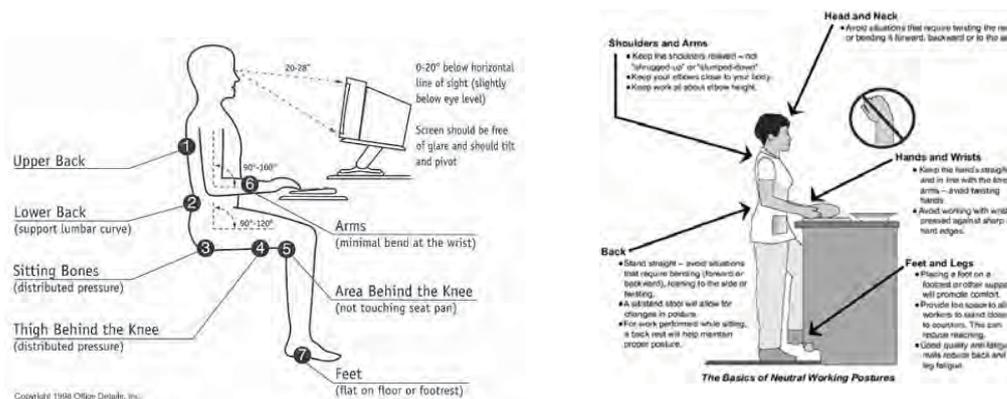


Figure 2: Recommended Sitting and Standing Posture  
 (Resource: available from [www.nismat.org](http://www.nismat.org) for share [33])

The goal of ergonomics approach on working postures is to provide the natural, safe and comfort position and organizes the work so that the usual operations are done within easy reach; avoid the awkward posture that causes over exertion and early fatigue.

### 4.3 Physical Environment and Organization

Study of physical environment including microclimate, lighting, noise, vibrate, dust, and dangerous materials. The main problem for office work such as for engineering design are about micro climate and lighting, while for construction process are mostly all of physical environment aspects. To provide the comfort work condition, all physical environment aspect must be control under threshold limit. It could be done through engineering redesign or organizing the work-rest schedule. For example: controlling noise hazard could be done by partition between noise resource and the workers or by organizing work-rest schedule based on threshold limit. For more than 85 dB (A), the noise exposure should be a quarter hour maximum or by providing the ear plug or muff as personal protection devise [36]. Hence, to protect the workers from the physical environment hazards, it needs the proper safety signs/symbol, training, and alarm system [26]. The exposure of physical environment up than threshold limit will give additional workload; workers got early fatigue that lead to the health impairment and the decreasing of productivity.

## 5. CONCLUSION

Based on the overviews both theoretical background and articles, it could be describing some important conclusion as follows:

- 1) The comprehensive ergonomics approach should be implemented in all human being activities to provide the safety, healthy, comfort, efficient, and productive work condition that lead to the better quality of life both for the workers and the industries.
- 2) The ergonomics aspects that must be considered for designers are the individual designer's characters, human-computers interface, and physical environment exposure.
- 3) The ergonomics aspects that must be considered for workers in construction process are the individual worker's characters, human-machine/tools interface, and physical environment exposure.

## 6. RECOMMENDATION

This study is general overview of comprehensive ergonomics aspects. For further study, it is recommended to conduct more indebt research to build a model of ergonomics approach for engineering design and construction processes that meets the potencies, capabilities, and limitation of both designer's and the workers.

## REFERENCES

- [1] William. S. Marras, PhD, CPE and W. Gary Allread, PhD, AEP, "How to Develop and Manage an Ergonomics Process". Institute for Ergonomics, The Ohio State University, *Columbus, Ohio*.
- [2] The council of the IEA, "The following definitions of Ergonomics", Available at [www.iea.cc](http://www.iea.cc). Access on December 23, 2012.
- [3] Manuaba A, "Competitive and Sustainable Humaine Technology is the Most relevan and reliable for Industry, Now and for Ever", in the "*Proceeding of National Ergonomics Conference*", Yogyakarta, April, 2006. (Indonesia version).
- [4] Manuaba, A, "Total Approach is a Must for Small and Medium Enterprise to attain Sustainable Working Conditions and Environment with Special Reference to Bali, Indonesia", *Industrial Health*, vol.44, 2006, pp 22-26.
- [5] Manuaba, A., "Total Ergonomics Approach to Enhance and Harmonize the Development of Agriculture, Tourism, and Small Scale Industry, with Special Reference to Bali", "*National Congress and Seminar of the Indonesian Ergonomics Association (PEI)*", Yogyakarta, September, 2003.
- [6] Klaus Zink, "Ergonomics in the past and the future: from a German perspective to an international one", *Ergonomics*, Vol. 23. Taylor & Francis, London, 2000.
- [7] Manuaba, A, "Total Ergonomics Approach on Product and Development to Attain Humaine, Competitive and Sustainable Work System and Product". "*National Seminar on Ergonomics 2007, Ergonomics Integration on Product Development*", Bandung – Indonesia, July, 2007, pp 26 – 28.
- [8] Lilik Sudiajeng, Wayan Sumetri, Inten Rumini and Patricia Paramita, "Total Ergonomics Approach in Developing Sustainable Mangrove Forest Action Project in Bali". "*Proceeding of Agriculture Ergonomics Development Conference*", Halimahtun M. Khalid, Lim Tek Yong, Nor Rozalita Bahar, Rosnah Mohd Yusuf, Mohd Asyraf Che Doi, 2007, pp 94-99.
- [9] Ertas, A. & Jones, J., "The Engineering Design Process". John Wiley & Sons, Inc, 2nd ed. New York, 1996.
- [10] Oliver Huxhold, Shu-Chen Li, Florian Schmiedek, Ulman Lindenberger, "Dual-tasking postural control: Aging and the effects of cognitive demand in conjunction with focus of attention". *Brain Research Bulletin*, No. 69, pp 294-305, 2006.
- [11] Gelderblom, "The Relationship of Age with Productivity and Wages". SEOR, Erasmus Universiteit Rotterdam, November, 2005.
- [12] Avolio, B. J. and D. A. Waldman. 1994. "Variations in Cognitive, Perceptual, and Psychomotor Abilities Across the Working Life Span: Examining the Effects of Race, Sex, Experience, Education, and Occupational Type.", *Psychology and Aging*. Vol. 9 (3): 430-442.
- [13] Skirbec V. 2003. Age and Individual Productivity: A Literature Survey. Max Planck Institute for Demographic Study. Germany.
- [14] Patrick Aubert and Bruno Crépon, "Are Older Workers Less Productive?" *Economie et Statistique*, No.363, pp.95-119. 2003.
- [15] Aubert, P. and Crépon, B. 2007. Are Older Workers Less Productive? Firm-Level Evidence on Age-Productivity and Age-Wage Profiles.

- [16] Bouchard C, Daw EW, Rice T, Pérusse L, Gagnon J, Province MA, Leon AS, Rao DC, Skinner JS, Wilmore JH., "Familial resemblance for VO<sub>2</sub>max in the sedentary state", *HERITAGE family study Medicine and Science in Sports and Exercise*, No. 30, pp 252-258, 1998.
- [17] Pate RR, Sparling PB, Wilson GE, Cureton KJ, Miller BJ, "Cardiorespiratory and metabolic responses to submaximal and maximal exercise in elite women distance runners". *International Journal of Sports Medicine*, No. 8 (Suppl.), pp 91-5, 1987.
- [18] Pollock ML., "Submaximal and maximal working capacity of elite distance runners", *Annals of the New York Academy of Sciences*, Part I, 1997, pp 301: 310.
- [19] Howley ET, Glover ME, "The caloric costs of running and walking one mile for men and women" , *Med Sci Sports*, Winter; 6 (4), 1974, pp 235-237.
- [20] Bransford DR, Howley ET., "Oxygen cost of running in trained and untrained men and women", *Med Sci Sports*, Spring;9(1), 1977, pp 41-44.
- [21] Kimura, Doreen, "Sex Differences in the Brain". *Scientific American*, No. 13, May 2002. Available at <http://www.sciam.com/article.cfm?id=00018E9D-879D-1D06-8E49809EC588EEDF>, Access December 20, 2012.
- [22] Pinker, Steven Spelke, Elizabeth, "The Science of Gender and Science: Pinker vs. Spelke. A Debate". *Edge; The Third Culture*, 16 May, 2005. Available at [http://www.edge.org/3rd\\_culture/debate05/debate05\\_index.html](http://www.edge.org/3rd_culture/debate05/debate05_index.html). Access, December 3, 2012.
- [23] Madibank Private, "The health of Australia's Workers", 2005. Available at [http://www.trenchhealth.com.au/articles/MEDI\\_Workplace\\_Web\\_Sp.pdf](http://www.trenchhealth.com.au/articles/MEDI_Workplace_Web_Sp.pdf), Access: December 3, 2012.
- [24] Matthew G. Wattles and Chad Harris, "The Relationship Between Fitness Levels and Employee Perceived Productivity, Job Satisfaction, and Absenteeism", *International Electronic Journal*, Volume 6, No. 1, February 2003.
- [25] Astuti, T. dan Lia, "Corelation Between Body Mass Index, Hemoglobin levels, Fitness levels, and Productivity of female workers at Packaging Department. (Case Study at PT Danliris, Banaran, Grogol, Sukoharjo-Indonesia)", 2007. Thesis, University of Diponegoro.
- [26] Wattles, M.G. & Harris, C., "The Relationship Between Fitness and Employee's Perceived Productivity, Job Satisfaction, and Absenteeism". *An International Electronic Journal*, Volume 6. 2003.
- [27] Karl H.E. Kroemer, "Fitting the Human, Introduction to Ergonomics" 6 Editions, Taylor and Francis Group. USA. 2009, pp 235-250.
- [28] Bridger, R.S, *Introduction to Ergonomics*, Taylor and Francis Inc. New York. 2003.
- [29] Sudiajeng, L.; Sutapa, N.; Wahyu, I.G.; and Sanjaya, N., "Ergonomics Redesign minimized unsafe action in a wood working workshop". *Ergonomics in Asia: Development, Opportunity, and Challenges*". Taylor and Francis Group. London, 2012, pp 289-293.
- [30] Titin Isna Oesman, Sudarsono, and I.Putu Gede Adiatmika, "Intervention in Stamping process has Improved Work Quality, Satisfaction, and Efficiency at PT. ADM Jakarta"Ergonomics Redesign minimized unsafe action in a wood working workshop". *Ergonomics in Asia: Development, Opportunity, and Challenges*". Taylor and Francis Group. London, 2012, pp 269-276.
- [31] United States Department of Labor. "Good Working Position". Available from <http://www.osha.gov/SLTC/etools/computerworkstations/positions.html>. Access: December 27, 2012
- [32] Ministry of Labor. "Computer Ergonomics: Work Station lay out and lighting", available at [www.labor.gov.on.ca](http://www.labor.gov.on.ca). Access: December 27, 2012.
- [33] "Ergonomics Standing Posture". Available from [www.nismat.org](http://www.nismat.org) for share. Access: December 27, 2012.
- [34] Grandjean, E. *Fitting the task to the man*. 4th ed., Taylor & Francis Inc., 2000.
- [35] "Sitting and Standing at Work". Available from Cornell University Ergonomics web. Access: December 27, 2012
- [36] David Grantham, *Occupational Health & Hygiene.*, D.L. Grantham. Brisbane, 1992.

# Ergonomics Analysis Of Medium-Range Twin-Engined Transport Plane Emergency Door

Armand Omar Moeis, Teuku Kanigara

Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel: (021) 7270011 ext 51. Fax: (021) 7270077  
E-mail: armand.omar@ui.ac.id

## ABSTRACT

Comfort and safety of passengers are main concerns in a flight. When a plane crashes and the main door is unable to be accessed, it is vital to have accessible and ergonomic emergency exit doors. This research studies the ergonomic aspects of a medium-range twin-engined transport plane emergency door design. The purpose of this research was to evaluate the design of an actual emergency door of such aircrafts and to determine the most ergonomic configuration using door height and width as primary consideration. As the result of this research, four configurations were made and analyzed. Those configurations were analyzed by using Jack 6.1 software. Posture Evaluation Index was used to integrate the analysis from three methods: Lower Back Analysis, Ovako Working Analysis System, and Rapid Upper Limb Analysis. The result of this research suggested that minor modification is necessary from original design.

## Keywords

*Ergonomics, Aircraft Design, Virtual Human, Virtual Environment, Posture Evaluation Index*

## 1. INTRODUCTION

Ergonomics is a discipline concerned with interaction between humans and other elements in a system. Furthermore, ergonomics is a science that contributes to the design and evaluation of a job, task, product, environment and systems in order to make these things fit the needs, capabilities and limitations of humans. Therefore, ergonomics is a science that is very important in the design of a product. Ergonomics can be applied in various fields of industry. One of them is aircraft industry.

Indonesia already had an aircraft industry in late 1940s. It was expanded from the Indonesian Air Force facility. During the 1970s, capitalizing money from natural resources sales, Indonesia built a full-sized aircraft industry. This industry had successfully developed several aircrafts. One of these aircrafts is a medium-range twin-engined transport plane that was jointly developed by Spain and Indonesia. Its primary roles include maritime patrol, surveillance, and air transport.

As in other medium-range transport aircrafts, this plane is obliged by regulation to have an emergency exit door for evacuation. The door has to be designed in particular ways so it can comply with safety regulations. This has implications on accessibility, accuracy, number of injured passengers and time to evacuate all passengers. This study analyzes the ergonomics aspect of the door. Research was conducted in virtual environment using software Jack 6.1, in particular the Posture Evaluation Index (PEI). PEI is a formula that consists of Low Back Analysis, Ovako Working Analysis System, and Rapid Upper Limb Assessment. Adjustments have been made on emergency exit design to obtain the ideal configuration.

## 2. BASIC THEORY

*Virtual environment* is a representation of a physical system generated by the computer. This representation allowed users to interact with a synthetic environment, which is similar with real environment [1]. A good simulation of virtual environments must be able to represent a virtual human model within the designed system/environments.

*Virtual human* is an accurate biomechanical model of the human figure. This model fully mimics human movement hence researchers might simulate the flow of work processes, and see how the workloads are received by the model when doing a certain job series.

Jack 6.1 is one of the ergonomic software that simulates how a human model can interact with virtual objects and environments, as well as getting the right response back from the object being manipulated. Jack is one of world's leading applications in ergonomic analysis software.

## 3. METHODOLOGY

The first step in this research was data collection. There are three types of data used in this research, namely the anthropometric data of Indonesian and American people, the size and shape of the actual emergency exit door, and evacuation posture

of passenger during emergency exit. For Indonesian anthropometric data, we used the latest data that has been published in prominent ergonomics scientific journal [2]. The data for the Americans were taken from ANSUR. Data specification of emergency exit was taken from direct measurements of the aircraft.

The second step, data processing, was performed by simulating evacuation posture on the Jack 6.1. It was started by creating the virtual environment. The virtual environment was created using NX. Jack and NX are developed by one company, so the translation/insertion of the environment model from NX to Jack was done seamlessly. The next step is to create a virtual human model. Furthermore, the human model was simulated in the virtual environment. From initial simulation, we determined design configuration for the emergency exit (see Table 1).

Table 1 : Configuration of emergency exit

Configuration	Height	Width	TYPE
1	91,5 cm	50,8 cm	ACTUAL
2	91,5 cm	55,8 cm	REDESIGN
3	96,5 cm	50,8 cm	REDESIGN
4	96,5 cm	55,8 cm	REDESIGN



Figure 1: Virtual Environment and Virtual Human

Moreover, we analyzed simulation results using Jack Task Analysis Toolkit. This toolkit calculates values like LBA (Lower Back Analysis), OWAS (Ovako Working Posture Analysis), and Rula (Rapid Upper Limb Assessment). These three calculations are then combined into PEI (Posture Evaluation Index), which is the value of the overall ergonomics of the human posture [3].

$$PEI = I_1 + I_2 + I_3 \cdot mr \quad (1)$$

$$I_1 = \frac{LBA}{3400N} \quad I_2 = \frac{OWAS}{4} \quad I_3 = \frac{RULA}{7} \quad (2)$$

#### 4. RESULTS AND DISCUSSION

The results of the simulation are shown in Table 2. Focus was given to configuration 1, 2, and 3 where the value of OWAS equals 3. This high number indicates that the current working posture significantly harm the human musculoskeletal system. Regarding RULA, high numbers exist in configuration 1 and 2. Moreover, results on LBA also show the very same pattern.

Table 2 : Recapitulation of PEI Result

CONFIGURATION	Sex	Percentile	LBA (N)	OWAS	RULA	PEI
1	Male	95	1232 N	3	7	2.532
	Male	5	641 N	3	6	2.157
	Female	95	1160 N	3	7	2.511
	Female	5	455 N	3	6	2.101
2	Male	95	1085 N	3	6	2.286
	Male	5	490 N	1	5	1.408
	Female	95	1026 N	3	6	2.269
	Female	5	359 N	1	5	1.370
3	Male	95	960 N	3	5	2.047
	Male	5	439 N	1	4	1.191
	Female	95	913 N	3	5	2.033
	Female	5	326 N	1	4	1.157
4	Male	95	466 N	1	4	1.199
	Male	5	427 N	1	3	0.984
	Female	95	464 N	1	4	1.197
	Female	5	319 N	1	3	0.952

Figure 2 is a graphic comparison of the PEI entire configuration of emergency exit design for 5th and 95th percentile for male and female. Our simulation shows that the initial design (configuration 1) poses high injury risk. Our proposed design (configuration 2, 3, and 4) delivers better ergonomics performance.

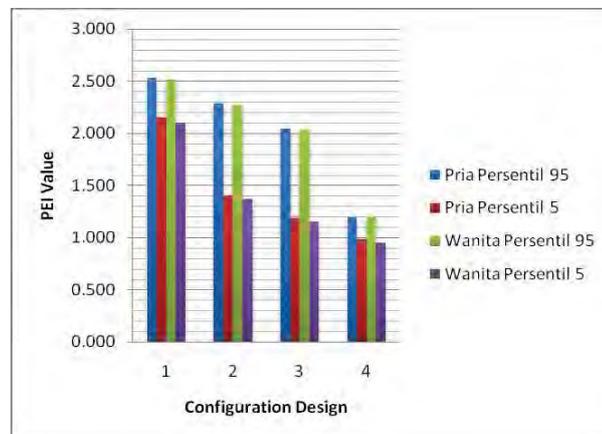


Figure 2: Value Comparison Graph of PEI

#### 5. CONCLUSION

Good human-machine interface will deliver better system performance. In aircraft design, ergonomics play major factor in determining, not only system performance, but also system safety. By using virtual environment, we can conduct ergonomics analysis during design phase. This will affect system performance and safety while keeping the development cost relatively low, since we do not need to construct a full mock-up in early design phase. Though that the design case was simple, this research gives us basis means to conduct further ergonomics study in aircraft design.

#### REFERENCES

- [1] Kalawsky, R. (1993). *The Science of Virtual Reality and Virtual Environments*. Cambridge: Addison Wesley Publishing Company.

- [2] Chuan, Tan Kay., Hartono, Markus., & Kumar, Naresh., (2010). Anthropometry of the Singaporean and Indonesian populations. National University of Singapore. *International Journal of Industrial Ergonomics* 40, 757-766.
- [3] Caputo, F., Di Gironimo, G., Marzano, A. (2006). Ergonomic Optimization of a Manufacturing System Work Cell in a Virtual Environment. *Acta Polytechnica*, 46, 5

## The Legibility Threshold of Chinese Characters in Three Type Styles

Dengchuan Cai , Chia-Fen Chi <sup>\*</sup>, Manlai You

*<sup>\*</sup>Department of Industrial Management, National Taiwan University of Science and Technology, Taiwan  
E-mail : chris@mail.ntust.edu.tw*

### ABSTRACT

A recognition test was conducted on the most commonly used Chinese characters in the Ming, Kai, and Li styles, measuring the minimum visible size of each character in each style. A total of 120 college students participated in the experiment. Each character was initially displayed on a PC screen at its minimum size and enlarged gradually until the participant could recognize it. Analysis of variance showed that character style and number of strokes both have a significant impact on the legibility threshold. Ming is the most legible among the three styles, and Kai is also significantly more legible than the Li style. A regression equation for predicting the legibility threshold based on the number of strokes in a character indicates that an increase of an additional stroke in a character must be compensated for by an enlargement of the character size of approximately 0.25 min of arc to maintain the same legibility.

### Keywords

*Chinese character, legibility, character style, stroke number*

## The Effect of Icon Formats on Vehicle Icon Recognition

Chia-Fen Chi <sup>a</sup>, Ratna Sari Dewi<sup>b</sup>, Shin-Cheng Chen <sup>c</sup>

<sup>a</sup>Department of Industrial Management, National Taiwan University of Science and Technology, Taiwan  
 E-mail : chris@mail.ntust.edu.tw

<sup>b</sup>Department of Industrial Management, National Taiwan University of Science and Technology, Taiwan  
 E-mail : ratna.sari.dewi80@gmail.com

<sup>c</sup>Department of Industrial Management, National Taiwan University of Science and Technology, Taiwan  
 E-mail : shincheng@hotmail.com.tw

### ABSTRACT

The current study collected matching accuracy, matching time, and matching sequence data on 95 icons of a vehicle. The ninety-five icons were divided into four different formats: image-related, concept-related, arbitrary, and text, to compare their matching performance. Forty participants with a university education took part in this experiment. Half of the participants had intensive driving experience while the other half had no driving experience. The results showed that the experienced drivers had significantly better recognition accuracy on all icon formats. However, all participants chose to match image-related icons before icons of the other three formats. With about the same recognition accuracy, the image-related format is recommended for use in the design of vehicle icons. Based on its high ratings on subjective design features, textual format can be used for functions describable using simple English and for users with English reading ability.

### Keywords

*image-related, matching test, icon design features*

### 1. INTRODUCTION

As the number of functions in the driving environment increases, icons that are compact and international (language)[1] are often used in a vehicle to convey information to the driver [2]. Effective icons can provide the driver with quick and complete understanding of information [3] to ensure driver safety. However, designing comprehensible icons was not a simple task. Saunby et al. [4] showed that only 16 of 25 car icons tested could be matched correctly by a minimum 75 per cent of experimental subjects.

An icon maybe comprised of border, background, symbol (consisting of graphical elements), and textual labels (Figure 1) [1], [5] although not all these components will be present in it. Each icon component can add meaning to an icon in its own way. Borders can make icons appear more consistent; background can help to group icons; and graphical and textual elements convey the main meaning of the icon[6].

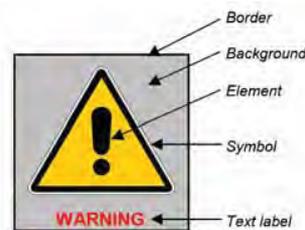


Figure 1: Key components of an icon [5]

To provide a useful framework for icon design and evaluation [7], icons can be classified into image-related (pictorial), concept-related (analogy), or arbitrary based on how far the graphical elements in an icon (Figure 1) resemble their referents. Image-related icons are typical pictorial representations of the object or act [8]. Concept-related icons attempt to visualize a concept that is not far but separate from the concrete image. Arbitrary icons have no obvious reference to their intended meaning but become meaningful only through convention and education [7], [8]. Goonetilleke et al. [8] added a fourth format: the use of text.

Prior researches compared the advantages of using each of the icon formats. Image-related icons have been considered the most effective for fast and accurate recognition response [9], [10], [11]. Educating people to associate arbitrary objects and their referents requires a considerable amount of funding and time, thus, arbitrary icons should be avoided[1]. Regarding textual icons, the general conclusion is that recognition of pictorial images has been found to be superior to that of text for

recall and recognition accuracy [12],[13] while text has been better for reaction time[14]. Thus, Muter & Mayson [15] and Egidio & Patterson [16] advocated the combining of graphical and textual elements to promote association and improve comprehension accuracy.

Most of the above statements seem to suggest that imaged-related icons combined with text would be the most effective. However, if we review the commonly used ISO standard icons, we will find that not all of the icons are image-related because for some functions or contexts, it is difficult or impossible to find a real object to represent the referent when creating image-related icons. Besides, most previous studies only compared three types of graphical icons[17], [18] or graphical vs. textual icons[3], [10]. Therefore, the current study categorized the existing icons used in a newly built vehicle into four different icon formats and compared the comprehension performance of the participants as they responded to the different formats.

Icons can be classified easily into graphical or textual formats based on the existence of textual/graphical elements. However, more caution is needed in classifying graphical icons into image-related, concept-related, or arbitrary formats. Icons will be classified as image-related if the graphical elements are highly pictorial representations of the object or act they represent [5]. The following icons were classified as image-related: , , , , , , , , , , , and . The above icons reveal that objects can be portrayed more easily than action.

Icons will be classified as concept-related if they attempt to visualize a concept that is not far but separate from the concrete image[7], [8]. For example,  (high beam) and  (front fog light) were classified as concept-related since the parabolic shape was used to denote the headlamp while the parallel straight and angled lines in front of the headlamp were used to denote the light beam. Both graphical elements were shape-related but somewhat different from the real image. The position of the lines relative to the parabolic shape indicates whether it is a front light or a rear light. Meanwhile, the wavy curve cross over the parallel lines tilted downward symbolized the fog. For icons containing both graphical and textual elements, the textual information can be ignored and they will be classified based only on the graphical elements. The lane departure warning system  is classified as image-related by ignoring the textual information LDWs+. Also, without clear standards, icons would be classified as concept-related if they are composed of image-related objects and concept-related actions such as air flow control  and recirculated air . In such cases, the arrow is a symbol used to denote air flow when presented together with a real object such as a car or a human being. There are similar examples for windscreen defrosting and demisting  and rear-window defrosting and demisting . Also,  (stability control system indicator) can be classified similarly because the action is the critical part that makes a difference. There was some confusion about classifying the car key reminder indicator  as either image-related or concept-related because of its poor image quality. Since image quality was not an attribute used for the classification of icon format,  was classified as imaged-related. Lastly, graphical icons will be classified as arbitrary if the graphical elements do not resemble the object or action they represent, e.g.,  for power on/off. Textual icons can be easily identified including alphabetical words/abbreviations, numerals or mathematical operators. Table 1 shows the classification of the 95 icons tested in the study.

Table 1: Icon classification

Icon Format	Icon list
Image-related	           
Concept-related	         
Arbitrary	        
Text	P P R D N + - 4WD FAIL TCS OFF TC OFF ESC CRUISE CRUISE ON/OFF RES/+ SET/- SNOW SNOW SOS P/B ON L R UP DOWN BACK MODE ENTER CH+ CH- SEEK ENTER VOL CD/DVD RADIO SET1 BAGLEV NIGHT VISION NAVI AFS ON/OFF A/C A/C TEMP AUTO OFF

Since subjective rating scales are easy to administer, at times they can be more sensitive than objective measurements [19], so these 95 icons would also be evaluated based on some subjective design features [20] such as familiarity, concreteness, visual complexity, and semantic distance. Each will be defined in the following [21], [22]. The subjective rating features can help to explain why some icons could be better recognized than others.

Familiarity reflects the frequency with which icons have been encountered. Concrete symbols tend to be more visually obvious and easier to use [23] because they depict real world objects and actions. Design guidelines typically suggest that icons should

be kept as simple as possible [23] meaning low visual complexity or not containing a lot of details. Semantic distance is the closeness of the relationship between what is depicted on an icon and what it is intended to represent. Among the four differential formats of icons (image-related, concept-related, arbitrary, and textual), all four subjective design features can be used to evaluate the first three graphical formats. However, for textual icons, besides evaluating semantic distance, participants were also asked about whether they understood the meaning of the word or abbreviation in an icon.

The education level (with university education vs. without) [21] and experience [8], [24] of the respondents were found to have significant effects on comprehension performance. Our experiment chose to test participants with at least a university-level education and divided their driving experience into having no driving experience and having intensive driving experience.

Geiser [25] divided the interactive tasks in a vehicle into three classes: primary, secondary and tertiary tasks. A primary task is about maneuvering the vehicle, secondary tasks are setting turning signals and activating the windshield wiper to increase driving safety while tertiary tasks serve the entertainment and information functions [26]. Based on Geiser [25], Tonnis et al. [26] classified input devices into primary, secondary, and tertiary devices and assigned them to specific locations in the car. For example, both primary and secondary devices are arranged close to the driver so that they are easy-to-reach. Secondary devices are often mounted on the backside of the steering wheel while tertiary devices are often placed in the center stack [26]. Therefore, the 95 icons were copied from the dashboard, steering wheel, and center stack of a newly built vehicle and presented on three task screens respectively. Participants will match each icon with the most appropriate referent name. The subjective design features would be rated for each icon after the matching test.

Ninety-five icons of a newly-built vehicle were categorized into four different formats to compare the matching accuracy, time, and sequence produced by the participants. The results obtained for the different icon formats on these performance measures can be used to perfect the ISO standard 2575 published by the International Organization of Standardization to facilitate the design of new icons for new contexts or applications, e.g., car panels.

## 2. METHODOLOGY

### 2.1 Participants

A matching experiment was designed to collect comprehension performance data on 95 icons followed by subjective ratings of their design features. The comprehension performance was measured by the matching time, matching sequence, and the percentage of participants who matched the icon correctly with its functional name (matching accuracy) [6]. Forty participants aged between 23 and 53 years old (mean = 30.4 years) took part in this experiment. All participants are students and staff members of National Taiwan University of Science and Technology with at least a university level education. They consisted of two different groups: those having driving experience (having driven at least once a week) and those without any driving experience (not having a driver's license and never having driven a car). Prior to the experiment, all participants were screened for visual acuity abnormality and color blindness. They were briefed about the experiment goal, and practiced the matching test routine. After the matching test, each participant was asked to give ratings on each of the subjective design features.

### 2.2 Equipment and Computer Programs

Two experimental modules were conducted on two Lenovo Think Centre A70z computers equipped with 19" screen monitors, i.e. the matching test and subjective rating evaluation. In the matching test, icons were displayed on a car dashboard layout to give context as suggested by Vukelich and Whitaker [27] and Wolff and Wogalter [28]. Since context delivers ecologically valid cues that limit the possible referents and the matching performance scores would certainly be raised by providing the testing context [28]. Hence, there may not be enough sensitivity in the matching accuracy. The matching sequence of each icon was retrieved from reviewing the videotape as an index of the matching difficulty.

Ninety-five icons were divided into three task screens - dashboard, steering wheel, and center stack - according to the icons' relative positions on a newly-built vehicle. In other words, the icon format was nested within the task screen [29]. The three task screens would be shown to each participant in random sequence to minimize the learning effect. One example of the task screens is depicted in Figure 2. Participants were asked to click on what they thought was the most appropriate referent name for a specific icon and drag it to the answer box. Each participant was allowed to revise her/his answer during the experiment without time limit. The computer program would collect the name of each icon and the time it took to match it. If the matching result had been altered in any way, all previous matching results would also be recorded.

In the subjective rating of design features, participants were asked to rate each icon in accordance with how much they perceived the icon to be familiar, concrete, simple, and strongly related to its referent on a 1-7 scale [30]. Figure 3 shows the test screen for subjective ratings of design features. Unlike the matching test where icon formats were nested in three separate task screens, in this subjective rating test screen, each icon was evaluated on an individual basis.

Performance Measures		Image-related	Concept-related	Arbitrary	Text
Matching accuracy	ND	76 ± 23%	68 ± 15%	66 ± 27%	67 ± 26%
	D	84 ± 17%	85 ± 12%	82 ± 18%	82 ± 22%
Matching Sequence	ND	11.8 ± 5.5	18.9 ± 7.0	17.1 ± 6.4	18.8 ± 6.6
	D	13.8 ± 5.3	18.5 ± 7.0	18.0 ± 9.0	18.0 ± 7.2
Matching Time (s)	ND	15.2 ± 3.3	13.5 ± 1.9	13.2 ± 1.5	12.5 ± 3.8
	D	18.2 ± 5.8	18.2 ± 5.1	23.6 ± 5.8	17.3 ± 5.8
N		20	22	9	44

Figure 2: Matching test task screen for center stack

### Car Icon Evaluation



Rear-window washer and wiper

Are you familiar with this icon?  
 Very unfamiliar 01 02 03 04 05 06 07 Very familiar

Is the icon abstract or concrete?  
 Definitely abstract 01 02 03 04 05 06 07 Definitely concrete

Is the icon complex or simple?  
 Very complex 01 02 03 04 05 06 07 Very simple

Is the icon closely related to its intended meaning?  
 Very weakly related 01 02 03 04 05 06 07 Very strongly related

Figure 3: Subjective rating test screen

## 3. RESULTS

### 2.3 Analysis of Variance

Table 2 summarizes the matching accuracy, matching sequence, and matching time for each icon format and for participants with and without driving experience. The nested Analysis of Variance (ANOVA) was performed on matching accuracy, matching sequence, and matching time to examine whether icon format and driving experience had a significant effect on the recognition performance.

The nested ANOVA result indicated that the task screen had a significant effect on all three performance measures (see Table 3). The result also indicated that driving experience had a significant effect on the matching accuracy ( $p < 0.01$ ). Participants with driving experience had significantly better recognition accuracy than participants without driving experience. On the other hand, icon format had a significant effect on matching sequence ( $p < 0.01$ ). For each task screen, image-related icons had significantly smaller means than all other icon formats, indicating that image-related icons were recognized faster. No significant difference was found in matching sequence between participants with and without driving experience.

Table 2: Mean performance measures for each icon format

Note: ND refers to subjects without driving experience; D refers to subject with driving experience

Table 3: ANOVA results of comprehension performance measures

Source	df	Matching accuracy		Matching sequence		Matching time	
		F	Sig.	F	Sig.	F	Sig.
Driving experience	1	12.70	<b>0.00</b>	0.05	0.83	64.69	<b>0.00</b>
Task screen	2	5.57	<b>0.00</b>	34.98	<b>0.00</b>	8.16	<b>0.00</b>
Icon format (Task screen)	9	1.74	0.08	3.31	<b>0.00</b>	2.59	<b>0.01</b>
Driving experience x Task screen	2	1.29	0.28	0.13	0.88	2.88	0.06
Driving experience x Icon format (Task screen)	9	0.29	0.98	0.35	0.96	1.69	0.09

Icon format and driving experience had a significant effect on the matching time. Arbitrary icons took significantly longer than all three other formats for experienced participants. Quite unexpectedly, participants with driving experience took significantly longer than those inexperienced participants. However, reaction time can be affected by the number of unmatched icons left (Hick-Hyman Law).

Image-related icons did not produce better matching performance than other icon formats. This could be because the half of the icons followed ISO standard or common practice, so they can be recognized reasonably well irrespective of their design format. Besides, all participants had a university-level education and basic reading capability for English text. As a result, the study revealed that participants without driving experience had a 100% recognition rate for  (snow mode switch and indicator) and , and an above 90% recognition rate for , , , , , , , and .

For the icons presented on each task screen, the reaction time was supposed to be affected by the number of unmatched icons and can be predicted by the Hick-Hyman Law [31] rather than by perception difficulties. However, after reviewing the videotape and the reaction time vs. the matching sequence curve, it was found that several icons matched last had the longest reaction times (see Figure 4). The matching accuracy had been raised to 70% for those without driving experience and 80% for those with experience because of there being very few possible referents left [28]. Under such conditions, matching sequence is more sensitive and reliable than matching accuracy, and the sequence indicated that participants chose to match image-related icons before icons of other formats. This has very important implications because the duration of any given glance during driving should be relatively short (shorter than 0.8 seconds), with there being about 3 seconds between glances [32]. Thus, those icons that had a high recognition rate but were matched at the last minute should not be used during driving.

#### 2.4 Subjective Rating on Icon Design Features

The means of the subjective ratings for each design feature are listed on Table 4. The analysis of variance was conducted to analyze whether icon format and driving experience have a significant effect on each design feature. Since each icon was evaluated individually without the task screen context, factorial ANOVA was conducted on subjective ratings of design features [29]. The ANOVA result (Table 5) indicated that experienced participants provided significantly higher ratings for all design features. Icon format had a significant effect on all subjective ratings except for familiarity. Concept-related icons had lower ratings on all design features compared to the other icon formats. Image-related icons were expected to have higher ratings on concreteness, simplicity and semantic distance than concept-related icons. However, arbitrary icons had even higher ratings on some of the design features because some arbitrary icons have been used in other contexts such as power on/off  and hazard warning  which are used in electronic devices and road signs, respectively. Besides, all participants had a university-level education and could read English. Thus, textual icons were perceived to have higher semantic distance ratings compared to image-related icons. Meanwhile, almost all concept-related icons were related to functions specific to vehicles, such as front fog light indicator  and engine coolant temperature indicator , which could explain why novice participants gave relatively low ratings on most subjective rating scales. Based on the subjective rating scales, textual icons could be a good choice for icons that can be described using simple English and for users who have some level of English reading ability.

Significant inter-correlation and the higher ratings perceived the by experienced participants proved that subjective rating scales are not diagnostic; they only provide an overall sense and indicators of what we intended to measure [19]. They can be more sensitive than objective measurements [33], [34]. Besides, different researchers have suggested distinctive criteria based on different application domains or data collection methods. For example, [33] suggested qualified computer icons should incorporate the following design criteria: styling, message quality, meaningfulness, locatability, and metaphor, and which has nothing in common with the current subjective rating scale we used here.

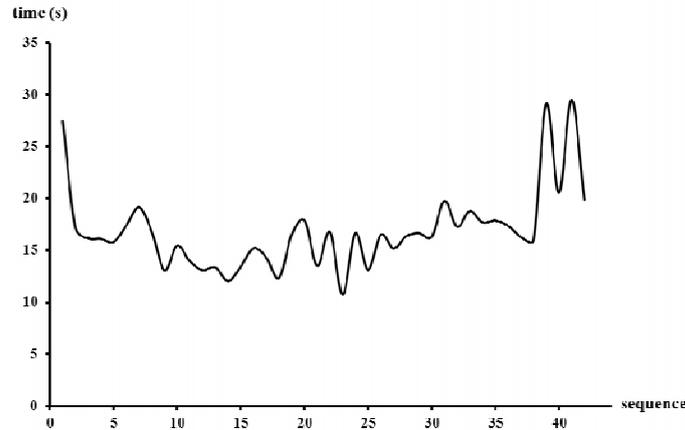


Figure 4: Matching time versus matching sequence for center stack

Table 4: The average of subjective ratings on icon design features

Note: ND refers to subjects without driving experience; D refers to subject with driving experience

Table 5: ANOVA on subjective rating of graphical icon design features

Source	df	Familiarity		Concreteness		Complexity		Semantic distance	
		F	Sig.	F	Sig.	F	Sig.	F	Sig.
Icon Format									
Driving Experience									
Icon Format × Driving Experience									
Image-related									
Arbitrary									
Textual									

4.

## DISCUSSION

Kern and Schmidt [35] suggested that designing user interfaces for computer domains where the user pays full attention to the application is totally different from that for cars, where the user's main focus has to be on the primary driving task. However, the current test scenario is more similar to the computer domain. Besides that, Ng and Chan [36] indicated that people with a university-level education or above perform significantly better in symbol comprehension tests than those without a university-level education. This study recruited participants with a university-level education and, as a result, all recognition performance could have been inflated. Also, the recognition performance improves dramatically as a result of learning from the driving experience ([24], [37]). The car manufacturer and interface designers must take notice that a great number of icons tested cannot be correctly recognized with the user's full attention and even worse recognition performance is expected in a real driving situation and in particular for users without a university-level education and without driving experience.

Although Lodding [7] stated that pictorial communication predated text communication and it is more natural to communicate with images, the current study failed to prove that image-related icons have a better matching accuracy than the textual icons. The result can be partially explained by the poor design quality of some of the image-related icons, just as Lodding [7] suggested that image-related icons will be clear and easy to understand when the image bears a close resemblance to a particular object and context is provided. For example, both the car key reminder indicator (🔑) and engine warning light (🚗) had poor recognition rates mainly because both images have poor resolution and do not resemble closely to, the key or engine, respectively. The findings highlighted the importance of the design quality in the resemblance to a real object.

The International Organization for Standardization ISO 2575: 2010 provided a list of standardized symbols for controls and indicators. Among the 95 icons tested in this study, 44 icons came from or were adopted from the ISO standard 2575:2010. If

we divided all 95 icons into the ISO group (n=44) and the non-ISO group (n=51), the t-test result proves that experienced participants had significantly better matching accuracy for icons following the ISO standard (ISO=88%, NON-ISO=79%), but the difference for novice participants (ISO=72%, NON-ISO=67%) was not significant. For conventional functions, the icon should follow the ISO standard since the matching performance was always better than that of the non-ISO for both novice and experienced drivers.

One important implication from the task screen is how many functions can be accessed easily without overloading the user [35]. After seeing the test results and feedback from the car users, designers of the manufacturer company became more cautious in placing too many icons (functions) into their new models. Luckily, some control functions can be replaced by automatic sensors or redundant coding. For example, the automatic induction light system can relieve the driver from having to turning on the beam light; the turning signal seldom relies on the visual sense but more on the sense of feel or touch. Above all, the most important issue here may not lie in the icon design itself but in the system design stage to determine what functions need to exist to meet the system objective and performance specification [38].

## 5. CONCLUSION

The current study evaluates the matching accuracy, response time, and matching sequence for 95 vehicle icons in four icon formats (image-related, concept-related, arbitrary and text). Two groups of participants, with and without driving experience, took part in this experiment. The results showed that driving experience had a significant effect on matching accuracy while the matching sequence was affected by the icon format. All participants chose to match image-related icons before other icon formats. Evaluating icon design features using subjective rating scales lacked diagnostic ability for improving the evaluated icon design. Incorporation of new icons (functions) should be carefully reviewed at the system design stage and be limited to minimize the visual and information processing load of a driver.

## REFERENCES

- [1] W. Horton, *The Icon Book: Visual Symbols for Computer Systems and Documentation*, 1st ed. Wiley, 1994.
- [2] P. Green, "Design and evaluation of symbols for automobile controls and displays," in *Automotive Ergonomics*, B. Peacock and W. Karwowski, Eds. Taylor & Francis Ltd, 1993.
- [3] C. Baber and J. Wankling, "An experimental comparison of test and symbols for in-car reconfigurable displays," *Applied Ergonomics*, vol. 23, no. 4, pp. 255–262, Aug. 1992.
- [4] C. S. Saunby, E. I. Farber, and J. DeMello, *Driver understanding and recognition of automotive ISO symbols*. Warrendale, PA: Society of Automotive Engineers, 1988.
- [5] J. L. Campbell, J. B. Richman, C. Carney, and J. D. Lee, "In-Vehicle Display Icons and Other Information Elements VOLUME I: GUIDELINES," Federal Highway Administration, Sep. 2004.
- [6] C. Carney, J. L. Campbell, and E. A. Mitchell, "In-Vehicle Display Icons and Other Information Elements: Literature Review," Federal Highway Administration, FHWA-RD-98-164, 1998.
- [7] K. N. Lodding, "Iconic Interfacing," *IEEE Computer Graphics and Applications*, vol. 3, no. 2, pp. 11–20, Mar. 1983.
- [8] R. S. Goonetilleke, M. S. Heloisa, H. K. On, and J. Fritsch, "Effects of training and representational characteristics in icon design," *International Journal of Human-Computer Studies*, vol. 55, no. 5, pp. 741–760, Nov. 2001.
- [9] S. Blankenberger and K. Hahn, "Effects of icon design on human-computer interaction," *International Journal of Man-Machine Studies*, vol. 35, no. 3, pp. 363–377, Sep. 1991.
- [10] S. Wiedenbeck, "The use of icons and labels in an end user application program: an empirical study of learning and retention," *Behaviour & Information Technology*, vol. 18, no. 2, pp. 68–82, 1999.
- [11] D. B. Stotts, "The Usefulness of Icons on the Computer Interface: Effect of Graphical Abstraction and Functional Representation on Experienced and Novice Users," *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 42, no. 5, pp. 453–457, Oct. 1998.
- [12] R. N. Shepard, "Recognition memory for words, sentences, and pictures 1," *Journal of Verbal Learning and Verbal Behavior*, vol. 6, no. 1, pp. 156–163, 1967.
- [13] A. Paivio, *Imagery and verbal processes*. Oxford, England: Holt, Rinehart & Winston, 1971.
- [14] R. E. Dewar, J. G. Ells, and G. Mundy, "Reaction Time as an Index of Traffic Sign Perception," *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 18, no. 4, pp. 381–392, 1976.
- [15] P. Muter and C. Mayson, "The role of graphics in item selection from menus," *Behaviour & Information Technology*, vol. 5, no. 1, pp. 89–95, 1986.
- [16] C. Egidio and J. Patterson, "Pictures and category labels as navigational aids for catalog browsing," in *Proceedings of ACM CHI '88 Conference on Human Factors in Computing Systems*, New York, NY, USA: ACM, 1988, pp. 127–132.
- [17] M. S. Woyalter, N. C. Silver, and S. D. Leonard, "Warning symbols," 2006.
- [18] T. E. Cyrs, "Visual Thinking: Let Them See What You Are Saying," *New Directions for Teaching and Learning*, vol. 1997, no. 71, pp. 27–32, Dec. 2002.
- [19] C. F. Chi and F. T. Lin, "A comparison of seven visual fatigue assessment techniques in three data-acquisition VDT tasks," *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 40, no. 4, pp. 577–590, 1998.
- [20] S. J. P. McDougall and I. Reppa, "Why do I like it The relationships between icon characteristics, user performance and aesthetic appeal," *Human Factors and Ergonomics Society Annual Meeting Proceedings*, vol. 52, no. 18, pp. 1257–1261, 2008.
- [21] A. W. Y. Ng and A. H. S. Chan, "The guessability of traffic signs: Effects of prospective-user factors and sign design features," *Accident Analysis & Prevention*, vol. 39, no. 6, pp. 1245–1257, Nov. 2007.

- [22] Y. C. Liu and C. H. Ho, "Age effect on comprehension of symbols in public transportation stations in Taiwan," in *Proceeding of APIEMS 2009*, 2009, pp. 658–664.
- [23] S. J. P. McDougall, M. B. Curry, and O. de Bruijn, "Measuring symbol and icon characteristics: Norms for concreteness, complexity, meaningfulness, familiarity, and semantic distance for 239 symbols," *Behavior Research Methods*, vol. 31, no. 3, pp. 487–519, 1999.
- [24] S. J. Isherwood, S. J. P. McDougall, and M. B. Curry, "Icon Identification in Context: The Changing Role of Icon Characteristics With User Experience," *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 49, no. 3, pp. 465–476, Jun. 2007.
- [25] G. Geiser, "Man machine interaction in vehicles," *ATZ*, vol. 87, pp. 74–77, 1985.
- [26] M. Tonnis, V. Broy, and G. Klinker, "A survey of challenges related to the design of 3D user interfaces for car drivers," in *3D User Interfaces, 2006. 3DUI 2006. IEEE Symposium on*, 2006, pp. 127–134.
- [27] M. Vukelich and L. A. Whitaker, "The effects of context on the comprehension of graphic symbols," in *Human Factors and Ergonomics Society Annual Meeting Proceedings*, 1993, vol. 37, pp. 511–515.
- [28] J. S. Wolff and M. S. Wogalter, "Comprehension of Pictorial Symbols: Effects of Context and Test Method," *Human Factors: The Journal of the Human Factors and Ergonomics Society*, vol. 40, no. 2, pp. 173–186, 1998.
- [29] D. C. Montgomery, *Design and Analysis of Experiments*. John Wiley & Sons, 2008.
- [30] C. C. Preston and A. M. Colman, "Optimal number of response categories in rating scales: reliability, validity, discriminating power, and respondent preferences," *Acta Psychologica*, vol. 104, no. 1, pp. 1–15, Mar. 2000.
- [31] A. Cockburn, C. Gutwin, and S. Greenberg, "A predictive model of menu performance," in *Proceedings of the SIGCHI conference on Human factors in computing systems*, 2007, pp. 627–636.
- [32] P. Green, "Visual and Task Demands of Driver information Systems.," Jun. 1999.
- [33] S.-M. Huang, K.-K. Shieh, and C.-F. Chi, "Factors affecting the design of computer icons," *International Journal of Industrial Ergonomics*, vol. 29, no. 4, pp. 211–218, Apr. 2002.
- [34] H. Saito, "Teachers' Practices and Students' Preferences for Feedback on Second Language Writing: A Case Study of Adult ESL Learners," *TESL Canada Journal*, vol. 11, no. 2, pp. 46–70, Oct. 1994.
- [35] D. Kern and A. Schmidt, "Design space for driver-based automotive user interfaces," in *Proceedings of the 1st International Conference on Automotive User Interfaces and Interactive Vehicular Applications*, New York, NY, USA, 2009, pp. 3–10.
- [36] A. W. Y. Ng and A. H. S. Chan, "The effects of driver factors and sign design features on the comprehensibility of traffic signs," *Journal of Safety Research*, vol. 39, no. 3, pp. 321–328, 2008.
- [37] S. Margono and B. Shneiderman, "1, 2 A study of file manipulation by novices using commands vs. direct manipulation," *Sparks of innovation in human-computer interaction*, p. 39, 1993.
- [38] A. Stevens, A. Quimby, A. Board, T. Kersloot, P. Burns, and T. R. L. Limited, *Design guidelines for safety of in-vehicle information systems*. TRL Limited, 2002.

# The Assessment of Acoustic and Lighting Condition in Auditoriums As Lecture Halls

Amalia Suzianti<sup>a</sup>, Sofrida Rosita<sup>b</sup>, Putri Ratnawisesa<sup>c</sup>

<sup>a</sup>Faculty of Engineering, Universitas Indonesia, Depok 16424  
E-mail : suzianti@ie.ui.ac.id

<sup>b</sup>Faculty of Engineering, Universitas Indonesia, Depok 16424  
E-mail : sofrida\_ti08@yahoo.com

<sup>c</sup>Faculty of Engineering, Universitas Indonesia, Depok 16424  
E-mail : sesa\_ti08@yahoo.com

## ABSTRACT

There are several environmental ergonomic factors that can affect the learning process of a student such as acoustic and lighting condition of the room that is used. At universities, auditoriums can be used as lecture rooms for lectures that have a large amount of participants. This research is focused on discovering the acoustic and lighting condition of auditoriums used as lecture halls at University of Indonesia. The result of this research that based on two auditoriums at University of Indonesia shows that these two auditoriums have not met the acoustic and lighting criteria set for supporting learning process.

## Keywords

*Environmental ergonomics, acoustic, lighting, auditorium, reverberation time*

## 1. INTRODUCTION

The effectiveness of the learning process can be maximized by a variety of ways, one of which is to consider the convenience of students as teaching and learning activities taking place. A student can go through the learning process in various ways: one is to see and hear. Knowing these facts, classroom facilities, site of learning activities should be able to help the human senses of sight and sound to work optimally [1].

The designer should consider that classroom environmental factors influencing the teaching-learning process in the classroom [2]. Designer in terms of classrooms, classroom factors ergonomics are a factor of major concern where the acoustics and lighting condition (audio-visual) is the physical environmental factors that influence the success of learning a student [3]. A study was also conducted by Caldwell that discussed the physical design of a university classroom to the student learning process and give estimates that the design and maintenance of a poor classroom can cause a decrease of student performance as much as 10-25% [4].

The state of the acoustics of a classroom is less well able to make the teaching-learning process. This is due to the difficulty of students to hear the material being conveyed verbally teaching, where the majority of teaching and learning activities using this communication medium. In addition, according to Burke and the Burke-Samide [5], lighting is one important element that affects the ability of students in learning. Obviously, the level of lighting in classrooms should be maintained so as not excessive [6]. This light source can be derived from artificial lighting, such as lamps and natural lighting, such as bright sky. Although much research focuses on the importance of natural light, the need for integration of natural and artificial lighting is widely accepted [6].

Although it has been known to influence of environmental factors on the performance of students in the learning process, the state of learning spaces for different levels of formal education in Indonesia is still very alarming. According to the Ministry of Education, at least 153.000 elementary school classrooms and middle schools in Indonesia are heavily damaged. In addition, there are also several classrooms at the University of Sam Ratulangi that are considered unsuitable because of the narrow room which causes learning activities not being carried out effectively. Both of these shows formal education classrooms still exist that have not been considered to support the study process and raises the question whether the University of Indonesia already has facilities that support classroom learning activities.

There are two types of commonly used classrooms at the University of Indonesia which are regular spaced classrooms and auditoriums or lecture halls. Both spaces are distinguished from the size and capacity. Regular classroom has a smaller size of the auditorium and has a capacity of 30 to 50 students. The auditorium has a size larger than regular classrooms, which can have a capacity of 100 to 300 students.

In fact, an auditorium space can indeed be said to be a space that has a variety of functions. Larger size and capacity of people to make the auditorium is used not only as a space for the implementation of college with a large number of participants, but also as a place to organize special events. However, based on research conducted by [7] on the acoustic design of a multifunctional auditorium, most auditoriums have problems with the background noise level required to affect the acoustic performance of the auditorium. Given the existence of the auditorium is a priority in the academic environment as a venue for the lecture by the number of participants, it must be noted whether the existing auditorium space can support the performance of students in learning activities. Therefore, the auditorium at the University of Indonesia needs to ensure decent enough condition to support the performance of students in learning activities, where the performance of students is one of the important role towards the success of students to compete in the global era and naming the University of Indonesia as a "World Class Research University".

## 2. METHODS

For this study, two samples taken are auditoriums at the University of Indonesia which is used for school activities. Both the auditoriums are located at the Faculty of Engineering and Faculty of Economics, where the auditorium is used not only for routine college activities that have attendees of more than 100 people, but also for student affairs and academic events. Acoustic parameters used to assess the condition of an acoustic space are:

- background noise level
- signal-to-noise ratio for speech intelligibility parameter space
- Reverberation time which is the time required by the source of sound that is stopped immediately (impulse noise) to step down in intensity by 60 dB from the initial intensity

According to the American Speech-Language-Hearing Association (ASHA), signal-to-noise ratio can be calculated by subtracting the intensity of sound that occurs with noise levels at the same location [8]. In addition, the parameters of reverberation time or reverberation time can be determined by conducting experiments with simulated impulse noise in a room or estimated by the Sabine formula. The Sabine formula is as follows:

$$RT = \frac{0,161V}{A} \quad (1)$$

Where:

RT = reverberation time in seconds

V = volume of space

A =  $\alpha \times S$ . Total absorption in the space obtained of the absorption coefficient of each surface coating material multiplied by the breadth of space.

$\alpha$  = absorption coefficient of materials

Lighting parameters used to evaluate the lighting conditions is the level of illumination (in lux) that occurs in areas of work in that space of each lecture seat. To take this research data, the devices used are a Larson-Davis Soundtrack Sound Level Meter for acoustic data as well as Smart Sensor AR-823 Digital Lux-meter. This device meets the normal specification indicated to measure the level of data noise and lighting for a work area. Before taking data, tools to be used should be calibrated prior to data obtained are accurate.

Acoustic parameter measurements are performed with two conditions; when unoccupied and when room is being used for lecture activity. Measurements made with the condition of room lights on; windows and doors closed. The instrument used for measuring is the sound level meter with a measurement scale with slow response. This is done to equalize ear hearing device with the human condition in general. Measurement points used in each auditorium can be seen in Figure 1 and Figure 2. Measurements are carried out for 30 seconds at a height of a normal human when sitting at each point.

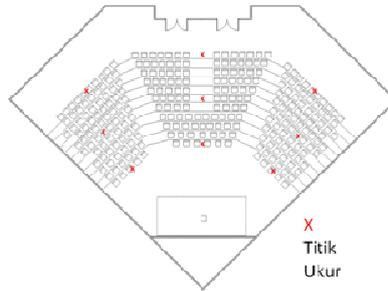


Figure 1: Measurement Points at Auditorium S. Soeria Atmadja (Faculty of Economics)

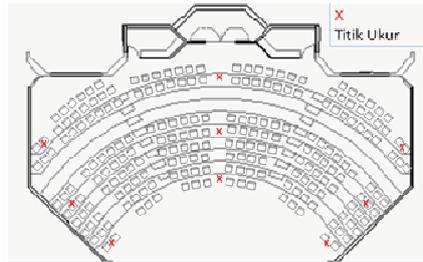


Figure 2: Measurement Points at Auditorium K301 (Faculty of Engineering)

The results of acoustic measurements using a sound level meter can be seen in Tables 1 and 2.

Table 1: Acoustic Measurement of Auditorium S. Soeria Atmadja

Row	Wing	Unoccupied (dB)	During Lecture Activity (dB)	Signal-to-Noise Ratio
1	Right	48.9	70.5	21.6
	Middle	46.8	70.1	23.3
	Left	49.1	70.6	21.5
6	Right	48.9	67.9	19
	Middle	47.2	67.3	20.1
	Left	49.1	68	18.9
11	Right	49.1	62.6	13.5
	Middle	48.2	61.2	13
	Left	47.2	62.9	15.7

Table 2: Acoustic Measurement of Auditorium Auditorium K301

Row	Wing	Unoccupied (dB)	During Lecture Activity (dB)	Signal-to-Noise Ratio
1	Right	54.8	65	10.2
	Middle	48	71	23
	Left	54.8	65.3	10.5
4	Right	48.9	61	12.1
	Middle	48	64.4	16.4
	Left	50.8	61.2	10.4
8	Right	53	56	3
	Middle	48.7	55	6.3
	Left	51.1	56.2	5.1

In this study, the parameters of reverberation time are done through estimation using the Sabine formula. To do this, a survey is conducted for both of the auditoriums to find out the inner surface material contained in the chamber and its area of each material. Tables 3 and 4 show the recorded material contained in both auditorium. After recording the materials, reverberation time is calculated in three frequencies, namely 500, 1000, and 2000 Hz. For estimation of reverberation time on speech auditorium, Acoustical Society of Acoustics says that it is essential to focus on the estimation at frequency 500, 1000, and 2000 Hz.

Table 3: Auditorium Inner Surface Material

Auditorium S. Soeria Atmadja		Auditorium K301	
Material	Area (m <sup>2</sup> )	Material	Area (m <sup>2</sup> )
Carpet	588.03	Wooden Panel	133.68
Concrete	17.75	Wooden Stage	28.3
Glass Door	72.96	Glass Door	3.8
Ceramic Tile	307.23	Chair	30.2
Wooden Panel	14.98	Gypsum Wall	36.48
Wooden Stage	52.37	Ceramic Tile	141.63
Light upholstery Chair	83.4	Concrete	233
Wooden Border	1.93	Muslin	143
		Gypsum Ceiling	306.9

For lighting measurements in auditorium, measurements are conducted using a lux-meter done on each lecture chair in the auditorium. This measurement is carried out in state where all lights were turned, where there are only sources of artificial lighting in the auditorium space.

### 3. RESULTS AND DISCUSSION

To analyze the condition of both the acoustic and lighting of the auditorium, the acoustics and lighting condition measurements that have been obtained can be compared to that of acoustics and lighting are recommended for the auditorium is used for learning activities. Acoustic parameters suggested by the Acoustical Society of America (ASA) [9] and the American Speech-Language-Hearing Association (ASHA) [8] are as follows:

- The noise level measured at each measurement point along with the average noise level is suggested that space does not exceed 35 dB.
- Reverberation time is suggested to be in the range of 1.0 to 1.5 seconds.
- Speech intelligibility can be determined by the value of Signal-to-Noise Ratio or the ratio S/N, where the ratio S/N are advised not less than +15 dB for the space used for the learning process.
- Parameter lighting for the auditorium used for lectures suggested activities are in category D which is visual task lighting to work with the contrast or large size (based on the Illumination Engineers Society) or a minimum of 250 lux on the working area [10].

#### 3.1. Noise Levels

To analyze the level of noise that occurs on both the auditorium were studied; the results of measurements have been made in terms of each measuring point. This is done to determine the cause of the noise that occurs. The cause of the noise that may occur will be analyzed based on its source is internal noise, or noise emanating from inside the room, as well as external noise, or noise emanating from the outdoor environment.

As can be seen in Tables 1 and 2, the noise levels measured in both the auditorium does not meet the recommended maximum noise level is 35 dB. In terms of external noise, the auditorium is located at a location quite alienated from environmental noise such as noise from transport. The noise level that occurs in both the auditorium can be derived from the internal noise such as equipment that functions in the space (air cooler, lighting equipment, and so on).

#### 3.2. Ratio Signal-to-Noise

To analyze the clarity of conversation in both the auditorium which has been investigated, it can be seen from the data that has been processed in Tables 1 and 2 to get the value of the ratio S / N. In the auditorium of S. Soeria Atmadja, there are seven of the nine points that already meet the standards of the ratio S / N of +15 recommended minimum. Two points which do not meet the standards of the ratio S / N suggested lies in the eleventh row in the middle and right wing with a large ratio of S / N

+13 and +13.5. Given the standard S / N ratio is recommended, both the value of this ratio is less than 2 dB to 2.5 dB in order to achieve good speech intelligibility. To find out the cause of the ratio S / N as well as how to fix it, can be seen from the two major variables that determine the ratio S / N is the noise level and sound intensity that occurs at each measuring point.

The average intensity of noise experienced by the space amounted to 66.8 dB with a fluctuation between the measuring point to 70.6 dB 61.2 dB. Sound intensity in the range of normal conversation in the room was supported by the laying of a sound source speaker as the output of the microphone used by the speaker. Speaker is laying there on both sides of the stage at a height of 5 meters. In addition, the ceiling of the auditorium has a special shape such as stairs. This causes the reflection of sound from the speakers pointed to the location of seat lecture on this space as shown in Figure 3 which shows the reflectance scheme for auditorium sound S. Soeria Atmadja.

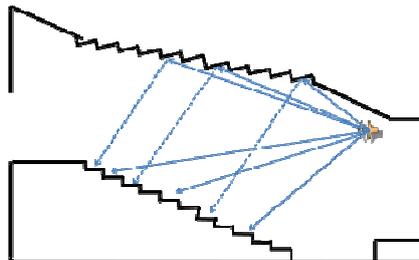


Figure 3: Sound Reflectance Scheme Auditorium S. Soeria Atmadja

In the auditorium of K301, it can be seen that only two points from nine measuring points of the space that meets the minimum value of the ratio S / N of +15 is suggested. The location of the measuring point is located in the middle of the wing first and fourth lines.

The average intensity of noise that occurs in the space of 61.7 dB with a relatively high fluctuation due to measuring point range between 55 dB to 71 dB. This suggests that the spread of the sound is not optimal, although still at the limit of the intensity of a normal conversation is between 50 to 70 dB.

These fluctuations are too large can be caused by the location of sound sources is a speaker that connects to the microphone as a speaker to speaker. The location of the speakers are on the floor in front of the stage space, so the spread of the sound is not optimal. With the laying of the speakers at the venue, the sound coming from the speaker are directed not optimal in terms of distance to reach the ears of listeners in the most remote locations. It can be seen from the schematic reflection sound contained in Figure 4 for this auditorium. Given the auditorium which has a volume of space, especially height, which is larger than the space in general, placement of the speakers should be positioned at a greater height to achieve the sound intensity is still quite enough to seat a distant location.

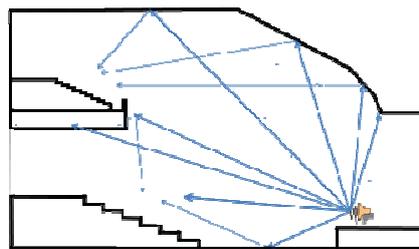


Figure 4: Sound Reflectance Scheme Auditorium K301

### 3.3. Reverberation Time

Reverberation time estimation results for both the auditorium can be seen in Table 4. Based on recommendation by the Acoustical Society of America [9], the RT of an auditorium that is used in an educational facility in the neighborhood suggested in the range of one to 1.5 seconds.

Table 4: Reverberation Time

S. Soeria Atmadja Room		K301 Room	
Frequency	RT	Frequency	RT
500 Hz	1.27	500 Hz	1.88

<b>1000 Hz</b>	1.13	<b>1000 Hz</b>	1.37
<b>2000 Hz</b>	1.02	<b>2000 Hz</b>	1.42
<b>RT<sub>60</sub></b>	<b>1.14</b>	<b>RT<sub>60</sub></b>	<b>1.56</b>

RT60 values for K301 auditorium is at 1.56 seconds is 0.06 seconds in which the value is greater than the upper limit of the recommended reverberation time. The RT that has been estimated at 500 Hz exceeds the upper limit of the recommended reverberation time, while the reverberation time at a frequency of 1000 Hz and 2000 Hz are still in a range of reverberation time recommended. Therefore, the reverberation time in the auditorium of K301 still be controlled to achieve a lower reverberation time for low frequency sound can have a lower reverberation time. To control the reverberation time in the auditorium of K301, can consider the absorbent materials used on the ceiling and the material used as a reflector panel.

RT60 values for the auditorium of S. Soeria Atmadja are within the range recommended reverberation time that is equal to 1.14 second. If you see the results of estimation of reverberation time for each frequency has been calculated that 500, 1000, and 2000 Hz, the estimated reverberation time is still within the range recommended reverberation time.

The results of the measurement data level of illumination at each seat in Auditorium K301 can be seen in Table 5. Standard lighting for a room that is used for learning is based on SNI 03-6575-2001 250 lux. Standard level of lighting can be categorized in the category D is a visual task lighting to work with the contrast or large size. As can be seen, there are still seats on the course of this space that do not meet the lighting standards of workmanship required for the illumination of 250 lux on the task. The number of college seats in this space that meets the standard of 250 lux illumination only two seats.

If viewed from the appropriate lighting levels for the activities carried on in the auditorium is the category D, there are eight seats that meet the lighting for that category. At this auditorium, there were already 152 seats or 69% of the total seats that meet the college level lighting to category C. Lighting levels for category B is owned by a 52 seat lecture or 24% of the total seats in college, while there are still three seats that meet the category A the category of the lowest standards of illumination. Table 4 shows the classification level of lighting in the lecture auditorium chairs S. Soeria Atmadja.

Table 5: Classification of Illuminations at Auditorium K301

Category	Activity	Lecture Seats	
		Amount	Percentage
A	Public place with low-lights illumination	3	1%
B	Temporary place for visit or orientation	52	24%
C	Working place for visual assignment	152	69%
D	Contrast or big scale visual assignment	8	4%
0 - 20	Unstated	5	2%

Table 6 shows the classification of college seats in the auditorium of S. Soeria Atmadja lighting by categories suggested by the Engineering Society Illumination by type of activity undertaken. Standard illumination of 250 lux lighting standards are included in category D, where already there are 30 seats that meet this category. However, the percentage of seats that meet this category only 11%. The highest percentage of seats by 36% to have lighting on the category B, where the lighting category is only intended as a temporary meeting area lighting. In addition, the seat lecture in this room there are those who are in category A which is the category with the lowest total lighting standards.

Table 6: Classification of College Seats in Auditorium S. Soeria Atmadja

Category	Activity	Lecture Seats	
		Amount	Percentage
A	Public place with low-lights illumination	32	12%
B	Temporary place for visit or orientation	99	36%
C	Working place for visual assignment	87	32%
D	Contrast or big scale visual assignment	30	11%
0 - 30 Lux	Unstated	27	10%

#### 4. CONCLUSION

- The acoustic condition of Auditorium K301 located at the Faculty of Engineering, University of Indonesia does not meet the acoustic criteria needed to support learning activities. It can be seen from the noise level exceeds the maximum limit of 35 dB, which exceeds the estimated reverberation time of 1.5 seconds, and the value of the ratio S / N of +15 dB has not met for all parts of the room.
- The acoustic condition of Auditorium S. Soeria Atmadja contained in the Faculty of Economics, University of Indonesia is good enough to meet the acoustic criteria needed to support learning activities. It can be seen that the estimated reverberation time in the range of 1 to 1.5 seconds and the value of the ratio S / N of +15 dB to meet almost all parts of the room. However, the noise level criteria for the auditorium of S. Soeria Atmadja not meet the criteria of a maximum of 35 dB.
- The lighting condition of Auditorium K301 has not fully met the recommended standards of illumination above 250 lux is based on SNI 03-6575-2001 on procedures for the design of artificial lighting systems in buildings and in Category D based on the minimum lighting category for activities in space suggested by the IES (Illumination Engineering Society). It can be concluded from the study 96% of the seats that have not been getting lighting in Category D.
- The lighting condition of Auditorium S. Soeria Atmadja has not fully meet the recommended standards of illumination above 250 lux is based on SNI 03-6575-2001 on procedures for the design of artificial lighting systems in buildings and in Category D based on the minimum lighting category for activities in space suggested by the IES (Illumination Engineering Society ). It can be concluded from the study 89% of the seats that have not been getting lighting in Category D.

## 5. REFERENCES

- [1] Felder, R.M., & Silverman, L.K. (1988). Learning and Teaching Styles In Engineering Education. *Engr. Education*, 78, 674–681.
- [2] Kr'uger, E.L., & Zannin, P.H.T. (2004). Acoustic, thermal and luminous comfort in classrooms. *Building and Environment*, 39, 1055 – 1063.
- [3] Epps, K.K. & Hill, M.C. (2009). Does physical classroom environment effect student performance, student satisfaction, and student evaluation of teaching in the college environment?. *Academy of Educational Leadership*, 14 (1), 15-19.
- [4] Smith, Thomas J. (2001). Educational ergonomics: educational design and educational performance. University of Minnesota, International Society for Occupational Ergonomics and Safety.
- [5] Burke, K, Samide. B. B. (2004). Required Changes in the Classroom Environment: It's a Matter of Design. *Journal of The Clearing House*, 77 (6),1-6.
- [6] Wilkins, A., & Winterbottom, M. (2009). Lighting and discomfort in the classroom. *Journal of Environmental Psychology*, 29, 63–75.
- [7] Legoh, F. (1993). Acoustic Design and Scale Model Testing at A Multi Pusrpose Auditorium. UK : The University of Salford.
- [8] American Speech-Language-Hearing Association (ASHA). (2005). Acoustics in Educational Settings: Technical Report. [www.asha.org/policy](http://www.asha.org/policy).
- [9] American National Standards Institute. (2002). American National Standards Institute. (2002). Acoustical performance criteria, design requirements, and guidelines for schools (S12.60-2002). Melville, NY: Author.
- [10] Badan Standarisasi Nasional Indonesia. (2001). Tata cara perancangan sistem pencahayaan buatan pada bangunan gedung (SNI 03-6575-2001). Jakarta:Author.

# Organisation Risk Management Maturity and Performance: Initial Evidence

DeoWijaya<sup>a</sup>, Budi Hartono<sup>b</sup>

<sup>a</sup>Mechanical and Industrial Engineering Department  
UniversitasGadjahMada, Yogyakarta, Indonesia  
Email: deo.wijaya@gmail.com

<sup>b</sup>Mechanical and Industrial Engineering Department  
UniversitasGadjahMada, Yogyakarta, Indonesia  
Email: boed@gadjahmada.edu

## ABSTRACT

*Risk is an inherent factor within any project implementation. In recent decades the number of project risk is increasing over time. Risk management is one the success factors to achieve project goals and to improve the organization overall performance. Traditional theories in strategic management suggest that the higher the level of project risk management the better the organization performance. On the other hand, more recent theories of strategic management suggest that there is no risk management that apply universally. It means that it is necessary to adjust project risk management for different needs and circumstances of the projects. Based on those two conflicting statements it is need a study to empirically assess instrument to measure the maturity level of project risk management compared to the performance of the organization is needed.*

*A valid and reliable instrument to measure the maturity of project risk management has been successfully developed. The instrument was adapted to Indonesia condition and well developed from six existing models that have been carried out by preview researcher through literature review and discussions with experts. The development starts with literature review to build theoretical model with several dimension, sub dimension and items. The study continues with pilot study to test the face and content validity of the instrument. Main survey is conducted to collect data from empirical study , followed by some statistical test. One of the method that being used is exploratory factor analysis. At the final step, model to indicated correlation between level of project risk management and organization performance is build.*

*The result of the research is a valid and reliable instrument well developed with empirical test. The result of empirical studies isa model to indicated the relationship between the maturity level of risk management and organizational performance is delivering with equation  $y = - 93.681 + 58.7x$ . Significance value is 0,00 which mean that there is a significant relationships between independent variables and the dependent variable. R-square value is 0.38, which mean the variation of the variables that form the organization's performance (y) can be explained by the variable level of project risk management maturity (x) by 38 per cent. Hence, this empirical study provides supporting evidence to the traditional theories*

## Keywords

*Project risk management, construction industry, top management*

## 1. INTRODUCTION

Project cannot be separated from risk, it is necessary to identify and analyze risks of the project to maximize positive effects and minimize the consequences of the negative effects. Identify and analyze the risks is called Project Risk Management [2]. Risk management is also a determining success factor of the project at the last few decades. In project risk management, risk of the project will increase caused by increasing unpredictable thing within the project [3].

The traditional theory state that the higher level of project risk management maturity of an organization is the higher value of the organization's performance [6].On the other hand [1]emerging new understanding of contingency theory. Contingency theoryis used to analyze the design and management systems to provide information that can be used by organization for various objectives. [1]states that in theory of contingency, there is no universal control system that always appropriate to be applied to all organizations in all circumstances.

The adjustment between the level of maturity and project risk management to the situation of a project needs to be done considering the trade-off between the level of use of project risk management and the costs to be incurred. [7]stated that the higher level of project risk management applied, the higher costs that may be occurred. Because of this fact, it is necessary to do empirically study, to find out which theory is the closest to the context of the conditions that exist in Indonesia. In the empirical study, an instrument needs to be developed to measure the maturity level of an organization applying their project

risk management. Then the instrument can be used to find the correlation between the levels of maturity of project risk management to organizational performance.

## **2. METHOD**

### **2.1 Research Objectives**

Generally, this study aims to determine the correlation between the level of maturity of project risk management and organization performance. Therefore it is needed to develop instrument that can be used to determine the maturity level of project risk management in the organization. This study specifically aims to: 1. Develop and test an instrument to measure the maturity level of project risk management of the organization. 2. Determine the correlation of the level of maturity of project risk management to organization's performance.

### **2.2 Stages of Research**

At this early stage, the literature study is conducted to obtain alternative variables that affect the level of maturity of an organization or company to apply project risk management. All variables that have been obtained from the study of literature are listed then be adjusted to respondents who are practitioners as contractors in the construction field in Indonesia. After selected significant variables that affecting the level of maturity of the organization then research instruments to measure the performance of the organization is developed. The next step, major surveys is conducted using instruments previously declared eligible by the pilot study, validity testing, reliability testing and exploratory factor analysis. The main survey was conducted using respondents who are practitioners to obtain empirical data.

## **3. RESULTS**

### **3.1 Development of Research Instrument**

#### **3.1.1 Literature Study**

At this stage, literature study is conducted on eight journal literature that discusses about measurement of the level of risk management models. From eight journals reviewed, there were found six different models of risk management maturity level measurement. The next step is to find the intersection from six models to develop a new model that more accurate calculation and efficient in calculating the level of maturity of an organization in the implementation of project risk management. The new model developed is also adapted to the Indonesian context.

Intersection dimension among six previous models are: culture, process, experience and application. All dimensions are used to develop new model in this study. Sub-dimension of each dimension is also developed from previous research studies. After selected the dimension and the sub-dimension the next step is to determine item questions then compiled into a questionnaire. All those things are developed and adjusted with the conditions that existed in Indonesia with a discussion with expert in the field of construction. The example of the item question is, "The project risk management in my organization is standardized", the possible answer are: Very agree, agree, disagree, vary disagree.

#### **3.1.2 Profile Respondent**

Respondents in this study are a practitioner in the construction area. Practitioners are devoted to the management organization who understands the project risk management system of the organization where they work. Respondents in this study must have working experience in the current company at least three years. That requirement is to ensure the accuracy of respondents' answers to be able to give information as closely as possible that reflect the company's current condition. Total of 35 questionnaires were returned, there are two questionnaires could not be used because the respondent has a work experience less than three years.

#### **3.1.3 Validity Testing**

Construct validity refers to whether a scale measures or correlates with the theorized psychological scientific construct that it purports to measure. It is related to the theoretical ideas behind the trait under consideration [4]. In this study validation test is conducted with look at the correlation between the items that are on the same sub-dimension (intra-correlations) than the correlation between the items at different sub-dimension (inter-correlation) [4]. Non-parametric procedure is applied because the data obtained does not fulfill normal distribution so that the correlation is used Spearman correlation [5]. As previously described instrument would be valid if the value of the correlation between the items on the sub dimension (intra-correlations) greater than correlation between items in different sub-dimension (inter-correlation). Items that did not pass the validation test will be removed from the questionnaire. The correlation items question in dimension A is presented in Table 1. Item X1.2, X1.1, X1.8 is removed from the questionnaire

Table 1: Correlation item in Dimension A

Dimension A		Sub Dim 1			Sub Dim 2			Sub Dim 3			Sub Dim 4		
		X1.2	X1.4	X1.7	X1.1	X1.5	X1.6	X1.3	X1.9	X1.11	X1.8	X1.10	X1.12
Sub Dim 1	X1.2	1											
	X1.4	<b>0.077</b>	1										
	X1.7	<b>0.15</b>	<b>.569**</b>	1									
Sub Dim 2	X1.1	0.036	<b>.483**</b>	0.208	1								
	X1.5	-0.076	0.356	0.236	<b>0.291</b>	1							
	X1.6	0.038	0.35	0.295	<b>0.323</b>	<b>.612**</b>	1						
Sub Dim 3	X1.3	<b>-.367*</b>	0.251	0.251	0.017	0.353	0.189	1					
	X1.9	0.062	0.166	<b>.488**</b>	-0.057	0.059	<b>.406*</b>	<b>.407*</b>	1				
	X1.11	0.017	0.274	<b>.539**</b>	-0.013	0.3	<b>.468**</b>	<b>.436*</b>	<b>.741**</b>	1			
Sub Dim 4	X1.8	0.095	0.3	<b>.596**</b>	0.008	-0.022	0.09	0.205	0.323	0.321	1		
	X1.10	0.141	0.285	<b>.635**</b>	-0.008	0.226	0.284	0.206	0.326	0.352	<b>0.308</b>	1	
	X1.12	0.164	<b>.461*</b>	<b>.480**</b>	0.179	0.335	<b>.382*</b>	0.282	0.343	<b>.469**</b>	<b>0.151</b>	<b>.440*</b>	1

### 3.1.4 Reliability Testing

Reliability testing is an index that indicates the accuracy measuring system can be trusted or reliable. Reliability indicates the consistency of a measuring instrument for measuring the same concept. The research instrument is reliable if have Cronbach Alpha above 0.70 [5]. Cronbach Alpha value for each sub-dimension as seen from Table 2, it shows that all Cronbach Alpha values exceeding 0.70. The results showed that all of the items for each sub-dimension are reliable

Table 2: Reliability Testing

Dim	Sub Dimension	n	Cronbach's Alpha	Intepretation
Dim A	Sub Dimension 1	2	0.713	Reliable
	Sub Dimension 2	2	0.818	Reliable
	Sub Dimension 3	3	0.812	Reliable
	Sub Dimension 4	2	0.703	Reliable
Dim B	Sub Dimension 1	2	0.736	Reliable
	Sub Dimension 2	3	0.739	Reliable
	Sub Dimension 3	2	0.798	Reliable
Dim C	Sub Dimension 1	3	0.799	Reliable
	Sub Dimension 2	3	0.799	Reliable
	Sub Dimension 3	3	0.832	Reliable
Dim D	Sub Dimension 1	3	0.774	Reliable
	Sub Dimension 2	2	0.722	Reliable
	Sub Dimension 3	3	0.732	Reliable

### 3.1.5 Exploratory Factor Analysis

Factor analysis is a multivariate method used to analyze the items that allegedly have links with each other [5]. The linkage can be described and mapped or grouped on the right factors. There are 33 items passed the test of validity and reliability. Those 33 items is tested with factor analysis. Test KMO (Kaiser-MeyerOlkin) conducted to determine the appropriateness of the factor analysis performed. Based on Table 3, it can be seen that the assumption of feasibility and adequacy of the data has been met, because there is not any value of KMO MSA less than the threshold value 0.5. Barlett Test is a statistical test to examine whether the items included in the one-dimensional cross-correlated [5]. The null hypothesis (Ho) is no correlation between the items, while the (Ha) is the correlation between items. Base on the calculation can be seen in Table 3 the significant 0.000. So Ho is rejected and Ha is accepted, it means there is an inter-item correlation

Table 3: KMO and Barlett test result

Dimensi	Kaiser's Measure of Sampling Adequacy	Barlett Test Sig.	Interpretasi
---------	---------------------------------------	-------------------	--------------

A	0.660	0,000	The data is correlated
B	0.517	0,000	The data is correlated
C	0.785	0,000	The data is correlated
D	0.571	0,000	The data is correlated

Determining the number of factors is based on Eigen value of a matrix of inter-item correlation. Factor analysis process will be terminated when the Eigen value is 1. Grouping described in detail in Table 4

Table 4: Total factor with eigenvalue calculation

Component	Total Eigenvalue			
	Dim A	Dim B	Dim C	Dim D
1	<b>4.023 (44.6%)</b>	<b>2.682 (38.3%)</b>	<b>4.607 (51.2%)</b>	<b>2.921 (36.5%)</b>
2	<b>1.448 (16.1%)</b>	<b>1.66 (23.7%)</b>	<b>1.568 (17.4%)</b>	<b>1.738 21.7%</b>
3	<b>1.198 (13.3%)</b>	<b>1.07 (15.2 %)</b>	0.801	<b>1.153 (14.4%)</b>
4	0.713	0.547	0.588	0.814
5	0.546	0.494	0.419	0.5
6	0.466	0.391	0.339	0.436
7	0.285	0.156	0.32	0.242
8	0.204		0.235	0.197
9	0.117		0.122	
	<b>3 factor</b>	<b>3 factor</b>	<b>2 factor</b>	<b>3 factor</b>

The extraction method used was principal components to distribution the items of the question in factor analysis. The division of the items into groups is based on a comparison of certain factors loading. Table 4 shows that the dimension A from nine items proposed is formed in to three factors. Component 1 had a total value of initial eigenvalues of 4.023 or 44.6%. It can be interpreted that factor one can explain 44.6% of the total factors that will influence the level of organizational maturity on the dimension of A, the dimension of culture and leadership, as well as for other dimension.

### 3.2 Correlation between Project Risk Management Maturity and Organization Performance

#### 3.2.1 Organization Performance

This section is talk about the effect of project risk management maturity level of the organization to their organizations' performance. The organizational performance is calculated based on the reduction of 100 percent (perfect condition) with a percentage of the discontinued projects, the percentage of projects that over-budget and late , the percentage of projects that experienced over budget but not delayed, the percentage of projects that are not delayed but over budget. The data of project value in organization can be collected from questioner.

### 3.2.2 Project Risk Management Maturity Level

Project risk management maturity level is obtained with factor score method. Factor score calculation is by assigning weights to each of the items that make up the sub-dimension. The weight is obtained from the value of the largest factor loading of each item in the sub-dimension. The weight is multiplied by the value of each item and then calculated as the average value of each item on the sub dimension. Distribution of the data calculated by the method of factor scores can be seen in Table 5 [5].

Table 5: Factor score calculation

	Dimension A	Dimension B	Dimension C	Dimension D	Total
Max	3.2	3.4	3.2	3.1	3.0
Min	1.8	2.1	1.7	1.9	2.0
Avg	2.7	2.7	2.5	2.4	2.6

### 3.2.3 The Model of Correlation between Project Risk Management Maturity and Organization Performance

Before performing linear regression analysis, there are some assumptions that must be met, including autocorrelation test, normality and nonheteroscedasticity error. Test the assumptions made and the data obtained that qualified to do linear regression

After linear regression assumptions are met then do a linear regression analysis. Linear regression is used to develop models to determine the correlation between maturity level of project risk management and organization performance

Table 6: linier regression result

Model	Unstandardized Coefficients		Sig.
	B	Std. Error	
(Constant)	-93.681	34.397	0.011
X	58.702	13.236	0

From the table 6 can be seen the significance value below 0.05 which means that there is significant correlation between the independent variables to the dependent variable. The regression equation can be interpreted that if the project risk management maturity level increases by one the organization's performance increased by 58.7 times with the constants value -93.681. The variable x has positive value which means that the higher the level of project risk management maturity, the higher the performance of the organization. The model is

$$y = -93.68 + 58.7x \quad (1)$$

## 4. CONCLUSION

An instrument to determine the maturity level of project risk management in the organization has been developed and have passed the test of validity and reliability. Instruments developed with reference to six similar models that have been developed by previous researchers. Instrument can be used to measure the maturity level of organization implementing project risk management adapted to the conditions that exist in Indonesia. Correlation between maturity level project risk management to organizational performance can be seen by the equation  $y = -93.681 + 58.7x$  with a significance value 0.00 and r-square 38%, which means there is a significant relationship between the independent variables and the dependent variable, in addition, the variation organizational performance variable (y) can be explained by variable levels of project risk management maturity (x) by 38%. In addition, there is a positive correlation between (y) and (x) so that it can simultaneously support the statement of [6] who said that the higher level of risk management maturity is the higher value of organization performance.

## REFERENCES

- [1] Sisaye, S., 2005, Organizational Change and Development in Management and Control System Process Innovation for Internal Auditing and Management Accounting, Elsevier Science Ltd, UK.
- [2] Project Management Institute (PMI), 1996, A Guide To The Project Management Body of Knowledge, Project Management Institute, USA.
- [3] Öngel, B., 2009, Assessing Risk Management Maturity: A Framework for the Construction Companies, The Graduate School of Natural Applied Sciences of Middle East Technical University, Turkey.
- [4] Trochim, W. M. (2006). "Construct Validity." Research Methods Knowledge Base, <<http://www.socialresearchmethods.net/kb/constval.php>> (20 Juni, 2012).

- [5] Hair, J. F., Black, W. C., Babin, B., Anderson, R. E., and Tatham, R. L. (2006). *Multivariate Data Analysis*, 6th Ed., Pearson Education, Inc., Upper Saddle River, NJ.
- [6] Elkington, S., Smallman, C., 2002, *Managing Project Risks: a Case Study from the Utilities Sector*, *Journal of Project Management* 20, pp. 49-57.
- [7] Barki, H., Rivard, S. Talbot, J., (2001), *Contingency Model of Software Project Risk Management*, *Journal of Management Information Systems*, Vol. 17, No 4 , pp. 37-69.

## Project Profit Margin Determination on Information Technology Contractors

Emmy Indriany<sup>a</sup>, Budi Hartono<sup>b</sup>

<sup>a</sup>Mechanical and Industrial Engineering Department  
Universitas Gadjah Mada, Yogyakarta, Indonesia  
Email: emmyindriany@gmail.com

<sup>b</sup>Mechanical and Industrial Engineering Department  
Universitas Gadjah Mada, Yogyakarta, Indonesia  
Email: boed@gadjahmada.edu

### ABSTRACT

The project has unique and temporary characteristics. These characters are not only found in construction projects, but also information technology (IT) projects. In the competition to win a project, contractors must carry out competitive bidding. The winner is often a contractor who offers the lowest price. Since the winner provides the lowest bid, it prones to small profit or even losses. Conversely, if the contractor expects a higher profit, then the chance of winning tender will be decreased. This is a trade-off in determining the offering price of the project.

The contractor performs the calculations by using intuitive judgment. The use of intuitive judgment sometimes produces biases. In this study, the risky behavior of bidders when determining profit margin is studied. The experiment was administered to 15 respondents from the IT solution provider companies (IT contractors). Scenarios were used in this experiment by referring to the orthogonal array (OA) of the Taguchi method. The experimental results were analyzed by using ANOVA, ANCOVA and t-test analysis then compared to the theoretical framework based on prospect theory.

Results showed that the experimental data only partially support the theory. ANOVA concluded that the scenarios tested on the respondent do not affect the respondent's decision in determining the profit margin. The analysis is continued by considering the influence of risk attitude toward profit margin. It was found that risk attitude dominates the decision determining the risk attitude profit margin as indicated in ANCOVA. The profit margin high when respondents are risk averse and risk is low when the respondents are seeking.

### Keywords

*Project, information technology (IT), bidding, experiment, prospect theory*

### 1. INTRODUCTION

According to the Project Management Institute [1] a project has two main characteristics namely temporary and unique. The project is unique based on the availability of historical data which is very limited. The limited data lead project practitioners, such as contractor, face the difficulties to make cost estimation.

In globalization era, challenges for the company to survive become much greater. One of the competitive strategies to increase the company's value is the implementation of information technology. Information technology (IT) becomes a business strategy for the company to maintain information's flow inside and outside organization. This opportunity used by the IT contractors to develop their business.

In Indonesia, bidding system that frequently used is contractors who offer the lowest price of the project will become the winner. Since the winner provides the lowest bid, it prones to small profit or even losses. Conversely, if the contractor expects a higher profit, then the chance of winning tender will be decreased. This is a trade-off in determining the offering price of the project. [2].

According to Hartono [3], there are four major components in the calculation of the project price estimation: project costs, overhead costs, contingency budget and profit margin. The profit margin determination is deemed crucial and complex from a contractor's perspective. It has a direct bearing toward contractors' well-being in the long term business. But, determining an accurate profit margin is not easy. The goal of maximizing the expected project profit was not always the case in project bids. The profit margin determination strategy might be driven by various motivations such as a strategic concern, resource capacity, and number of competitors and so on.

The fact that a profit margin determination was performed mostly by senior management by using subjective judgment that leads to human error [4]. The limited mental processing capability of human decision makers may cause errors in judgment which could eventually lead to less than accurate results (biases).

## 2. METHOD

### 2.1 Research Objects

This study will use primary data in the form of data samples to be obtained through the experimental method using a questionnaire as a research instrument. Respondents expected in this research are the senior/mid-level managers in IT contractor (IT solution provider) which has a direct involvement in the decision-making process of project bidding.

The sample size required in a study depends on the type of statistical analysis methods used. Statistical methods will be used in this study are t-test, ANOVA and ANCOVA. Field [5] says that one of the assumptions of the t-test, ANOVA and ANCOVA is normally distributed. When the data were normally distributed, the data considered sufficient. This study used 15 respondents for each scenario.

### 2.2 Stages of Research

In general, the research stage is divided into three phases, namely the development of a theoretical model, instrument development and implementation of the main experiment. Development of a theoretical model refers to one-reason decision framework developed by Hartono [3].

After the theoretical model established, the scenarios for the development of research instruments developed. The research instrument was a questionnaire form consists of several parts, namely respondent and company profiles, analytical scenarios and risk attitude measurement. Measuring risk attitude using decision analysis theory with the case of change orders that are familiar to practitioners of the project.

Before the questionnaires distributed, a pilot study conducted to validate the research instrument. Validation of the survey instrument is conducted qualitatively by the pilot study respondents to assess the design of the survey instrument. Pilot study respondents were coming from the project management student to the respondents with experience in IT projects.

## 3. RESULTS

### 3.1 Development of Theoretical Models

#### 3.1.1 Prospect Theory and Framing Effect in a Profit Margin Determination Context

The model was built following the principles of parsimony and based on relevant theories and supported by previous studies. In the development of theoretical models, the first step is to elaborate the variables that affect the determination of the profit margin in this study. Secondly, described the relationship of each variable with the determination of the profit margin. Relationship between variables past financial performance ( $X_1$ ), project backlogs ( $X_2$ ), project strategic importance ( $X_3$ ) and contractor size ( $X_5$ ) is based on research Hartono [3]. While the risk attitude variable ( $X_4$ ) is based on Kahneman and Tversky [6]'s research. Prospect Theory and Framing Effects by Kahneman and Tversky [6] are used to explain the beginning theory of the decision-making by practitioners in determining the profit margin.

In this study, the practical definition of risk was applied. Risk was related to possible downside effects on the profit margin determination. In this sense, contractors would see a profit margin determination which leads to a failure as riskier alternative. Conceptually, there are two possible competing conceptions regarding to what constitutes risky bidding, namely (a) not getting the contract; (b) getting the contract but eventually earning profit less than the aspiration [3]. The two competing conceptions are presented in Table 1.

*Table 1: Two Competing Conception on Risky Bidding*

No.		High Profit Margin	Low Profit Margin
1	The chance of NOT getting the project	Higher chance (riskier)	Lower chance (less risky)
2	The chance of earning	Lower chance (less risky)	Higher chance (riskier)

profits LESS than aspirations	
-------------------------------	--

So the hypothesis can be made as follows:

*Bidders who view their company's performance as being below aspirations tend to engage in risk seeking behavior by providing a low profit margin. While bidders who view their company's performance as being above aspirations tend to engage risk averse behavior by providing a high profit margin.*

### 3.1.2 Relationships between Past Financial Performance and Profit Margin Determination

Decision-makers in determining the profit margin consider the financial state of the company in the previous period as the aspiration to measure the level of risk. According to Prospect Theory [6] when the financial company is in the negative frame or below expectations, the decision makers will generally behave as risk seeking and provide the relatively low profit margins. This suggests an aggressive stance to increase the likelihood of winning the tender. Conversely, when decision makers see the state of the company as above expectations, the level of need for new projects is low, so the decision makers set a high profit margin. In accordance with Hartono [3], the hypothesis can be made as follows:

*H<sub>1a</sub>: Bidders who view their own companies' prior performances as being below aspirations (in terms of company-level rate of returns) tend to engage risk seeking behaviors by providing low bid markups;*

*H<sub>1b</sub>: Bidders who view their own companies' prior performances as being above aspirations (in terms of company-level rate of returns) tend to engage risk averse behaviors by providing high bid markups.*

### 3.1.3 Relationships between Project Backlogs and Profit Margin Determination

Project backlogs will reflect the company's performance in the future. When the project backlogs above company expectations, the decision makers would think that the company does not require additional project, so the motivation to win new projects will be low. Besides, if it wins a new project, it will have an impact on the need for extra capacity and will incur additional costs [7]. This will affect the decision of determining the profit margin, where the decision will set a high profit margin. And vice versa.

From this analysis, the hypothesis can be made as follows:

*H<sub>2a</sub>: Bidders who view their companies' project backlogs as being below aspirations tend to engage risk seeking behaviors by providing low bid markups;*

*H<sub>2b</sub>: Bidders who view their companies' project backlogs as being above aspirations tend to engage risk averse behaviors by providing high bid markups.*

### 3.1.4 Relationships between Project Strategic Importance and Profit Margin Determination

A project can be considered to be of strategic importance for the company, so the motivation to win such a big project. For instance, the decision maker knows that the winning project, the opportunity to get similar projects in the future more wide open. Winning projects can provide benefits to the company in the long run. From the motivations, decision-makers will act in risk seeking to determine risk low profit margins in order to win the tender project.

Conversely, if the project according to the decision maker does not provide a strategic advantage for the company, the profit margins are higher because the project is not so exciting to win. From the analysis of Hartono [3], the hypothesis is as follows:

*H<sub>3a</sub>: Bidders who view the projects as having high values of strategic importance tend to engage risk seeking behaviors by providing low bid markups;*

*H<sub>3b</sub>: Bidders who view the projects as having low values of strategic importance tend to engage risk seeking behaviors by providing low bid markups.*

### 3.1.5 Relationships between Risk Attitude and Profit Margin Determination

When associated with the determination of the profit margin, the risk factors will affect the attitude of a decision maker (estimator) in determining the profit margin of the project by ignoring the uncertainty; do overestimates or underestimates in the calculation and assessment without any clear basis [8]. Decision makers' risk behavior will be consistent with their risk propensities [8], the hypothesis is as follows:

*H<sub>4a</sub>: Risk averse bidder will provide a high profit margin*

*H<sub>4b</sub>: Risk seeking bidder will provide a low profit margin*

## 3.2 A Contingency Framework to Explain and Predict Profit Margin Determination

Hypotheses H<sub>1</sub> through H<sub>3</sub> shows the effect of each independent variable to the determination of the profit margin. Just look at their relationship when standing alone cannot represent the determination of the profit margin when all the variables that appears in the process of determining the profit margin.

Contingency approach is needed in this study to see how these three variables in the scenario of the past financial performance ( $X_1$ ), project backlogs ( $X_2$ ) and the project of strategic importance ( $X_3$ ) calculated and combined in the process of determining the profit margin.

One Reason Decision Model [9] used in this study, where a decision maker will ultimately make a decision based on one excuse after observation and a review of some of the information could potentially be a factor that influenced the decision. One Reason Decision Model consists of the priority rule, stopping rule and decision rule [9].

Initial allegations to the order of priorities in this study followed Hartono's research [2] is project strategic important ( $X_3$ ) in the order of priority. Second are project backlogs ( $X_2$ ). Last is the past financial performance ( $X_1$ ). Some of the scenarios in Table 2 were created for the show One Reason Decision Models in this study.

Table 2: Contingency Framework of Profit Margin Determination

Scenarios	$X_1$	$X_2$	$X_3$	Predicted Y Profit Margin
	Past Financial	Backlogs	Strategic	
Scenario 1	Not relevant	Not relevant	H	L
Scenario 2	Not relevant	A	L	H
Scenario 3	At least one of the three variables is B		L	L

Note: A: above aspiration, B: below aspiration, H: high, L: low

The first scenario ( $S_1$ ): decision-makers focus on the project strategic importance. In this scenario, a bidder perceives that the project strategic importance ( $X_3$ ) of a project being observed is 'high' and disregards the values of other determinants. Referring to the hypothesis  $H_3$  is when decision makers see the strategic side of a project gives high value to the company, the decision-makers will be set low profit margins to increase the probabilities of winning the project.

The second scenario ( $S_2$ ): decision makers shift his/her attention to the project backlogs. This is due to the decision makers do not see the project delivering strategic value to the company. In this scenario, the state of project backlogs companies is above expectations. This information is a stopping rule for decision-making. Referring to the hypothesis  $H_2$ , then when the project backlogs above expectations, decision makers will set a high profit margin.

The third scenario ( $S_3$ ): decision-makers shift their focus on the company's financial condition. When the financial condition of the company in the previous period below the expectation, then the decision will set a low profit margin to win the project. This scenario refers to the hypothesis  $H_1$ .

### 3.3 Instrument Development and Evaluation

Conjoint Analysis Methods or Design of Experiment (DoE) was used, using three factors (past financial performance, project backlogs and project strategic importance) and two levels. Then the full-factorial experimental design was adopted in part by using standard orthogonal array of Taguchi method.

Taguchi method was chosen because this method does not require a lot of mathematical calculations to figure combination scenario, unlike fractional factorial. In addition, by using a standardized method of Taguchi experiments, so that for the same problem is expected to provide similar results although done by different researchers [10]. Design  $2^3$  has an orthogonal array for each variable are shown in Table 3.

### 3.4 Data Processing

#### 3.4.1 Analysis of Variance (ANOVA) and Analysis of Covariance (ANCOVA)

ANOVA and ANCOVA analysis was conducted to see if the covariate risk attitude ( $X_4$ ) and the size of the contractor ( $X_5$ ) have a significant influence on the decision of determining the profit margin in IT projects.

Before the main analysis of the data, Levene's homogeneity test was conducted. Levene's test results showed that the *Sig.* > .05, It can be said to be a variant on the covariates is the same scenario that is not affected by stimulus experiments, thus meeting the assumption of independence.

Table 3: Description of Each Scenario with Taguchi Orthogonal Array

Profile#	Description		
	Level:		
	$X_1$ (past financial performance)	$X_2$ (project backlogs)	$X_3$ (project strategic importance)

1	Negative	Negative	Low
2	Positive	Negative	High
3	Negative	Positive	High
4	Positive	Positive	Low

When the model including only the three main variables that past financial performance ( $X_1$ ), project backlogs ( $X_2$ ) and the project of strategic importance ( $X_3$ ) the corrected model (SSM) is obtained 111,679. After a variable risk attitude ( $X_4$ ) is entered, corrected model (SSM) rose significantly to 529,088 by contribution risk attitude variable ( $X_4$ ) of 417,408. Is said to be a significant covariate seen from sig. processing results with SPSS,  $F(2.54) = 4.75$ ,  $p = 0.013$ , whereas the  $p$ -value  $< 0.05$ , it can be said to be a significant variable affecting the model.

Then ANCOVA analysis performed by including a contractor size ( $X_5$ ). Corrected model (SSM) ride, but not too significant, namely a 530,425 with contributions from risk attitude variable ( $X_4$ ) of 365,992 and a variable sized contractors ( $X_5$ ) of 1338. Judging from the size of the contractor's significance insignificant seen from  $F(1.53) = 0.030$ ,  $p = 0.863$ , while the risk attitude variable ( $X_4$ ) is still significant, namely  $F(2.53) = 4.090$ ,  $p = 0.022$ .

The conclusion of this analysis is the risk attitude variable ( $X_4$ ) deserve inclusion in subsequent analyzes because it proved to have a significant effect on the model. Contractor size ( $X_5$ ) does not need to be included in the analysis because it does not affect the model significantly.

### 3.4.2 Scenario's Result Based on Theory

By using one-reason decision-making determination of the approximate profit margin of each scenario can be seen in Table 4.

Table 4: The decision results from the Profit Margin Determination Theory One-Reason Decision

Scenarios	Profile Descriptions			Profit Margin
	Level of:			
	$X_1$ (past financial performance)	$X_2$ (project backlogs)	$X_3$ (project strategic importance)	
1	N	N	N	L
2	P	N	P	L
3	N	P	P	L
4	P	P	N	H

Note: P: positive, N: negative, H: high, L: low

### 3.4.3 Grand Mean Calculation

This study uses four scenarios; each scenario has 15 data from respondents. The data include respondents expected profit margin and profit margin estimates for each scenario respondent. The calculation of the average in the study using the relative profit margin ('Yhat'), which estimates the profit margin profit margin expectation reduced respondents. Grand mean calculation results are shown in Table 5.

### 3.4.4 Comparison of Results Based on average and Grand Mean Each Scenario

From Table 5, it can be interpreted that the scenario has an average below the grand mean would result in a decision determining the low profit margins. While the scenarios that have above average grand mean will result in a decision determining the high profit margins.

Table 5: The calculation results of average and Grand Mean (n=60)

		Mean (Standard deviation)	The grand mean (Standard deviation)
Yhat	Scenario 1	1.12 (8.35)	-0.54 (7.01)
	Scenario 2	-1.55 (6.27)	
	Scenario 3	-2.18 (5.88)	
	Scenario 4	0.45 (7.46)	

The decision determining the profit margin from the results of comparing the average of each scenario with its grand mean was then compared with the theoretical profit margin in Table 4. The results of the comparison are shown in Table 6.

Table 6. Profit Margin Scenario Comparison and Theory

	Theory	Yhat
<b>Scenario 1</b>	L	H
<b>Scenario 2</b>	L	L
<b>Scenario 3</b>	L	L
<b>Scenario 4</b>	H	H

Note: H: high profit margin, L: low profit margin

Table 6 shows the correspondence between the decision determining the profit margin based on the theory and experiment. Most of the experimental results fit with the theory, which are in Scenario 2, Scenario 3 and Scenario 4. While in Scenario 1, there is a mismatch between theory and experimental results.

Scenario 1 is the scenario in which all variables are negative (below expectations). Based on the theory of one-reason decision, should decide on Scenario 1 produces low profit margins. From the experimental results, Scenario 1 apparently resulted in the decision set a high profit margin, contradicting the theory.

### 3.4.5 T-test Analysis

Analysis of t-test conducted to prove the comparison of the average of each scenario with the grand mean and to see the effect of stimulus scenarios on decisions determining the profit margin

Analysis of t-test were used in this study is a one-tailed t-test. These selections were due early predictions against experimental results, which is based on theories that have been described previously. T-test analysis was performed using SPSS 16.0 software, which the adjustment to the calculation of significance using the analysis of two-tailed t-test, so as to know the sig. one-tailed t-test should be halved in advance as shown in Table 7.

Table 7. T-test Results Each Scenario (n=60, df=14)

		Standard Error	t	Sig. (2-tailed)	Sig. (1-tailed)
<b>Yhat</b>	Scenario 1	2.16	.769	.455	.228
	Scenario 2	1.62	-.623	.543	.272
	Scenario 3	1.52	-1.080	.298	.149
	Scenario 4	1.93	.515	.615	.308

From Table 7 it can be seen that the value of sig. from the Yhat's calculation are  $> .05$  so  $t$  is not significant. Each t-test calculations have a confidence level (confidence level) of 95% for the difference in the average. So, if it is assumed there are 100 samples, 95 samples will have an average value of between -4.90 to 6:28. Interval values gives the average probability is zero which means that both the average group compared samples did not differ (same), thus indicating the samples come from the same group.

The conclusion that can be drawn from this analysis of the t-test is that the sample for each scenario comes from the same population. Scenario experiments designed to manipulate variables thought to affect the determination of the profit margin, did not significantly affect the decision of the respondent in determining profit margins.

### 3.4.6 Subgroup Analysis with Entering Risk Attitude ( $X_4$ )

It has been in the ANCOVA analysis that risk attitude variable ( $X_4$ ) worth taken into account as it significantly affects the corrected model (SSM) model. In this section will analyze the profit margin ratio determination theory with experimental results which consider risk attitude held by the respondent.

The theory underlying the determination of the profit margin from the perspective of risk has been elaborated in Prospect Theory [6] that when a person has a risk-seeking nature it will be aggressive to win the tender in a way set a low profit margin. Conversely, when a person has a risk averse nature it would be conservative to maintain the peg profit margins high.

Table 8. Comparison of Theoretical and Experimental Results with Risk Attitude (n=60)

	Theory		Yhat		
			Mean	Stdev	Category
Scenario 1	<i>Seeking</i>	L	-0.1	5.366563	L
	<i>Neutral</i>	L	-1.55	2.294014	L

	<i>Averse</i>	L	5	13.43503	H
Scenario2	<i>Seeking</i>	L	-5.1	3.879433	L
	<i>Neutral</i>	L	-2.15	2.42126	L
	<i>Averse</i>	L	2.6	8.876936	H
Scenario3	<i>Seeking</i>	L	-6.1	5.683309	L
	<i>Neutral</i>	L	-1.65	2.713393	L
	<i>Averse</i>	L	1.2	6.906519	H
Scenario4	<i>Seeking</i>	H	-0.1	8.876936	L
	<i>Neutral</i>	H	-2.35	2.73633	L
	<i>Averse</i>	H	3.8	9.176056	H

Table 8 shows the comparison of the average of each subgroup with the grand mean. Can be observed that in Scenario 1, Scenario 2 and Scenario 3 the experimental results are not always the same in accordance with the theory that when respondents are risk averse. Scenario 4 shows the results of the contrary, the experiments with risk averse respondents resulted in the decision of determining the profit margin in accordance with the theory, while the other two risk attitude (seeking and neutral) resulted in a decision that profit margins are not in accordance with the theory.

It can be concluded that the risk attitude of respondents strongly influences decisions in determining profit margins. This is indicated by the overall suitability of the experimental results with the Framing Effect in Prospect Theory [6], the profit margin will be higher when respondents are risk averse and low when respondents are risk seeking.

#### 4. CONCLUSION

Based on the research that has been done, it can be concluded that in addition to the variable past financial performance, project backlogs and project strategic importance, risk attitude also significantly affects the determination of profit margins in the IT project.

From the experiments that have been conducted that analysis results obtained experimental results with a combination of variables past financial performance, project backlogs and project strategic importance only supports some theories. In addition, empirical data can be predicted better by considering risk attitude.

#### REFERENCES

- [1] Project Management Institute. (1996). *A Guide to the Project Management Knowledge*, Four Campus Boulevard, New Town Square.
- [2] Akintoye, A., and Skitmore, M. (1992). "Pricing Approaches in the Construction Industry." *Industrial Marketing Management*, 21 (4), 311-318.
- [3] Hartono, B. (2010). *Investigating Risky Decision of Construction Contractors in Competitive Bid Markups*. Doctor Philosophy's Thesis, NTU, Singapore.
- [4] Ahmad, I., and Minkarah, I. (1988). "Questionnaire Survey on Bidding in Construction." *Journal of Management in Engineering*, 4 (3), 229-243.
- [5] Field, A. (2009). *Discovering Statistic using SPSS*, 3<sup>rd</sup> Ed., Sage Publications Ltd, Los Angeles.
- [6] Kahneman, D., and Tversky, A. (1979). "Prospect Theory: An Analysis of Decision under Risk." *Econometrical*, 47(2), 263-292.
- [7] Fayek, A., Young, D. M., and Duffield, C. F. (1998). "A Survey of Tendering Practices in the Australian Construction Industry." *Engineering Management Journal*, 10, 29-34.
- [8] Sitkin, S.B., and Pablo, A.L. (1992). "Reconceptualizing the Determinants of Risk Behavior." *The Academy of Management Review*, 17(1), 9-38.
- [9] Todd, P. (2002). "Fast and Frugal Heuristics for Environmentally Bounded Minds." In: *Bounded Rationality: the Adaptive Toolbox*, G. Gigerenzer and R. Selten, eds., MIT press.
- [10] Myers, R.H., Khuri, A.I., and Vining, G. (1992). "Response Surface Alternative to the Taguchi Robust Parameter Design Approach." *The American Statiscian*, 46(2), 131-139.

# Project Risk Management Implementation in Indonesia: Initial Study

Hilya Mudrika Arini<sup>a</sup>, Budi Hartono<sup>b</sup>

<sup>a</sup> Dept of Mechanical and Industrial Engineering, Faculty of Engineering  
 Universitas Gadjah Mada, Yogyakarta, 55281  
 E-mail : hilya.mudrika.a@mail.ugm.ac.id

<sup>b</sup> Dept of Mechanical and Industrial Engineering, Faculty of Engineering  
 Universitas Gadjah Mada, Yogyakarta, 55281  
 E-mail : boed@gadjahmada.edu

## ABSTRACT

One of the success keys in project implementation is the effectiveness of implementation level of project risk management (PRM). By implementing PRM, many opportunities and risks in uncertainty project can be anticipated immediately. However, the study for capturing condition and PRM implementation in Indonesia is not yet conducted. Therefore, this study aims providing initial representation of implementation risk management project in Indonesia. This study was focused on observing the implementation level of PRM from the organization perspectives. The questionnaire was developed and distributed to 61 top managements in the construction industry with a 57.4% response rate. The questionnaire item developed considered on the study of [1] which is grouped into four dimensions, namely culture, process, experience and application. According to the culture, process, experience dimensions, the PRM implementation in Indonesia can be stated as satisfied. Nevertheless, in the application dimension, the implementation is not yet applied completely. It is depicted on the formal technique in the risk analysis which is rarely used in Indonesia (73%). This result is similar with other countries which is not yet conducted the formal technique of PRM.

## Keywords

*Project risk management, construction industry, top management, implementation*

## 1. INTRODUCTION

Project is indicated by the unique characteristics and the limited project duration [2]. Many companies and organizations conduct project management for many crucial activities such as business process re-engineering [3], change management [4], new product development and infrastructure installation. However, CHAOS report conducted by Standish Group found that in many project performances were below expectation. The trend of project performance in Indonesia is seems to be similar to those studied by Standish Group. A comprehensive study explaining about the project performance in Indonesia is not yet conducted.

One of the success keys in the project is the effectiveness of implement level of project risk management [5]. By implementing good project risk management (PRM), many opportunities and risks in uncertainty project can be anticipated immediately [5]. In addition, reference [6] also stated that the risk in projects will increase when the uncertainty level of project is high. Therefore, good implementing of risk management is prominent in order to obtain the goal of the project.

Many empirical studies had been carried on in many countries to observe actual condition and level implementation of PRM in project. Empirical studies reported that framework, method, and tools related with PRM are rarely applied by practitioner. Therefore, risk management approach has ad-hoc characteristics and not yet to be generalized because of the lack of familiarity [7], the lack of understanding [8], the insufficient knowledge and the experience [9] on applying PRM. On the other hand, time and human resource limitation become another important reason for accomplishing PRM implementation [8]. Reference [9] also argued that technical reason, such as data limitation, essentially influences in risk analysis. Otherwise, the environment factors, such as government policy and business motivation, also affect PRM implementation of industry. For instance in US nuclear power operation development, government policy significantly supported the US industry to adopt advanced PRM approach [10]. However, several empirical studies are conducted only in developed countries as resumed on Table 1. Hence, the study for capturing condition and PRM implementation in developing countries contexts, particularly in Indonesia, are strongly limited and must be conducted immediately.

Table 1: Empirical study in PRM implementation

No.	Author, Year	Domain	Location	Method
-----	--------------	--------	----------	--------

1	Akintoye and MacLeod, 1997	Construction industry	UK	Questionnaire
2	Shen, 1997	Building Contractors	Hong Kong	Questionnaire and Interview
3	Raz and Michael, 2001	Software & High-tech industries	Israel	Questionnaire
4	Wood and Ellis, 2003	Cost Consultant companies	UK	Semi-structured interview
5	Lyons and Skitmore, 2004	Construction Industry	Queensland, Australia	Questionnaire
6	Simu, 2005	Small Projects	Sweden	Semi-structured Interview
7	Tang et al., 2007	Construction Industry	China	Questionnaire, Interview & Case Study
8	Paté-Cornell & Dillon, 2001	NASA	US	[not a formal empirical study]
9	Apostolakis, 2004	Safety	'---	[not a formal empirical study]

Therefore, this study in Indonesian PRM implementation is significantly important because by capturing the actual condition of implementation PRM in Indonesia, the big picture will be used as a foundation for many initiatives related in implementing project risk management. On the other hand, in academic perspective, this overview will be used as future research foundation and framework, method and tools of risk management development in Indonesia.

## 2. METHOD

This research is a part of a series of studies to understand, to develop and to adapt novel PRM methods in Indonesia. Purposing to recognize initial condition of PRM in Indonesia, this research falls under the first stage of “understanding” stage. This research is more focused on observing the implementation level of PRM in organization perspectives rather than project practitioner perspectives. Therefore, to represent the organization perspective, this research used top management in the construction company as respondents. In addition, this research was conducted by empirical approach known as cross-sectional survey with using primary data provided by questionnaire and survey. Table 2 explains about the response rate, in which there were two methods for distributing questionnaire, namely email (26 questionnaires) and survey mail (35 questionnaires). A response rate of 57.4% is achieved with the sample size of 35 respondents.

Several stages were carried out to conduct the research. Firstly, the development of survey instrument was accomplished by adopting question items from literature studies, which was adjusted in Indonesian contexts. Afterwards, the question items were assessed qualitatively, namely face validity and content validity by conducting pilot study. Face validity and content validity are obtained by using the pilot study to six practitioners about their respond on instrument proposed. Subsequently, the instrument would be revised until the numbers of feedback were omitted. Therefore, the proposed instrument could be claimed as valid and ready to use. Finally, the result is assessed by descriptive statistics and compared by the PRM previous study in developed countries.

Table 2: Response rate

Questionnaire Distributed		Response Rate
Email	26	57.4 %
Survey Mail	35	
Total distributed	61	

## 3. RESULT AND DISCUSSION

### 3.1 Profile of Respondent

Having distributed by online survey and mail survey, the questionnaire was returned to researchers with a response rate of 57.4% (35 respondents) showed on Table 2. However by data cleansing, 2 of 35 data cannot be used in the result analysis because of the lack of experience of respondents regarding to Certified Associate in Project Management (CAPM). CAPM stated that the project practitioners can be guaranteed as the experience practitioners when they have experience more than three years. Thus, for preserving accuracy and capturing actual condition, two respondents were excluded because they only have experiences less than three years.

On the other hand, this experiment was focused on the organization perspectives. Therefore, there is required the reliable sample who must understand wholly in term of their organizations. One way to provide the reliable sample is by knowing their background, such as respondent’s position, scale of industry and so forth. Table 3 explains about the current position of respondents, which is divided into three groups, namely top management such as general manager, vice president, project manager and so forth; mid management such as process engineer, engineering staff and project control engineer; and low

management such as technical administration and technical laboratory. Regarding to Table 3, most of respondents are the top management with portion as much as 80%.

Table 3: Descriptive statistics of respondent's positions (n=30)

No	Positions	Total	Percentage (%)
1	Top Management	24	80
2	Mid Management	4	13
3	Low Management	2	7
	Grand Total	30	100

On the other hand, respondents are also classified into their company size. According to *Badan Pusat Statistika* (BPS), there are four types of company size, namely micro enterprise, small enterprise, medium enterprise and large enterprise. The first type of company size is the micro enterprise which has employee less than four people. The second type of company size is the small enterprise which the company has the employee between 5-19 people. Meanwhile, the third and fourth company size regarding to BPS are the medium enterprise which has the employee roughly 20-99 people and the large enterprise which has the employee more than 100 people. Table 4 explains the respondents according to their enterprise scale. Indeed, considering the Table 4, most of the respondents come from the small and medium enterprise.

Table 4: The size of industry based on the number of employee

No	Size of Industry	Total	Percentage (%)
1	Micro Enterprise	1	3.3
2	Small Enterprise	10	33.3
3	Medium Enterprise	14	46.7
4	Large Enterprise	5	16.7
	Grand Total	30	100

As explained before, the respondent background is also described into their experience in project management. There are three types of experience regarding to the time depicted on Table 5, namely 3-5 years, 5-10 years, and more than 10 years. The minimum requirement of respondents is three years experience for securing accuracy to figure out precisely the actual condition in their company.

Table 5: The experience of respondents

No	Experience Time	Total	Percentage (%)
1	3- 5 years	9	30
2	5-10 years	13	43
3	>10 years	8	26
	Grand Total	30	100

According to Table 5, most of respondents had been working for approximately more than five years. Hence, they understand completely in term of the risk management in their industry due to their experiences.

Table 6: The comparison between criteria in each category

Criteria	Current Study	More Successful	Less Successful	CHAOS report 2008
	Mean (%)			
Project Success	58	78.9	37	16
Project Challenged	38.6	20.3	57	53
Project Impaired	3.4	0.8	6	31

Ultimately, the respondent is divided in terms of the accomplishment in completing project during the last three years. Based on CHAOS report developed by Standish Group [11], the accomplishment in completing the project is divided into three criteria, namely project successful, project challenged and project impaired. The successful project is the project completed on-time and on budget with all features and functions as initially specified. Meanwhile, project challenged can be described as the project operated completely yet over-budget, behind schedule and offers fewer features and functions than originally specified;

and the impaired project is the project cancelled at some point during the development cycle. Hence, to compare the study result and the CHAOS report, the study also divides the respondents into three criteria which the same with CHAOS report criteria. However, to make it detail, this study also divides the respondent into two groups, namely more successful and less successful based on their performance to accomplish the project. The more successful group is the respondent having the portion of project success under the average (58%) and vice versa.

Table 6 compares between the portions of project performances of the respondent and CHAOS report. The percentage of project success in this study is more than three times higher rather than CHAOS report. On the other hand, the percentage of project impaired according to CHAOS report is ten times higher than PRM in Indonesia. Briefly, in a glance, the accomplishment level of successful project in Indonesia is better than result of CHAOS report in 2008.

Meanwhile, considering the group of project performance, the more successful group has the highest number in the portion of project success and the lowest number in the portion of project impaired. Meanwhile, compared to the others, the less successful group has the highest number in the portion of project challenged, in which it is similar to the CHAOS report.

### 3.2 Project Risk Management Implementation in Indonesia

The questions item consists of four dimensions considering the previous study conducted by [11], namely culture, process, experience and application. The summary of the comparison of each dimensions depicted in Table 7. Culture dimension is related to the companies' awareness of the important of PRM implementation [6]. This dimension explains comprehensively about the attitude of each company eliminates risk during the project, such as senior manager's response as well as commitment and leadership of the organizations to support the implementation of PRM.

According to the data collected, 90% of respondents are aware to PRM implementation. It is depicted on their commitment that PRM is one of the success keys and a part of sequential efforts to achieve the company's target. Compared to the developed country, such as UK, the companies' awareness of PRM in Indonesia is significantly excellent. It occurred since PRM members in UK are unconscious to conduct PRM due to the lack of familiarity in term of risk management [8]. The top management in most of project in UK did not provide the contribution to conduct the PRM. It is similar to the PRM implementation in Queensland which the most barriers for implementing PM are the top management [7]. Nevertheless, it is strongly different with 96.7% of the top management in Indonesia who always supports and contributes to PRM implementation by being a raw-model through providing the real evidence to other members. On the other hand, 76.7% of the top management also awards an achievement to project member who has the most contribution in PRM.

On the other hand, in order to conduct PRM, not only top management which must aware to PRM implementation, but also all of members related to project. All members must understand the possibility of risk embedded during the project. This behavior to inform and notify the risk to all members had been applied in Israel, Queensland and China. They utilize the brainstorming to identify risk information before the project started. Surprisingly, this behavior to inform risk to all project members is also adopted by 93.3% of construction industry in Indonesia.

The second dimension is process dimension. It highlights about the standard process and the ability of organization in term of dealing with risk [6]. In this dimension, the good risk management is a stepwise procedure composed of several processes whether it can be repeated continuously throughout the project lifecycle. Commonly, the organization which is aware to risk uses the historical data in term of risk in the last similar project in order to become the standard process of the next project. According to the data collected particularly in this dimension, 96.7% of PRM implementation in Indonesia also uses the historical data by collecting the feedback of the last similar project to improve their performance in the further similar project. The other way to improve the performance is conducting the monitoring, evaluation and audit process during the project. This is similar with PRM in Indonesia which 90% of project in construction industries use them for improving the further project. Meanwhile, PRM implementation in China uses another way called joint evaluation in order to assess risk [12]. Surprisingly, the use of PRM is not only applied on the developed countries but it is also implemented other domains, such as US Nuclear project and NASA. US Nuclear project had conducted integration among other PRM processes in order to obtain the effectiveness of project, such as quality management and government policy. Therefore, many project members tried to use the advanced PRM approach in order to accomplish the policy. In line with US Nuclear Power, NASA also used PRM as the routine procedure [10]. Hence, it is not separated from the project implementation itself. However, the implementation of PRM in two instance domains are significantly different with PRM implementation in Indonesia which tends to ad-hoc rather than make PRM as the routine procedure equal to NASA project.

The third dimension is known as experience dimension explaining about how the organization members face the project risk. The goal of this dimension can be achieved successfully when all members can use basic risk management skill in order to support risk management process in the organization. Therefore, the regular training to enhance the skill of PRM members is strongly required obtain the goal of this dimension [1].

Table 7: The comparison between PRM in Indonesia and other developed countries

Point of Interest	Past Studies		Current Study
	Location, Year	Findings	
1. Culture	UK, 1997	Most of PRM member in UK is not aware to conduct PRM because of the lack of familiarity [8]	90% of respondents stated that their company is aware whether PRM is one of success factors and a part of sequential effort in their company
	Queensland, Australia, 2004	Most of PRM barrier is caused by resource constraint [7]	60% of their top management always supports and commits PRM implementation with real evidences. 76.7% of respondents stated that their company always provides an achievement to project member who has the most contribution in PRM
	Israel, Queensland and China	Brainstorming is conducted to identify and provide risk information	93.3% of respondents stated that their company usually notified risk information
2. Process	US, 2001	US Nuclear regulations push the industry to adopt more advanced PRM approach [10]	90% of respondents stated that PRM process in their company is integrated with the other PRM process, such as quality management, government policy and so forth.
	US, 2001	PRM is lagging behind other domains such as NASA in applying risk concepts. NASA has risk standardization, from resistance to routine procedure [10]	Only 73.3% of respondents stated that ad-hoc PRM is usually used in their company
3. Experience	Queensland, Australia, 2004	Most of PRM barrier is caused by resource constraint [7]	73.3% of respondents stated that PRM training is usually conducted in their company
	China, 2007	PRM member usually conduct joint evaluation to analyze risk [12]	86.7% of respondents stated that their company usually uses the evaluation of project as a lesson learning
	UK, 1997	Lack of understanding in PRM [8]	86.7% of respondents stated that project member in their company is understand of PRM concept
	Hong Kong, 1997	Insufficient knowledge and experience on applying PRM [9]	
4. Methods	UK, 1997	The increased availability of computers do not appear to have much impact on the tools being used [7]	90% of respondents stated that their company has operated the computer to PRM activity, for instance cost accounting, database and scheduling.
	Queensland, Australia, 2004	The use of computers was found to be consistently lower in PRM than this in other project applications, such as cost accounting, database and scheduling [9]	
	China, 2007	The use of computers and modeling techniques in risk analysis is seldom used [12]	
	UK, 1997	PRM uses few formal techniques [8]	26.7% of respondents stated that their company rarely used formal technique in risk analysis in PRM implementation

Regarding to the data collected, 86.7% of PRM members in Indonesia are sufficient in understanding of PRM concept. This condition is strongly influenced by the effectiveness and the frequency of training and evaluation which are conducted frequently to urge the PRM knowledge of each member. This strategy, training and evaluation, had been conducted by China

as well for eliminating the probability of risk in the further project [12]. Therefore, surprisingly, it significantly influences the project performance in China.

Dissimilar to China, the project members in UK and Hong Kong have different knowledge of PRM in which the knowledge is not distributed uniformly in each member. Thus, only particular project member understands comprehensively in terms of PRM [9]. Whereas, supporting of all project members in the implementation of PRM is strongly prominent because the commitment of top manager in the first dimensions is not adequate without the commitment of all members as well to accomplish the project goal. Hence, the strategy such as explained before is important to conduct it.

Meanwhile, the last dimension is the application dimension. It provides detail in tools and method required to handle risk. Reference [1] stated that the good project organization in this dimension must identify and analysis risk with integrating and using both quantitative and qualitative methods and tools. Practically, tools and method using in PRM implementation in Indonesia is more advance and sophisticated rather than other developed countries. It is supported by two evidences. Firstly, 90% of respondents have operated the computer to PRM activity, for example cost accounting, database and scheduling. Whereas, many countries in China, UK and Queensland, rarely use computer in PRM activity compared to other countries. Reference [7] stated that the computers for PRM activity rarely use particularly in Queensland. In line with reference [7], reference [12] stated that the use of computer and modelling techniques in risk analysis are seldom utilized in China since the increasing of availability of computers does not affect significantly in the project performance.

Secondly, 73% of respondents argued that simple technique is worthless to prevent risk in PRM implementation. Therefore, PRM practitioner in Indonesia tends to provide advanced method to eliminate risk. Compared to several projects in UK, they only use the simplest model to estimate the risk which will be probably appeared [13]. As the consequences, the tools such as influence diagram, neural network and other complex tools are rarely used in develop countries to estimate the risks.

Nevertheless, though PRM has the excellent on the application of this dimension, the formal technique in risk analysis is rarely used in Indonesia (73%). In line with PRM Indonesia, reference [8] conducting PRM research in UK stated that PRM implementation in UK also uses few formal techniques, similar to Sweden and China.

#### 4. CONCLUSION

According to the result in the previous chapter, explained that most of the dimensions are placed in the pleasant condition. Firstly, PRM implementation in Indonesia is incredibly excellent not only in their member and top management but also in providing risk information in the culture dimension. Secondly, related to process dimension, PRM implementation in Indonesia is conducted smoothly. For instance, it can apply in the routine procedure as other domains. Thirdly, considering on experience dimension, PRM member is categorized as a proficient member because of their knowledge of PRM due to their frequently training. Ultimately, however, in the last dimension, PRM in Indonesia must be improved particularly in term of using the formal technique. In conclusion, by considering on the four dimensions, PRM implementation in Indonesia can be categorized as the good implementation of PRM.

Nevertheless, this study about PRM implementation in Indonesia is not completely explain the detail condition PRM implementation in Indonesia but only provide the big picture of PRM implementation in Indonesia due to three reasons. First, the type of industry used on this study is only construction industry. Therefore, other type of industry such as service, information technology (IT) industry and so forth are not considered. Hence, the further research can be more considering towards other enterprise types in order to represent the detail and the real condition in Indonesia.

Second, this study is conducted on the newest period compared to other PRM study in the developed countries. The last study in the literature review is study conducted by reference [12]. Hence, it might appear the improvement of PRM implementation after five years of Tang's study.

Third, the use of expert judgment as the input of this study does not accurately represent the real condition during the project. Reference [14] stated that the expert judgment can provide the systematic bias when they must estimate. Therefore, to solve this limitation, the further study must be conducted particularly to develop the standard instrument to measure the expert judgments particularly when they must estimate risks which will be appeared.

#### REFERENCES

- [1] D. Hillson, "Understanding risk exposure using multiple hierarchies", *PMI Global Congress EMEA Proceedings*, 2007, Budapest.
- [2] PMI, "Guide to the project management body of knowledge 2000 ed.", *Project Management Institute, Pennsylvania, USA*, 2000.
- [3] J. Valimaki and T. Tissari, "Risk management focus in business reengineering initiatives", *The IPMA Symposium on Project Management 1997*, Managing Risk in Projects. Helsinki, Finland, 1997, pp. 233-242.

- [4] J. Pollack, "The changing paradigms of project management.", *International Journal of Project Management*, vol. 25, 2007, pp. 266-274.
- [5] C. Chapman and S. Ward, "Project risk management: process, techniques, and insights 2nd ed", 2003, John Wiley & Sons, West Sussex.
- [6] B. Öngel, "Assesing risk management maturity: a framework for the construction companies", *The Graduate School of Natural Applied Sciences of Middle East Technical University*, Turkey, 2009.
- [7] T. Lyons and M. Skitmore, "Project risk management in the Queensland engineering construction industry: a survey, *International Journal of Project Management*, 2004, pp. 22(1), 51-61.
- [8] A.S. Akintoye, A.S. and M.J. MacLeod, "Risk analysis and management in construction, *International Journal of Project Management*, vol. 15 no.1, 1997, pp. 31-38.
- [9] L.Y. Shen, "Project risk management in Hong Kong", *International Journal of Project Management*, vol. 15, 1997, pp. 101-105.
- [10] E. Paté-Cornell and R. Dillon, "Probabilistic risk analysis for the NASA space shuttle: a brief history and current work." *Reliability Engineering & System Safety*, vol. 74 no.3, pp. 345-352, 2001.
- [11] Standish Group, CHAOS Report, Standish Group International, 2008.
- [12] W. Tang, "Risk management in the Chinese construction industry", *Journal of Construction Engineering and Management*, vol.133 no.12, 2007, pp. 944-956.
- [13] G.D. Wood and R.C.T. Ellis,"Risk management practices of leading UK cost consultants", *Engineering, Construction and Architectural Management*, vol. 10, 2003, pp. 254-262.
- [14] F.I. Nugroho, "Judgmental Biases on Project Time Estimation Utilizing on Expert Judgment: an Experimental Approach", 2011, Undergraduate Thesis, Mechanical and Industrial Engineering, Universitas Gadjah Mada.

## Feasibility Study on the Selection of Alternative Access Road to Gunaksa Harbor

Hermawati,Putu<sup>a</sup>; Sudiarsa,Made<sup>b</sup>; Mas Pertiwi,I.G.A.I<sup>c</sup>; Oka Aryawan,I.G.M<sup>d</sup>; Salain,P.D.P<sup>e</sup>

<sup>a,b,c,d,e</sup> Civil Engineering Department  
 Bali State Polytechnic, Kuta Utara Badung Bali 80363  
 Tel : (0361) 701981. Fax : (0361) 701128  
<sup>a</sup>E-mail : pt\_herma@yahoo.com  
<sup>b</sup>E-mail : madesudiarsa42@yahoo.com  
<sup>c</sup>E-mail : aishwtari@yahoo.com  
<sup>d</sup>E-mail : okaaryawanigedemede@yahoo.com  
<sup>e</sup>E-mail : danasalain@pnb.ac.id

### ABSTRACT

*Gunaksa harbor is a harbor which provides crossing from Bali to Nusa Penida Island or vice versa. The harbor is located at Gunaksa beach, which has not had access to harbor. Thus, a way leading to Gunaksa harbor needs to be built to ease the accessibility and mobility from and to the harbor. Except being a crossing site, the harbor is going to be developed to be a tourist harbor and a back up for Padang Bai harbor. In addition, at area at the harbor surroundings (the ex of entrenchment) will be developed from a nonproductive land to be a land related to tourism, residence, and other public facilities. To realize road construction to the harbor, a feasibility study of some aspects, including route, environment, economics, as well as financial aspect should be undertaken.*

*Construction of a new road generally requires quite high financial investment and maintenance cost, that aspect of needs and functions for society and its investment feasibility should be considered. Due to the construction plan there are four alternative routes that should be analyzed, including: 1) that with 1.77 kilometers long, 2) that with 2.02 kilometers long, 3) that with 2.05 kilometers long, and 4) that with 2.25 kilometers long. The four alternatives will be analyzed with a number of indicating variables, such as length or distance, congestion rate, land acquisition, travel cost (travel time value and vehicle operating cost), environmental impact and area development using Analytical Hierarchy Process (AHP) method. AHP is a method implemented to analyze a complex multiple criteria to be a hierarchy which is then analyzed using matrix to obtain range of priority based on the criteria. The analysis result showed that access alternative 1 has the highest matrix score or is the 1<sup>st</sup> rank.*

*By operating the access alternative 1, the travel time spent will be 2.655 minutes, the lowest travelling time value is Rp 89,488,813 per year, the lowest vehicle operating cost is Rp 40,325,515 per year. It will result in the lowest travelling cost Rp 129,814,328 per year and the benefit will frequently increase in the future.*

*Analysis on investment feasibility based on criteria used with interest rate 12%, 15%, and 18% showed that the total NPV values was positive; BCR > 1 with the lowest BCR value 1.98. Pursuant to assumption of bank interest rate 18% per year, IRR value was 33.52% which is higher than the interest rate. It indicates that the alternative access investment is economically feasible. Based on sensitivity analysis with assumption of interest rate 18%, that there was increase in cost 20% and decrease in benefit 20%, the analysis also showed that NPV > 0, BCR = 1.5, and IRR = 24,86% which is higher than the interest rate. It indicates that the investment was not sensitive to change of benefit and cost to 20%. It can be concluded that based on all indicators used in this study showed that the construction of alternative access 1 to Gunaksa Harbor is feasible to undertake.*

### Keywords

*Vehicle Operating Cost (VOC) Saving, Travelling Time Value, Net Present Value (NPV), Benefit Cost Ratio (BCR), Internal Rate of Return (IRR)*

### 1. INTRODUCTION

Klungkung regency is located at east Bali. The regency has a major island of Nusa Penida which is separated from the main land of Klungkung and is still under the administration of Klungkung Regency. Seeing from its area width composition, one

third of the regency total width is located at the main land (11,216 Ha) and the rest two third is at the island of Nusa Penida (20,284 Ha). Since 2007 until 2012 the Government of Klungkung had been establishing Gunaksa harbor as the access for crossing to the Nusa Penida island. The harbor construction is intended to smooth sea transportation and accessibility between the two lands, i.e. Klungkung main land and Nusa Penida Island in order to maintain a better, routine, and fast transportation.

Development of sea transportation is closely related to land transportation as a supporting access to the continuity of the harbor operational. To achieve this target, this shall be supported with a good access road to the harbor which connect harbor hinterland and harbor area. The planned construction of access road to Gunaksa harbor is a transportation facility between Nusa Penida harbor with Gunaksa harbor. The access road plays a role strategically and importantly as it is one of knot crossing network of which break the isolation of island outside Bali area and is hoped to enhance economic activities in Klungkung regency particularly and in Bali generally.

In line with the rapid development of economy in Indonesia in general and in Bali particularly, development of access road to Gunaksa harbor is completely needed. In order for them to realize it, study on the best alternative access to the harbor shall be conducted to see its feasibility based on a number of aspects, such as route, environment, economy and financial aspect. The empirical study can be used as a reference for the Government of Klungkung in prioritizing development in that area.

## **2. THEORETICAL BACKGROUND**

### **2.1 Project Feasibility Study**

Feasibility study is a research or study undertaken comprehensively based on some aspects in purpose to analyze a project's level of feasibility. A project's level of feasibility is an important initiating stage of the activity of a set of project cycle. The same case is also valid for projects of transportation. The result of the study is a recommendation whether the project needs to be continued to further stage. In other word, the study of feasibility is intended to analyze to what extent the project's level of feasibility, so that the limited natural resource can be allocated appropriately, efficiently, and effectively. A project shall be executed in the case that it can be accountable economically and financially (Kadariah, 2001). Thus, it is very clear that a project's feasibility study is required as an assistance for a decision making process.

### **2.2 AHP (Analytical Hierarchy Process) Method**

AHP is a decision supporting model developed by Thomas L. Saaty (1994). The model will break down a complex multiple-factor problem or multiple criteria to be a hierarchy. According to Saaty, hierarchy is defined as a representation of a complex problem in a multiple level structure where the first level is purposed, followed by factor level, criteria, sub criteria and further down until the last level of alternative. With a hierarchy, a complex problem can be broken down into its groups, then it managed into hierarchy format so the problems show more structurally and more systematically.

### **2.3 Vehicle Operating Cost (VOC) Saving**

Theoretically, vehicle operational cost is influenced by a number of factors, such as vehicle condition and type, environment, rider habit, road condition, as well as traffic. The cost is estimated for types of vehicle representing their group, and is stated in a monetary per unit of distance (Rp/km). Nowadays, there are various model and method of calculating VOCS, namely Pacific Consultant International (PCI) Capacity Manual, Highway Design and Maintenance (HDM), World Bank, Indonesian Highway Capacity Manual (IHCM), and Central Road Research Institute (CRRI). There are also a number of VOCS counting models in Indonesia. In this research, the vehicle operation cost model which is focusing on vehicle speed by LPM ITB whereas vehicle operation cost is the total of running cost and standing cost.

### **2.4 Travelling Time Value**

Time is a real cost in transportation. Travelling time value or time saving value is defined as the total amount of money willing to spend by someone to save one time unit of journey (Hensher, 1988). In a project's feasibility study, traveling time saving is total travel time deviation with that or with no project. Saving time value per time unit which is usually taken per hour, shall be counting also the time daily saving. The total daily time cost is then converted into yearly time cost and then its result is used to be net value to obtain time cost saving.

## **3. RESEARCH METHOD**

### **3.1 Access Alternative Selection Method**

For the best alternative choosing from a number of existing access alternatives, method of AHP was applied. In this method, some stages were conducted as follows:

1. Defining problems and determining solution used.
2. Making a hierarchic structure preceded by the main goals
3. Making a paired comparing matrix describing relative contribution or the influence of each element to aim or criteria which is at the same level as that above it.
4. Defining paired comparison to obtain the total assessment result of  $n \times [(n-1) 2]$  pieces.
5. Counting value of Eigen and examining its consistence.
6. Rewinding steps 3, 4, and 5 to all levels of hierarchy.
7. Counting Eigen vector of each matrix of paired comparison which is the value of each element for determining priority on the elements at the level of the lowest hierarchy to achieve the goal.
8. Checking hierarchic consistence with consistence risk of lower than the same as 10%.

### 3.2 Economic Feasibility Assessment Method

Some investment criteria will be used to evaluate the project feasibility economically or financially is Net Present Value (NPV), Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR). Economic analysis is based on net economic cost-benefit analysis by comparing economic benefit “with” and ”without” project. The benefit difference between “with” and “without” project development is benefit gained by the project development.

#### 3.2.1 Net Present Value (NPV)

*Net Present value* (NPV) used base point at present. Thus, all inflow and outflow are converted to the present value with interest rate determined. It is then formulized mathematically as follows.

$$NPV = \sum_{n=0}^N \frac{B_n - C_n}{(1+i)^n} = \sum_{n=0}^N \frac{F_n}{(1+i)^n} \quad (2)$$

NPV > 0 investment is considered to be economical

NPV < 0 investment is not considered economical

where:

$B_n$  = benefit accepted in the end of the year n

$C_n$  = cost spent in the end of the year n

$F_n$  = difference between cost and benefit in the end of the year n

#### 3.2.2 Benefit Coat Ratio (BCR)

Benefit cost ratio (BCR) is comparison between benefit and cost at a same point, such as present worth, future worth or annual worth

$$BCR = \frac{PresentWorthBenefit}{PresentWorthCost} \quad (3)$$

BCR > 1, investment is considered economical

BCR < 1, investment is not considered economical

#### 3.2.3 Internal Rate of Return (IRR)

Internal rate of return is interest rate producing NPV equally zero. In IRR analysis we wish to know what “r” is, thus:

$$\sum \frac{B_t - C_t}{(1+r)^t} = 0 \quad (4)$$

Where:

Bt = total of project advantage component in the first year.

Ct = total of cost component in the first year

r = IRR producing NPV = 0

The value of  $r$  making  $NPV = 0$  is then called IRR of the project. Criteria used to determine whether a project is considered feasible is the condition where IRR is bigger than discount rate or  $IRR > i$ .

### 3.2.4 Analysis of Sensitivity

In order to know how sensitive a decision is to factors change that is influencing it, every decision making on technical economics shall be with analysis of sensitivity. The analysis of sensitivity is will contribute to a description to what extent a decision will be strong enough to face factors change or parameter influencing it. In case that the factors change results in change in the decision, the decision is said to be sensitive to the parameter value change (Pujawan, 1995). Analysis of sensitivity was done by changing value of a parameter a time, then we had to see how is it impact to acceptability of an investment alternative. The Parameters which usually change and whose change can influence decisions in technical economics study is investment cost, benefit value, interest rate, and others.

## 4 RESULT AND DISCUSSION

### 4.1 Access Road Alternative Conditions

Road access to Gunaksa harbor is designed with 4 alternatives (figure 1), where the alternatives are designed with the same road class as the figure beneath.

- a. Road Type and class : type II, class I
- b. Functional Class : Primary collector road
- c. Road length : 1.770m (Sta 0+000 to Sta 1+770)
- d. Median : completed
- e. Track number and width : 2 tracks, 4 sub tracks, 4 X 3.5 m
- f. Own Road Width : 30 m wide

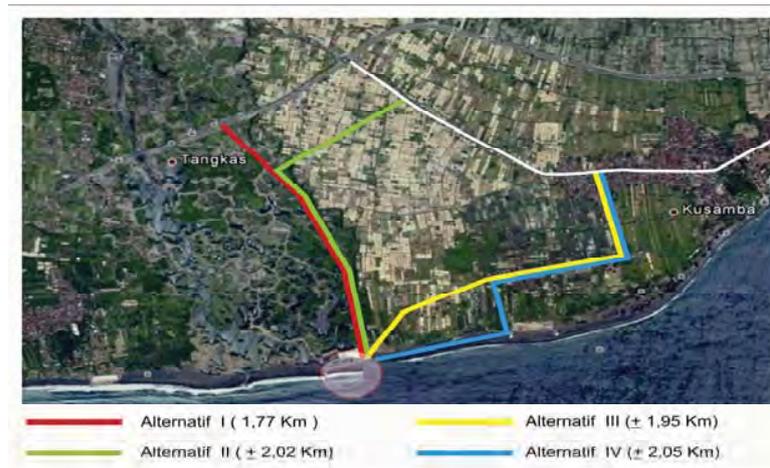


Figure 1: Four Alternatives Route to Gunaksa Harbour

Technical data and Environment for four route alternatives :

#### a. Alternative 1

- Its location is at Gunaksa Village extending from the North (at eastern part of Bridge of Unda River II) to south until the End of Gunaksa Harbor
- Road alignments are made to connect the harbor with the hinterland
- The road alignment site was consolidated by Government of Klungkung. The alignments are made 1.770 m long extending from the highway of Ida Bagus Mantra until Gunaksa harbor.
- Basically, its horizontal alignments can be said to be straight without any sharp turning and its vertical alignments are considered extreme since there are fairly deep entrenchments.
- The topographic condition of the lower road varied where there are a lot of entrenchments ex using power tools and sand suction machine with extremely 15 meters deep. The entrenchments are full of water.
- There are 4 big entrenchments in the site, there are Sta. 0+625, sta. 1+450, sta 1+550, and sta. 1+700. The extremely deepest entrenchment is that of 15dpl at sta. 1+700.
- Apart from the entrenchment there is dry land with topography between 0 until +12.00 dpl. The dry land consists of mound of sand and soil.

- Basically, the land is not inhabited by people. However, some people are fond to do activities of traditional mining.
- There is no wet agricultural land at all.

**b. Alternative 2**

- The site of the second alternative is quite similar to the first alternative, from Kusamba street exactly 500 meter from the High Way cross road going to Kusamba going through rice field area to west part reaching sta. 0 +500 in alternative 1, and extending to the south until the end of the harbor.
- Some of the alignment sites had been consolidated by Klungkung government. The alignments are made for 2.020 meters length extending from Kusamba street until Gunaksa Harbor.
- Based on horizontal alignment, the road alignment is shaped L where there is one quite sharp turning. However, based on vertical alignment, the alignment condition is very extreme because there are ponds and quite deep entrenchments about 1.200 and it is a rice field area of about 800 m long.

**c. Alternative 3**

- Its location is at Kusamba village starting from Gunung Batur street (Batur and Rame sub-village). It is following the existing road to Karangdadi sub-village existing to the west going to the harbor.
- Half of the alignment is using the existing road of 3–5 m wide, and the rest half of the alignment is still a rice field area.
- The alignment is made 1.950 m long extending from Kusamba streets to Gunaksa harbor.
- Based on its horizontal alignment, the road alignments are quite winding, and based on its vertical alignment the condition of alignment is not very extreme because some of the alignment area is the existing area where there are housing and rice field along the road.
- Its topographic condition is quite good since there are not entrenchment as in alternative 1 and 2.
- The area is basically a residing area.
- The wet agricultural activities are still productive at the area since 60% of all citizens are farmers and fishermen.

**d. Alternative 4**

- It is located at Kusamba village, starting from Batur street (Batur and Rame sub village), following the existing road to Karangdadi sub village, and then turn to the south to the Fish Docking Harbor (FDH) of Karangdadi and extending to west to the harbor passing the beach.
- Half of the alignment is the existing road with width of 3 – 5 m. The rest area of the alignment is still in form of rice field area. The alignment is made 2.050 m long extending from Kusamba street until Gunaksa harbor.
- Based on its horizontal alignment, the road alignment is quite winding. However, based on vertical alignment, the road alignment condition is not too extreme as the half of the alignment is the existing street which is still surrounded with residing place and rice field area.
- Some parts of the area is dry sand land as it is located at the beach side of Gunaksa.

**4.2 The route choosing analysis with Analytical Hierarchy Process (AHP) method.**

Diagram of decision making on route maintenance is shown in figure 2 as the basis for making matrix with the following variables.

Choice of Variable:

I = alternatif 1 with distance 1,770 Km

II = alternatif 2 with distance 2,02 Km

III = alternatif 3 with distance 2,05 Km

IV = alternatif 4 with distance 2,25 Km

Variable of comparing Criteria (indicator)

A = distance/length

B = level of density

C = land acquisition

D = travel cost

E = environment impact

F = area development

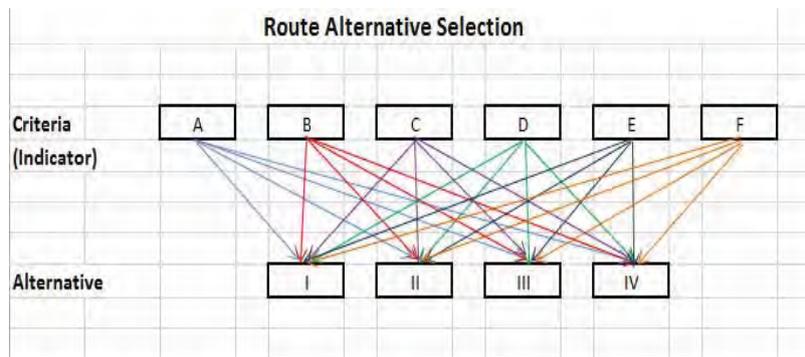


Figure 2: Decision Making Diagram

Based on matrix analysis in some stages with various above mentioned criteria, matrix result is shown as in table 1. The table shows that the one obtaining the highest matrix multiplying score (rank 1) which is considered as the best alternative is alternative access road route 1 whose location is based on the figure 1.

Table 1: Final Matrix on AHP Analysis Result

	A	B	C	D	E	F	MULTIPLICATION MATRICS	RANK ALTERNATIVE
I	0.18	0.24	0.25	0.18	0.10	0.05	0.46	1
II	0.66	0.07	0.58	0.67	0.58	0.10	0.19	2
III	0.17	0.14	0.21	0.17	0.30	0.16	0.17	4
IV	0.13	0.30	0.13	0.12	0.07	0.28	0.18	3
	0.04	0.48	0.07	0.04	0.05	0.47	1	
	1	1	1	1	1	1	1	

### 4.3 Economic Feasibility Analysis

Economic feasibility analysis will be carried out to access road alternative to Gunaksa harbor obtaining the highest rank based on the above mentioned analysis which also has various betterment, that is access road of alternative 1.

#### 4.3.1 Project Cost

Cost component calculated in planning the investment on the access road development to Gunaksa harbor consists of:

1. Investment cost estimation
  - Land procurement cost
  - Construction coast
  - Study, design, and maintenance cost
2. Operational and maintenance cost estimation

Description and amount of the cost component is as follows:

##### 1. Land Procurement cost

Cost for the land consolidation refers to the Tax Object Selling Price (TOSP) per area at the access road which will be built. The cost of land consolidation will generally be decided pursuant to area width and the building, as well as number of utility and plantation that will be removed prior to the construction. Basically, there are not people residing in alternative 1 area. However, there are some people who just work as traditional miners. The wet land or rice field agricultural activities are brushed up. There have been street alignment built and the land consolidation for the harbor done by Government of Klungkung since 2001 and it has been in the 4<sup>th</sup> term with average land width 99.999 m<sup>2</sup>. The amount of compensation is Rp.13.999.860.000,- which is Rp.140.000,- per m<sup>2</sup>. The access road to the harbor procurement cost is Rp.7.434.000.000,- per 5,31 Ha with Rp.140.000 per m<sup>2</sup>.

##### 2. Construction Cost

Construction cost estimation will be determined by calculating quality of each item of work based on pre-planning design and unit price of the work item. The estimated cost includes general cost, drainage work, soil work, street body, graining work, asphalt work, structure work, and other minor work is Rp.90.152.449.000,-. In this study, with yearly inflation 8,49% the construction cost in 2014 will be Rp.124.892.501.899,61.

### 3. Design and Construction Supervising

The planning cost includes cost of study, design and project supervision. In the study, the cost amount is assumed 3,5% of the construction, i.e. Rp.4.371.237.566,49.

### 4. Operational and Maintenance Cost

Operational and maintenance cost is that spent for the routine operational activity and road maintenance including its facilities and the road supporting equipment. The cost is prepared in order that the road condition and its facilities is continuously proper. The operational and routine annual cost starting from the opening of the road in 2016 is Rp.4.036.962.785,15 and the periodically 5 year maintenance is Rp.6.728.271.308,59.

## 4.3.2 Economic Benefit Analysis

The estimated economic benefit of the access road development to Gunaksa harbor will be correlated directly with the harbor operating time as the pair of Nusa Penida harbor. Benefit of the road constructing project based on economic aspect commonly calculated as direct benefit for road user, such as Vehicle Operating Cost Saving (VCOS), Time Value Saving (TVS). The indirect benefit includes multiplier effect in study of road economic development like impact of macro-economic increase like increase of Gross Regional Domestic Product (GRDP) as the result of tourist activity increase, development of area and increase in GRDP of other business sectors upon the new road operation.

#### 1. Vehicle Operating Cost (VOC) Saving

VOC saving is counted from difference VOC prior to project and upon the project where crossing was done at Padangbai harbor with distance of 11.68 km. The crossing through Gunaksa harbor with 1.77 km at land. VOC is counted based on components related to vehicle operation, including some components: 1) use of fuel; 2) oil (lubricant), 3) tire; 4) vehicle repair and maintenance; 5) vehicle depreciation; and 6) interest, insurance, and overhead. The result of analysis show VOC without project is Rp381.208.332 in 2006, and the VOC value with the project is Rp.60.607.792 with the total saving of Rp.320.600.539,-

#### 2. Time Value Saving

The amount of time value for road users is the description of consumer time service given by road to its user. The time value allocated in this study is total time value at land and at sea through Padangbai harbor or through Gunaksa harbor to Nusa Penida. The approach used for time value calculating at land is personal income from GRDP divided by population. Time value of at seat passengers is counted based on the valid tariff for adult passengers crossing by Ferry RoRo from Padangbai. Time Value Saving is counted based on difference between travelling time prior to and upon the project either for the land and sea travel time value. The total time value saving in 2016 after being predicted based on level of growth is 7,19% or Rp.253.593.006.

#### 3. Multiplier Effect of Tourism to GRDP and Regional Revenue (RR)

Concept multiplier in these activities is based on the fact that many sector supporting tourism has relation and is dependent on one local economic community. Thus, each tourism expenses change will affect income, employment, and government revenue. Change ration in each variable above as the result of the change is called multiplier. In other word, multiplier is a risk of change of each variable to tourism expenses change. The number of foreign tourists visit in 2010 in Klugkung regency was 280.871 people and the Nusa Penida was 174.831 people. Upon the project, it is assumed that 45% tourist use the access road to go to Nusa Penida, and their average cost of purchasing is \$45 per day and the assumed average of their visit is 2 day. This results in an effect to multiplier to increase of GRDP and RR

## 4.4 Feasibility Analysis

Feasibility analysis conducted based on some assessing indicators leads in values as shown in table 2.

Table 2: Feasibility Analysis result

<b>Cost</b>	
Land Procurement cost (in year 2013)	7.434.000.000
Construction cost (in year 2014 – 2015)	124.892.501.900
Total of construction and land procurement cost non tax	132.326.501.899.61
Operational and annual routine maintenance cost	4.036.962.785.15
5 yearly routine maintenance cost	6.728.271.308.59
<b>Benefit</b>	
Vehicle operating cost Saving (operational start in year 2016)	320.600.539.76
Travelling time value Saving in operational year 2016	253.593.066.00
Multiplier effect benefit	71.825.034.414.09
Total of Benefit (operational start in year 2016)	72.399.228.019,86

Assesment Indicator		
Interest 12%	NPV	292.015.144.622
	BCR	3,46
	IRR	33,52%
Interest 15%	NPV	185.726.438.290
	BCR	2,76
	IRR	33,52%
Interest 18%	NPV	86.596.726.821
	BCR	1,98
	IRR	33,52%
Sensitivity for the assumed interest rate 18%		
Cost increased 20%, benefit fixed	NPV	100.366.162.799
	BCR	1,89
	IRR	29,68%
Cost fixed, benefit decreased 20%	NPV	75.501.973.939
	BCR	1,80
	IRR	28,49%
Cost increased 20%, benefit decreased 20%	NPV	56.587.192.516
	BCR	1,50
	IRR	24,86%

## 5. CONCLUSION

Based on the above theoretical background it can be described some important conclusion as follows:

1. The best alternative is the alternative 1, located at Gunaksa Village, based on short route, ready site, relatively minor social and environmental problem
2. Investment feasibility analysis based on the used criteria with interest rate 12%, 15%, and 18% showed that all NPV valued positive (NPV > 0), BCR > 1 with the lowest BCR value 1,98 and IRR= 33,52% with the assumed bank rate 18% per year.
3. Seeing from NPV, BCR, and IRR value, economically the access road is feasible to develop.
4. Pursuant to the sensitivity analysis conducted with assumption of interest rate 18%, increase in cost is 20% and decrease in benefit is 20%, consequently, all parameters used showed that the access road to Gunaksa harbor is feasible to develop where NPV = Rp.56.587.192 > 0, BCR = 1,5 > 1 and IRR= 24,86% which higher than the valid interest rate.

## 6. RECOMMENDATION

For further study, it is recommended to conduct activities as follows.

- Synchronization shall be synergized and made to some local development plans at the area of project.
- The more detail study to plan of cross road to harbor and Ida Bagus Mantra high way needs to be conducted.

## REFERENCES

- [1] Chesher, A. and Harrison, R. (1987). *Vehicle Operating Costs, Evidence from Developing Countries*, A World Bank Publication, USA
- [2] Curry, S. And Weiss, J (1993). *Project Analysis in Developing Countries*, St. Martin's Press Inc. New York
- [3] Hensher, D.A, et all (1988). *Urban Tolled Roads and The Value of Travel Time Savings*, Institute of Transport Study Working Paper No. 47, University of Sydney, Australia
- [4] Kadariah (2001). *Pengantar Evaluasi Proyek*, Universitas Indonesia, Jakarta
- [5] Kantor Statistik Kabupaten Klungkung (2011). *Klungkung Dalam Angka 2011*, Klungkung
- [6] Kodoatie, R.J. (1995). *Analisis Ekonomi Teknik*, Penerbit Andi Offset, Yogyakarta
- [7] LPM-ITB. (1997). *Modul Pelatihan, Studi Kelayakan Proyek Transportasi*, Lembaga Pengabdian Masyarakat ITB bekerjasama dengan Kelompok Bidang Keahlian Rekayasa Transportasi Jurusan Teknik Sipil ITB, Bandung
- [8] National & Local Studies (1995 – 1997). *Review of Value of Travel Time Estimates in Indonesia*, Appendix A of PTS-BUIP (1999)
- [9] Pelensky, S. (1970). *Cost of Urban Car Travel*. Australian Road Research Board, Special report No. 5 December 1970, Australia
- [10] Pujawan, I.N. (1995). *Ekonomi Teknik*, Penerbit PT. Guna Widya, Jakarta
- [11] Saaty, T.L Vargas, L.G (1994), *Decision Making in Economic, Political, Social and Technological Environment, The Analytic Hierarchy Process*, RWS Publications, Pittsburg
- [12] Saaty, T.L (1986), *Pengambilan Keputusan Bagi Para Pemimpin, Proses Hirarki Analitik untuk Pengambilan Keputusan dalam Situasi yang Kompleks*, PT. Pustaka Binaman Pressindo (1991)

## Service Dimension for Information System in Higher Education Field

Rahman Dwi Wahyudi<sup>a</sup>, Arbi Hadiyat<sup>b</sup>

<sup>a</sup>Faculty of Engineering  
University of Surabaya, Raya Kalirungkut, Surabaya 60293  
Tel : (031)298 1392  
E-mail : rahman.dwi.wahyudi@staff.ubaya.ac.id

<sup>b</sup>Faculty of Engineering  
University of Surabaya, Raya Kalirungkut, Surabaya 60293  
Tel : (031)298 1392  
E-mail : arbi@staff.ubaya.ac.id

### ABSTRACT

Presently, information system is increasingly important to support many fields such as business and education. The implementation of good information system also becomes attention improving customer satisfaction. One of some tools to analyze customer satisfaction is SERVQUAL. However, five service dimensions formulated by SERVQUAL are not always able to cover all of service attribute in some different case such as in information system field. Based on this phenomenon, it indicates that adjustment of types and number of dimension are extremely needed in special case. Information system field has different service attribute uniquely used in service performance assessment. In addition, there is also different service dimension between information system for education and for business. However, there are few researches focusing on determining service dimension of information system for higher education field, which become attention in assessing service performance. The importance of types and number of dimension results SERVQUAL evaluation. The scope of this research is determining service dimension for information system in higher education field. This research will be conducted by survey. In detail, the respondent in this research will be user of information system such as lecturer, student and management of education institution. They are stratified based on their accessibility and interest. Collected data of service attribute from this survey will be analyzed by factor analysis. The output of this analysis is service dimension.

### Keywords

*Service dimension, service quality, information system, SERVQUAL*

### 1. INTRODUCTION

Today, service activities are regarded as increasingly important for running the business [1] [2] [3] [4]. Adding service to product can influence customer satisfaction. A kind of service that can be provided by management is the implementation of information system in business system [5]. Business process will be more relatively effective and efficient by using information system. However, the effort to improve customer satisfaction by using information system should be evaluated in order it is able to understand customers' wants and needs. It is very important to understand service given to customers that is meeting with their wants and needs to establish customers' loyalty and to pursue potential customers. This is supported by empirical study that mention qualified service can increase customer satisfaction, then customer satisfaction will build customer loyalty and customer loyalty will give profitability to company [6]. One of some tools to analyze whether service given can meet customers' wants and needs is SERVQUAL. By using SERVQUAL, the performance of service given is evaluated from gap between customers' expectation and customers' perception. Those services given can be grouped into several dimensions based on the equality of function and of impact in satisfaction improvement. There are five dimensions formulated in SERVQUAL that become general model to accommodate much kind of services given. They are tangible, responsiveness, reliability, assurance, and empathy. However, five service dimensions formulated by SERVQUAL are not always able to cover all of service attribute in some different case. Based on this phenomenon, it indicates that adjustment of types and number of dimension are extremely needed in special case. The benefit of this adjustment is to avoid the misleading in understanding and in interpretation of the performance of certain service dimensions due to categorize inappropriate service attribute to certain service dimension. This adjustment had been conducted several times in previous research [7].

Based on background above, the objective of this research is to investigate the suitable service dimension for information system in higher education field. As the fact of the powerful of technology, education field also depends on information system to conduct their activities. Information system in education is like the basic needs and it expedites learning process. However, there are few researches focusing on determining service dimension of information system for education fields, which become attention in assessing service performance. The importance of types and number of dimension results SERVQUAL evaluation.

Generally, the benefit of this research is able to improve users' satisfaction by using wise service dimensions. The scope of this research is determining service dimension for information system in higher education field. This research will be conducted by method of survey.

**2. SERVICE DIMENSIONS IN SERVQUAL**

Over the years management literature has proposed many concepts and instruments concerning how to measure the service quality. Some of them are service quality (SERVQUAL), and quality function deployment (QFD). QFD is commonly used in SEE methodology to translate voice of customer in first phase into technical design in third phase. The use of QFD in process design is straightforward. However, good service delivery is a successful strategy to serve customer. Thus, knowing the gap between customer's expectation and customer's experience is important. QFD cannot record the gap. There are several gaps in service field which consists of following gaps: customers' expectation versus their understanding by manager; managers' perception of customers' expectation versus service specifications; service specification versus fulfillment; information about service versus service that is actually provided; and customers' expectations versus service provided.

Reference [8] mentioned that to evaluate service, SERVQUAL divide attributes of service into five dimensions which consist of follows:

1. **Tangibles** : The appearance of physical facilities, equipment, personnel and communications material.
2. **Reliability** : The ability to perform the promised service dependably and accurately.
3. **Responsiveness** : The willingness to help customers and provide prompt service.
4. **Assurance** : The knowledge and courtesy of employees and their ability to convey trust and confidence.
5. **Empathy** : The caring, individualized attention the firm provides its customers.

In most cases of SERVQUAL, five service dimensions above become general model to evaluate and improve service given. Whereas in some other cases, there are several services those have not been able to be covered by those five dimensions mentioned before. In addition, customer or user is very sensitive to service given selection. Thus, mistake in classifying service attributes into dimension will give bias assessment and misleading interpretation to service performance itself [7]. Obviously, service dimension will influence the assessment of service quality. Service quality of a specific service dimension is defined as the attitude of the customers' perceptions towards the specific service dimension according to their experience of uses at a specific time [9].

In fact, adjustment of the number and the kind of service dimensions is previously done in several researches. Reference [7] gave the chronologies as follow:

*Table 1: The Chronologies of Service Dimension Development*

Year	Proposer	Component/ Dimension	Additional Information
1982	Lehtinen	<ul style="list-style-type: none"> <li>• Interactive Quality</li> <li>• Physical Quality</li> <li>• Corporate Quality</li> </ul>	

*Table2: The Chronologies of Service Dimension Development (Cont.)*

Year	Proposer	Component/ Dimension	Additional Information
1984	Gronroos	<ul style="list-style-type: none"> <li>• Structure-Technical Quality</li> <li>• Functional Quality</li> <li>• Reputational Quality</li> </ul>	
1988	Leblanc and Nguyen	<ul style="list-style-type: none"> <li>• Corporate Image</li> <li>• Internal Organization</li> <li>• Physical Support of The Service Producing System</li> <li>• Staff/ Customer interaction</li> <li>• The Level of Customer Satisfaction</li> </ul>	
1988	Parasuraman, Zeithml and Berry	<ul style="list-style-type: none"> <li>• Tangibles</li> <li>• Reliability</li> <li>• Responsiveness</li> <li>• Assurance</li> <li>• Empathy</li> </ul>	Eventually led to the development of SERVQUAL
1988	Garvin	<ul style="list-style-type: none"> <li>• Performance</li> </ul>	

Year	Proposer	Component/ Dimension	Additional Information
		<ul style="list-style-type: none"> <li>• Features</li> <li>• Conformance</li> <li>• Reliability</li> <li>• Durability</li> <li>• Service</li> <li>• Response</li> <li>• Aesthetics</li> <li>• Reputation</li> </ul>	
1989	Hedvall and Paltshik	<ul style="list-style-type: none"> <li>• Willingness</li> <li>• Ability to Serve</li> </ul>	
1994	Oliver and Rust	<ul style="list-style-type: none"> <li>• Functional Quality</li> <li>• Technical Quality</li> <li>• Environment Quality</li> </ul>	

The other example given for service dimension adjustment is adjustment of SERVQUAL's five dimension in airlines industry. In airlines industry, SERVQUAL's five dimensions are difficult to apply to airlines. This is because the SERVQUAL instrument does not address other important aspects of airline service such as in-flight meals, frequent flyer programs, seat space and legroom [10]. In addition, reference [10] also showed that they adjusted the SERVQUAL's service dimension became three dimensions. Those three dimensions are as follows

- Dimension 1: Reliability and Customer Service
- Dimension 2: Convenience and Accessibility
- Dimension 3: In-flight Service

Regarding the benefits of SERVQUAL itself, reference [11] summarized the benefits of SERVQUAL as follows:

1. It is useful in understanding the opinion of customers regarding a service delivery, for example perception, expectation, and satisfaction.
2. The model alerts management to consider expectations and perceptions.
3. The gaps among different people, and at different time periods regarding expectation and perceptions can be identified,
4. It is useful in identifying specific areas of weaknesses and dissatisfaction.
5. It helps prioritize areas of service weakness to focus effort on.
6. It provides benchmarking analysis for organizations in the same service sector.
7. It can work as a basis for gathering customer requirements to explore further quality improvement analysis.

### 3. SERVICE ATTRIBUTES FOR INFORMATION SYSTEM IN HIGHER EDUCATION FIELD

Presently, organizations continue to increase spending on information technology (IT). The impacts of IT are often indirect and influenced by human, organizational, and environmental factors; therefore, measurement of information systems (IS) success is both complex and illusive [12]. Nevertheless, measurement of information system success related to users' satisfaction is extremely needed.

Users' satisfaction has close relationship with service quality. The determination of service quality is considered as a comparison process between an expected level of service and the service perceived by the user. The relationship between service quality and users' satisfaction is showed by reference [13] as follows:

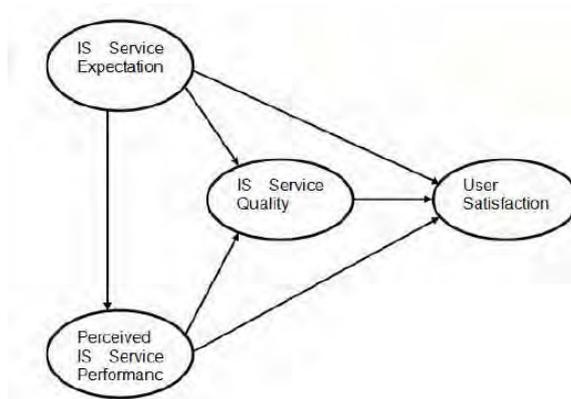


Figure 1: Users' Satisfaction Determination

In order, the measurement of success of users' satisfaction will not be misleading and bias, service dimension determination becomes something crucial [12]. Service dimension is group of some service attributes those have the same function and impact to satisfaction improvement. So that classifying of certain service attributes into inappropriate dimension will cause misleading in interpretation of performance of service dimension itself. Service attributes can be generated by several ways such as based on ISO as a fulfillment of basic requirement standard, based on the same previous research and based on voice of customer as service development indicator. Generally, service attributes used as key of success measurement in information system are as follows:

Table 1: Service Attributes for Information System

No	Service Attribute	Reference
1	Ease of using system	Research
2	Ease of learning system	Research
3	System accuracy	Research
6	Flexibility of system	Research
7	Sophistication of system	Research
8	Integration	ISO, Research

Table4: Service Attributes for Information System (cont.)

No	Service Attribute	Reference
9	Customization of system	Research
10	Consistency of network connection	Research
11	Availability of information	Research
12	Usability of information	Research
13	Understandability of information	Research
14	Relevancy of information	Research
15	Format of information/documents	Research
16	Conciseness of information	Research
17	Individual learning impact	Research
18	Individual awareness impact	Research
19	Individual decision effectiveness impact	Research
20	Individual productivity impact	Research
21	Organizational cost impact	Research
22	Overall productivity impact	Research
23	Improved outcomes impact	Research
24	Ease of accessibility	Voice of Customer
25	Speed of access and operation	Voice of Customer
26	Communication media provision	Voice of Customer
27	Quota of downloading and uploading file	Voice of Customer
28	Green information system	Voice of Customer
29	Protection from virus, spam, worm and so forth	Voice of Customer
30	Broadcasting of latest information (news, advertisement, announcement, so forth)	Voice of Customer
31	Supporting vision organization	Voice of Customer
32	Information security policy	ISO, Voice of Customer
33	Management commitment to information security	ISO
34	Confidentiality agreement	ISO

No	Service Attribute	Reference
35	Independent review of information security	ISO
36	Information classification guideline	ISO

Table 5: Service Attributes for Information System (cont.)

No	Service Attribute	Reference
37	Information labeling and handling	ISO
38	Network control and maintenance	ISO
39	On line transaction	ISO
40	Protection of log information	ISO
41	Clock synchronization	ISO
42	Privilege management	ISO
43	User password management	ISO
44	Review of user access right	ISO

Based on service attributes list above, some service attributes cannot be fitted into tangible, reliability, assurance, responsiveness and empathy. Service attributes mentioned above are service attributes which are commonly used either for information system either in business field or education field. Whereas, there are differences in both business field and education field, especially higher education field. The differences are fundamentally associated with the goal of using information system. So that, it needs to be adapted to use service attributes mentioned before for information system in higher education field. Here are several additional service attributes for information system in higher education field.

Table 6: Additional Service Attributes for Information System in Higher Education

No	Service Attribute	Reference
1	E-learning	Voice of Customer
2	On line-class	Voice of Customer
3	On line-examination	Voice of Customer
4	Cloud computing	Voice of Customer
5	Automatic examination mark calculation	Voice of Customer
6	Restricted web that is visited	Voice of Customer
7	Ease of registration	Voice of Customer
8	WIFI availability	Voice of Customer
9	Ease of device setting	Voice of Customer
10	Quota of cloud computing	Voice of Customer
11	Filtering plagiarism	Voice of Customer
12	Concern to copyright (software, ebook, research, journal and so forth)	Voice of Customer
13	Supporting for student presence, lecturer presence and employee presence	Voice of Customer
14	Paperless data back up	ISO, Voice of Customer
15	Durability of storing file to cloud computing	Voice of Customer

## 4. DETERMINING SERVICE DIMENSION FOR INFORMATION SYSTEM IN HIGHER EDUCATION FIELD

### 4.1 Questionnaire Design and Sample

Data collecting is conducted by distributing questionnaire to respondents that is defined before. The respondent in this research will be user of information system such as lecturer, student and management of education institution. They are stratified based on their accessibility and interest. The given questionnaire contains service attributes list for information system in higher education. Those service attributes are generated as method explained before. Respondents are asked to determine the importance level of those service attributes. Importance level of service is filled based on respondent's expectation toward the importance of certain service. This study adapted the SERVQUAL scale to the specific context of aviation by generating additional quality related measures or items other than the ones already included in the SERVQUAL instrument. This study will change the measurement items and the dimensions to develop a more appropriate scale for measuring service quality of information system in higher education.

### 4.2 Factor Analysis

In this study, factor analysis is used to determine the service dimension based on the importance level of service attributes which have been assessed by respondent. Factor analysis is a method for investigating whether a number of variables of

interest  $Y_1, Y_2, \dots, Y_i$ , are linearly related to a smaller number of unobservable factors  $F_1, F_2, \dots, F_k$ . Variable of  $Y_i$  in this study refers to service attribute and Factor of  $F_j$  in this study refers to service dimension.

#### 4.3 Reliability of Measures

The next step after getting the new service dimension from factor analysis is the reliability test of the new service dimension itself. Reliability test is used to know the internal consistency of service dimension and to know whether the service dimension is able to be credible measurement tools in service evaluation. The first step to do reliability test is establishing the hypothesis as follows:  $H_0$ : questionnaire is reliable;  $H_a$ : questionnaire is not reliable. Decision is taken by comparing Cronbach's alpha and R-value from table. Cronbach's alpha was used to assess internal consistency.

### 5. ANALYSIS

Based on service attribute generation on Table 3.1 and Table 3.2, at glance it can be analyzed that there are some service attributes uncovered by 5 SERVQUAL service dimension. This is probably caused that there are two different respon variable in information system field which have the same importance level in user assessment. Both the variables are related to either system quality or information quality alone. So that, both of the variables should be separately analyzed because they are not the same. In the other hand, analysis conducted by 5 SERVQUAL service dimension is general and tending to system quality in delivering service. Before grouping the attribute by using factor analysis, at glance the attributes on Table 3.1 and Table 3.2 can form dimensions based on D&M model as follows: (1) system quality is the desirable characteristics of an information system, (2) information quality is the desirable characteristics of the system outputs, (3) security is dimension protecting some either information or data, (4) Education support is dimension supporting activities for educational purpose, (5) Assurance is the knowledge and courtesy of employees and their ability to convey trust and confidence, (6) Empathy is the caring, individualized attention the firm provides its customers.

Based on service dimensions above, dimension of information quality, security and education support are uncovered by 5 SERVQUAL service dimensions. In fact, dimension of responsiveness, assurance and reliability in SERVQUAL can be covered by either system quality or information quality. There is interesting point about assurance here. Assurance in SERVQUAL is intended to guarantee and certainty of service given to user meeting with promised service to user. In the other hand, assurance in information system field is more intended to guarantee of confidential of either data or information uploaded to information system. Both of that guarantees are surely different. Therefore, service dimension of security is needed in service evaluation for information system. However, service dimension of tangible and empathy still occur in both of 5 SERVQUAL service dimensions and service dimensions above. This probably shows that tangible and empathy are service dimensions always attracting user's attention and assessment. This dimension looks like being favorite dimension for user so that it is always well provided by provider. It is probably caused by recognition of senses. While empathy is dimension covering service attribute that supports making customer intimacy. Actually service dimensions having formed above can be used for service evaluation not only in information system for higher education field but also in general information system by removing service dimension of education support. Service dimension of education support can be only used in information system for higher education because the function of implementing information system in both of them are different. The implementation of information system in education field must be based on the great value of education and it is not profit or business oriented as the main goal, so there are some service attributes used to limit and support the utilization of information system for educational purpose such as online class, concern to copyright, issue of plagiarism and so forth.

### 6. CONCLUSION

Service attributes for many kind of field are not exactly the same, so that the different field will have different service dimensions too. Based on service attributes which are in line with ISO 27001 and generating idea from voice of customer, service dimensions for information system in higher education field must be unique dimensions. It is because SERVQUAL's five dimension are not exactly fit with and cannot cover all of the available service attributes. The adjustment of service dimension was also done time by time. That adjustment could be done by using factor analysis.

### 7. REFERENCES

- [1] J. Bowen, "Development of a Taxonomy of Services to Gain Strategic Marketing Insights," *Journal of the Academy of Marketing Science*, pp. 43-49, 1990.
- [2] D. P. Cook, C.-H. Goh dan H. C. Chen, "Service Typologies: A State of The Art Survey," *Production and Operation Management*, pp. 318-338, 1999.
- [3] R. A. Paton dan S. McLaughlin, "Service Innovation: Knowledge transfer and the supply chain," *European Management Journal*, pp. 77-83, 2008.

- [4] L. Yang dan D.-j. Song, "Conceptualizing Service Innovation and Service Innovation Model Constructing," *IEEE*, pp. 381-386, 2009.
- [5] G. Gable dan A. Rai, "Reconceptualising The Information System As a Service," dalam *17th European Conference on Information Systems*, Verona, 2009.
- [6] R. Hallowell, "The relationships of Customer Satisfaction, Customer Loyalty, and Profitability:an Empirical Study," *International Journal of Service Industry Management*, pp. 27-42, 1996.
- [7] S. B. Sachdev dan H. V. Verma, "Relative Importance of Service Quality Dimensions: A Multisectoral Study," *Journal of Service Research* , pp. 93-116, 2004.
- [8] S. A. George dan N. Chattopadhyay, "Analysis of Service Quality: Insights from a Comparative Case Study from the Indian Concontext," dalam *INFORMS Service Science Conference*, Taipei, 2010.
- [9] K.-K. Chen, D.-H. Hsiao dan C.-H. A. Hsieh, "Service Quality Radar Map and Two-Stage Service Quality Score," *Journal of Marine Science and Technology*, pp. 123-133, 2008.
- [10] J.-W. Park, R. Robertson dan C.-L. Wu, "Investigating the Effects of Airline Service Quality on Airline Image and Passengers' Future Behavioural Intentions: Findings from Australian International Air Passengers," *The Journal of Tourism Studies*, pp. 2-11, 2005.
- [11] M. Xie, K.-C. Tan dan T.-N. Goh, *Advanced QFD Applications*, United States of America: American Society for Quality (ASQ), 2003.
- [12] S. Petter, W. DeLone dan E. McLean, "Measuring Information Systems Success: Models, Dimensions, Measures, and Interrelationships," *European Journal of Information Systems*, p. 236-263, 2008.
- [13] J. J. Jiang, G. Klein, N. Parolia dan Y. Li, "An Analysis of Three SERVQUAL Variations in Measuring Information System Service Quality," *Electronic Journal Information Systems Evaluation*, pp. 149-162, 2012.

# Industrial Symbiosis: Past Researches, Current Findings, and Future Direction

Bertha Maya Sopha

*Department of Mechanical and Industrial Engineering  
Universitas Gadjah Mada, Yogyakarta, INDONESIA  
E-mail : bertha\_sopha@ugm.ac.id*

## ABSTRACT

High quality, non-renewable, resource depletion through various consumptive industrial activities, as well as, emissions and wastes during resources transformation have made current industrial systems unsustainable. Industrial symbiosis, coupling economic growth with environment protection, is one of various attempts toward sustainable industrial practice. The literature on industrial symbiosis continues to grow even though the industrial symbiosis practices have been there for quite some time. However, researches on industrial symbiosis are varied and vibrant yet fragmented. This present paper therefore attempts to organize and to review the burgeoning industrial symbiosis literatures by analyzing their state-of-art whether there are gaps. The literature review was based on articles drawn from 13 databases and one internet-based research engine. The literatures are analyzed with respect to evolutions of the concept development and the degree to which material are closed and exchanged, barriers and success factors, performance indicators, and modeling techniques implemented. Research findings are further synthesized to identify direction for potential future research.

## Keywords

*Industrial Symbiosis, Literature Review, Concept Development, Barriers and Success Factors, Modeling Techniques*

## 1. INTRODUCTION

High quality, non-renewable, resource depletion through various consumptive industrial activities, as well as, emissions and wastes during resources transformation have made current industrial systems unsustainable. This will lead that the current resource use dynamics cannot be maintained for existing human populations. Therefore, people are now trying to bring about a change in the way their operation so that the negative impacts towards ecosystem can be stopped or at least minimized. Industrial symbiosis, coupling economic growth with environment protection, is one of various attempts toward sustainable industrial practice. The most famous case study of industrial symbiosis is probably the industrial district at Kalundborg, Denmark. During the development of industrial symbiosis, a number of ways to design and implement industrial symbiosis exist. Moreover, industrial symbiosis has also referred to various names, such as eco-industrial park, industrial eco-system, etc. The literature on industrial symbiosis continues to grow even though the industrial symbiosis practices have been there for quite some time. However, researches on industrial symbiosis are varied and vibrant yet fragmented.

This present paper therefore attempts to organize and to review the burgeoning industrial symbiosis literatures by analyzing their state-of-art whether there are gaps. The literature review is therefore more than a mere description. The paper follows the following methodological approach to conduct the review: building conceptual framework, searching and collecting literatures, analyzing and synthesizing findings from literatures.

## 2. FRAMEWORK

The industrial symbiosis literatures are ranging from the conceptual study to empirical study, from broad-brush exploration to in-depth case study. This present paper arranges the literatures by creating an organizing template for this work. Although several templates are possible, a framework used in this paper is built in such a way to map the literatures based on its context into two streams of research: conceptual development of industrial symbiosis (group 1) and tool used or applied in designing and implementing industrial symbiosis (group 2). The review is shaped around these streams because each of stream has distinct body of research. Group 1 deals with attempts to investigate industrial symbiosis concept, formulate its principles and elements. As a new field, industrial ecology and/or industrial symbiosis literatures are seeking to formulate a set of fundamental beliefs and cohesive concepts that lend a common meaning to all players in the field. These literatures are mainly based on conceptual-grounded work. Group 2 deals with issues and approaches related to industrial symbiosis establishment such as performance indicators, modeling and evaluation as well as barriers and success factors of industrial symbiosis around the world. The papers on this category are empirically grounded results, experiences from practice.

### 3. DATA COLLECTION

Due to the multidisciplinary nature of industrial symbiosis, the literature search was organized so that all the related field of industrial symbiosis was covered so that it could be analyzed in different context. Fields included in the literature research includes engineering, economics, environment, and business. The framework above was applied to all areas. Ten sources from databases, e-journal and internet, most of them containing articles, are explored. The data collection was conducted in four steps following the steps below,

1. Screening of databases, journals, conferences proceedings, etc to find references to publications related to industrial symbiosis
2. All the selected references were coded according to our framework, empirical and conceptual research as well as classified into two groups determined in the framework
3. Investigation of most important/central references
4. Identification of potential research themes

→ *Table 1: Databases and search terms employed in literatures*

Sources	Search term
1. ISI Web of Science	1. industrial symbiosis
2. EBSCO	2. industrial ecosystem
3. ECO Electronic Collection (OCLC)	3. eco-industrial park
4. Ingenta	4. eco-industrial estate
5. JSTOR	5. eco-industrial network
6. Science direct (Elsevier)	6. by-product synergy
7. SpringerLink	7. by-product exchange
8. Wiley Interscience Journal	
9. Blackwell Synergy	
10. Google scholar (internet)	

### 4. RESULTS AND DISCUSSIONS

#### 4.1 Literature Description

Judging from the numbers of references, research on industrial symbiosis have not yet got a foothold. As new emerging discipline the literatures of industrial symbiosis are evolving in the same way as is industrial ecology. This section addresses the industrial symbiosis literatures evolution to point the center of attention to identify the potential research agenda as well as to provide innovative routes in changing present unsustainable industrial systems.

The concept of industrial ecology was firstly introduced in 1989 [1]. Figure 1 and 2 illustrate the literatures based on the framework discussed in section 2. Tin the early stage, industrial symbiosis literatures were mainly working on the conceptual definition. With respect to the empirical case, the Kalundborg case in Denmark appeared in 1996 literature was the first working model of industrial symbiosis. Afterwards, the industrial symbiosis concept has been refined and the numbers of case and/or project on industrial symbiosis have been increasing since then. The conceptual literatures have given a baseline for studying the cases while case study literatures have inspired to further distill the concept. Case study literatures also contribute to the development of tools for designing and developing industrial symbiosis. Early study on industrial symbiosis was dominated with the technical and economic perspectives. Therefore, there was unbalance between the social and technology study in the area of industrial symbiosis as sustainability is not only based on technology and economy aspects but also social aspect. Furthermore, Cohen-Rosenthal [2] challenged the reductionist and engineering approaches in industrial ecology in general and industrial symbiosis in particular by stressing the importance of solid understanding of the functioning of industrial network and the role of human resources. Human dimension and inter-organizational issues was then addressed in 2006 literatures. Recent development in industrial symbiosis literatures is an attempt to adopt systemic perspective when designing and evaluating industrial symbiosis.

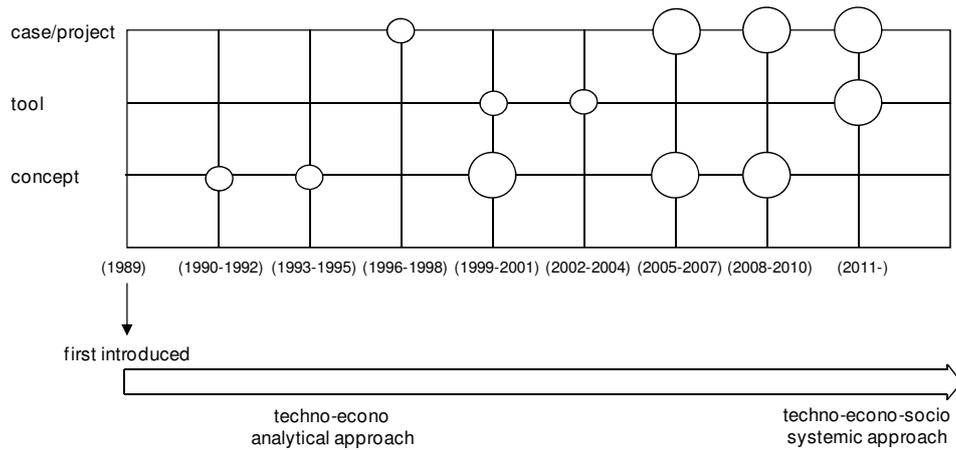


Figure 1: Industrial symbiosis literatures (Note: bigger circles reflect more literatures)

Figure 2 further illustrates that the number of empirical studies are higher than conceptual studies because more literatures presents and explores practices from cases in order to formulate the concept as well as implementing approaches. In turn, the formulated concept will help to learn, design and plan for other cases/projects. The process is however not linear. Theoretical and empirical data collection and generation work is done at the same time.

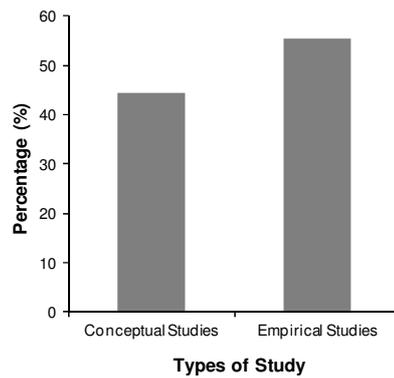


Figure 2: Industrial symbiosis literatures by group based on the framework (Group 1: Conceptual studies, Group 2: Empirical studies)

#### 4.2 Industrial Symbiosis Definition

Industrial symbiosis is perhaps the best-known application of Industrial Ecology principles. There are various definitions of the concept with different implications. Industrial symbiosis normally regards as the exchange of by-products, energy, water, emissions among closely situated firms. There are several terms in the literatures which are used interchangeably. Table 2 provides the terms as well as the definition which develops over time. The early definition is put more focus on trading material, and then it is enriched by the synergy/collaboration within geographic proximity in addition to material exchange. Table 2 also implies that the expressions from different authors are varying depending on the system boundaries, specifics of the project, its management umbrella or geographical location. However, they have one thing in common is that they attempt to create a system by exchanging material/energy with collaboration among companies within region/geographic proximity whose objective to improve economic, environmental, social performance.

Tabel 2: Concepts and definitions in Industrial Symbiosis

Term used	Definition	References
Industrial Ecosystem	In an Industrial Ecosystem, the traditional model of industrial activity is transformed into a more integrated system, in which the consumption of energy and materials is optimized and the effluents of one process serve as the raw material for another process	[1]
Industrial Ecosystem	A community or network of companies and other organizations in a region who choose to interact by exchanging and making use of byproducts and/or energy in a way that provides one or more of the following benefits over traditional, non-linked operations: reduction in the use of virgin materials as resources input, increased energy efficiency leading to reduced	[3]

Term used	Definition	References
	systemic energy use, reduction in the volume of waste products requiring disposal, increase in the amount and types of process output that have market value	
Eco-industrial park	a community of manufacturing and service firms located together in a common property. Member businesses seek enhanced environmental, economic and social performance through collaboration in managing environmental and resource issues. By working together, the community of businesses seeks a collective benefit that is greater than the sum of individual benefits each company would realize by only optimizing its individual performance	[4]
Industrial symbiosis	Industrial Symbiosis engages traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or byproducts. The keys to Industrial Symbiosis are collaboration and the synergistic possibilities offered by geographic proximity	[5]

The latest definition on industrial symbiosis also takes into account on the common objectives to pursue performance targets. This is quite in line with principles proposed by Korhonen [6], the development of natural ecosystems is driven by roundup, diversity, locality and gradual change, as industrial ecology metaphors.

Table 3: Ecosystem principles applied to natural and industrial ecosystem (adapted from [6])

Ecosystem principles	In Natural Ecosystem	In industrial Ecosystem
Roundup	Recycling of matter Cascading of energy	Recycling of matter Cascading of energy
Diversity	Biodiversity Diversity in species, organism Diversity in interdependency and cooperation Diversity in information	Diversity in actors, in interdependency, and in co-operation Diversity in industrial input and output
Locality	Utilizing local resources Respecting the local natural limiting factors Local interdependency and cooperation	Utilizing local resources, wastes Respecting the local natural limiting factors Co-operation between local actors
Gradual change	Evolution using solar energy Evolution through reproduction Cyclical time, seasons time Slow time rates in development of system diversity	Using waste material and energy and renewable resources Gradual development of the system diversity

Summarizing, the basic concept of industrial symbiosis is attempting to learn and apply ecosystem principles to an industrial system. The ability to articulate and conceptualize industrial symbiosis is crucial because different conceptualizations of industrial ecology suggest different political solutions and different focuses on the environment [7]. Moreover, the principles can be useful either for stimulating creative thinking, innovation, and for providing inspiration for establish industrial symbiosis.

#### 4.3 Barriers and Success Factors

There are two opinions regarding the IS establishment. First, based on the success story of existing IS, the development of IS is *self-organizing* driven by market forces, spontaneously evolved market coordination [8]. Industrial symbiosis is a complex system that is very difficult to intentionally plan, design or manage [9]. However, the second opinion is that the IS development is *planning-based* is that the public planning could foster greater level of industrial symbiosis [10].

There are various barriers and success factors found in the literatures. For example, Ehrenfeld and Gertler [9] found barriers toward industrial symbiosis included lack of technical and economic appeal of continuous sources of feedstock, high transaction costs, small lot sizes, and cognitive domain when wastes have such a long history of being ignored that it is difficult for firms to integrate these output of their activities into their strategic processes. Case study of a Swedish municipality with a developed forest industry results that the greatest barriers were lack of knowledge and resources, attitudes, time frames, development consent and lack of continuity and local power for some companies [11]. On the study of CHP-based energy production in an industrial recycling network, Korhonen [6] identified the barriers are economic barrier, unhealthy dependencies (conflicting interest or diversity of technical requirements), regulation and policy (taxation of fossil fuels), large unit sizes and awareness related to information and know-how. He also discussed on the conditions of success including renewable flow resources as fuels, co-production of district heat and electricity, co-production of industrial heat/steam and electricity, public ownership in related to trust and inability to incorporate as well as local condition that provides market in which this is very much in line with the success factors for Kalunborg due to chemical and other technical compatibility, economic feasibility, organizational arrangements that minimizes transaction cost, regulatory context that is consultative, open and flexible to further reduce emission and adjust prices to make industrial symbiosis economically attractive [9]. Furthermore, case studies of eight eco-industrial park in the Netherlands showed that factors of social cohesion between the partner companies plays, physical and social features as well as the nature of the decision making process determine the degree of success in achieving symbiosis and/or utility sharing in eco-industrial park [12]. Furthermore, the comparative study conducted on six industrial symbiosis projects in the US and the Netherland pointed the factor that essential

to project success is active participation from a number of stakeholders in the planning stages of the project, however, the reasons causing problems or failure is more diverse in nature, ranging from lack of finances, lack of company interest, relatively large distance between companies, different opinions and interest among stakeholders [13].

Summarizing, barrier and success factors on industrial symbiosis project are case-specific; however, there are some commons among the cases. Summarized, the development and functioning of industrial symbiosis depend on the various factors rooted in the different domains [13,14],

- Technical: an exchange is technically feasible in terms of physical, chemical and spatial attributes of in- and output streams, compatibilities between needs and capacities, availability of reliable and cost efficient technologies
- Economic: an exchange might be economically sound or economically not risky from a company perspective in terms of costs of virgin inputs, value of waste and by-product streams, transaction and opportunity costs, size of capital investment and discount rates
- Political/regulatory/legal: caused by the jungle of environmental laws and regulations for example: overarching environmental policies, nature and implications of relevant laws and regulations, relevant fiscal elements (taxes, fees, fines, levies, subsidies and credits)
- Informational: the right people have the needed information at the right time, for example: access to relevant info, availability of timely and reliable information from a wide spectrum of areas to the right parties, continued review of information.
- Organizational and Institutional: the intended exchange might not fit in the current corporate organizational structure in terms of trust, openness, environmental maturity, level of social interaction and mental proximity, local availability of decision-making power, organization history, nature of interaction among industry, policy makers and regulators, social embeddings (degree of familiarity).

#### 4.4 Tools

In order to able to reproduce the success of industrial symbiosis at Kalundborg, Denmark to other places around the world, researchers from different area attempt to develop tools, instruments and/or approaches derived from other different fields. This sub-section will discussed tools and approaches found in the literatures for evaluating industrial symbiosis. Most the published studies on evaluation of industrial symbiosis evaluation is mainly descriptive, leaving out the specific methodology utilized. This section limits discussion by addressing only on performance indicator and modeling techniques of industrial symbiosis.

##### 4.4.1 Performance Indicators

There is very few literatures presenting on the performance indicators of industrial symbiosis. The indicators for evaluating industrial symbiosis should incorporate both environment and economic aspects. Some authors therefore suggest efficiency indicators to measure environmental and financial performances. The study conducted by Biswas *et al.* [15] stated that indicators which reflect environmental, economic, health and safety issues, have been categorized as micro-econometrics and macro-econometrics, and often economic, technical and societal factors are embedded into these measures. The paper however left out specific indicators to measure environmental, economic and social performances.

##### 4.4.2 Modeling Techniques

The primary requirement for establishing industrial symbiosis is that it must be technically feasible. Therefore, the first attempt towards modeling of industrial symbiosis is by modeling the material (raw materials, products, by-products, waste) and energy flow. Tools used for modeling technical aspect are chemical process simulation, linear programming, other operation research tools such as game theory, queue theory, monte carlo simulation, system dynamics, etc. There are many studies that have been done by chemical engineers to seek for the potential linkages among the member in the industrial symbiosis. It can be evaluated using a variety of techniques, such as exergy analysis [16] and emergy analysis[17,18]. They are modeling exergy or emergy flow of the system. This type of modeling tried to model the influence of uncertainty such as market fluctuation, operational uncertainty, etc., using operational research principles, for example game theory [18] and hierarchical pareto optimization [19]. This modeling is to seek the optimal operation of industrial symbiosis economically and environmentally. Moreover, there is industrial ecosystems toolkit developed by Industrial Economics Inc. in partnership with Clark University for the US EPA's Office of Policy, Planning and Evaluation, Urban and Economic Development Division in 1999. It consists of Facility Synergy Tool (FaST), Designing Industrial Ecosystems Tool (DIET), Regulatory, Economic and Logistics Tool (REaLiTy). Other toolkits such as MatchMaker that matches the user specific or generic data, Integrated Materials Exchange Tool that integrates linier programming optimization with a visual GIS map based framework, was also available. The presented modeling techniques seek to model the technical system, on the other hand, industrial symbiosis is not only consisting of machine and money but also man (human) in which poorly addressed. Therefore, the recent proposal for modeling industrial symbiosis is the use of agent-based modeling to facilitate the interaction of stakeholder in industrial symbiosis [20,21], however, the application toward real cases are still lack.

## 5. FUTURE DIRECTION

Extracted from the literatures, this section identifies themes which are crucial to be considered when establishing and developing industrial symbiosis. The themes relate to industrial symbiosis concept, performance indicator, human dimension, linkage to business, as well as, modeling techniques. With respect to the concept of industrial symbiosis, due to various proposed definition, no single consensus, it calls to more further research in order to refine the concept of industrial ecology that is widely accepted and useful as the metaphor to be a source of inspiration and creativity in the transformation of management and strategic visions towards a new sustainability culture. Furthermore, with respect to performance indicator, a set of indicators informing stakeholders on how well the system is working is necessary. The future research could be studying on developing key performance indicators to measure industrial symbiosis performance in terms of economy, technology, as well as, environment.

Based on the previous findings mentioned on the barrier of industrial symbiosis establishment and development, it is seen that, sometimes, other barriers and incentives exist which are not directly linked to whether the investment on industrial symbiosis is profitable or not. Human are unique among species, possessing language and intentionality. There is other factor that important for integration, that is human dimension, i.e., inter-organizational management, human action toward the vision of Industrial symbiosis. It echo to the slogan "knowledge makes it possible, people make it happen". Therefore, research on human dimension toward the industrial symbiosis establishment is also required. The linkage toward business models is also particularly important. More often that not it tends to look at industrial ecosystems, industrial metabolism and industrial symbiosis from a biological and engineering point of view. Business people look things differently and even have different languages. There is a need towards any efforts to try to understand symbiosis using business models. This will allow to make better cases once all of the business benefits are understood. Reducing environmental impacts and even making more efficient use of resources don't appear to be enough to make symbioses happen [22]. It is supported by Baumann [23] emphasizes that different ways of managing industrial production results in different environmental performance. Industrial performance does not depend on solely the technology but also depend on how we manage it.

Since industrial symbiosis is complex system, there is a call for applying the systemic approach to understand the problem. There is a strong need for a systemic approach to better understand the full implications of the choice and its attractiveness in terms of resilience [24]. Moreover, Garner and Keoleian [25] argued that environmental problems from industrial processes are systemic and would need a system approach in proffering solutions to them which would involve connections linking industrial practices to human activities in addition to maintaining environmental or ecological integrity. Most authors believe that a systems approach also provides a holistic view of environmental problems thereby making it possible to see and solve these problems that would in turn create advantages towards achieving sustainable industrial systems. To sum up, there is a strong need to provide the modeling technique that can model the system based on the holistic perspective. The possible contribution towards the knowledge development in the area of industrial symbiosis could be on the development of simulation software, optimization techniques (multi-scale) as well as policy that drives or may hinder industrial symbiosis. At the end, all the mentioned potential research themes would contribute to the building of practical framework to establish industrial symbiosis.

## REFERENCES

- [1] R.A. Froesch, N. E. Gallopoulos, "Strategies for Manufacturing", *Scientific American*, vol. 261, no. 3, pp. 144-152, 1989.
- [2] E., Cohen-Rosenthal, E., "A walk on the human side of Industrial Ecology", *American Behavioral Scientist*, vol. 44, no. 2, pp. 245-264, 2000.
- [3] N. Gertler, "*Industrial ecosystem: developing sustainable industrial structures*", Dissertation for master of science in technology and policy and master of science in civil and environmental engineering, Massachusetts Institute of Technology, Cambridge, MA, 1995
- [4] E. A. Lowe, "Creating by-product resource exchanges: strategies for eco-industrial parks." *Journal of Cleaner Production*, vol. 5, no. 1-2, pp. 57-65, 1997
- [5] M. Chertow, "Industrial Symbiosis: Literature and Taxonomy", *Annual Review of Energy and Environment*, vol. 25, pp. 313-337, 2000
- [6] J. Korhonen, "A material and energy flow model for co-production of heat and power." *Journal of Cleaner Production*, vol. 10, pp. 537-544, 2001.
- [7] H. N. Opoku, "Policy implications of industrial ecology conceptions", *Business Strategy and the Environment*, vol. 13, pp. 320-333, 2004
- [8] P. Desrochers, "Industrial symbiosis: the case for market coordination". *Journal of Cleaner Production Special Issue 'Applications of Industrial Ecology'*, vol. 12, no.8-10, pp. 1099-1110, 2004
- [9] J. Ehrenfeld, N. Gertler, "Industrial Ecology in Practice: The Evolution of interdependence at Kalunborg", *Journal of Industrial Ecology*, vol. 1, no. 1, pp. 67-79, 1997
- [10] R. U. Ayres, L. U., Ayres, "*Industrial Ecology – Towards Closing the Material Cycle*". Elgar: Cheltenham, 1996
- [11] A. Wolf, M. Eklund, "Towards cooperation in industrial symbiosis: considering the importance of the human dimension", *Progress in Industrial Ecology*, vol. 2, no. 2, pp. 185-199, 2004
- [12] J. A. M. Eilerling, W. J. V. Vermeulen, "Eco-industrial parks: toward industrial symbiosis and utility sharing practice", *Progress in Industrial Ecology*, vol. 1, no. (1/2/3), pp. 245-270, 2004
- [13] R. R. Heeres, W. J. V. Vermeulen, "Eco-industrial park initiatives in the USA and the Netherlands: first lessons" *Journal of Cleaner Production*, vol. 12, pp. 985-995, 2004

- [14] M. Mirata, M. "Industrial Symbiosis: A Tool for More Sustainable Regions?", Doctoral dissertation, Lund University, Sweden, 2005
- [15] G. Biswas, R. Clift, J. Ehrenfeld, R. Forster, O. Jolliet, I. Knoepfel, U. Luterbacher, D. Russel, D. Hunkeler, "Ecometrics: Identification, Categorization and Life Cycle Validation", *International Journal of Life Cycle Assessment*, vol. 3, no. 4, pp. 184-190, 1998
- [16] M. T. Brown, R. A. Herendeen, "Embodied energy analysis and emergy analysis: a comparative view". *Ecological Economics*, vol. 19, pp. 219-235, 1996
- [17] L. Young, "By-product Synergy: A Demonstration Project Tampico, Mexico", Business Council for Sustainable development – Gulf of Mexico, 1999
- [18] H. H. Lou, M. A. Kulkarni, "A game theory based approach for emergy analysis of industrial ecosystem under uncertainty". *Clean Technology and Environmental Policy*, vol. 6, pp. 156-161, 2004
- [19] A. Singh, H. H. Lou, "Hierarchical pareto optimization for the sustainable development of industrial ecosystems". *Industrial and Engineering Chemical Research*, vol. 45, pp. 3265-3279, 2006
- [20] R. L. Axtell, C. J. Andrews, "Agent-based modeling and industrial ecology". *Journal of Industrial Ecology*, vol 5, no. 4, 10-12, 2002
- [21] S. Kraines, D. Wallace, "Applying agent-based simulation in industrial ecology". *Journal of Industrial Ecology*, vol. 10, no. 1-2, pp. 15-18, 2006
- [22] R. P. Cote, "A primer on industrial ecosystem: a strategy for sustainable industrial development", Eco-Efficiency Center, School for Resource and Environmental Studies, Faculty of Management, Dalhousie University, Halifax, Nova Scotia, 2003
- [23] H. Baumann, "Environmental assessment of organizing: towards a framework for the study of organizational influence on environmental performance", *Progress in Industrial Ecology*, vol. 1, no. 1/2/3, pp. 292-306, 2004
- [24] J. Fiksel, "Sustainability and resilience: toward a systems approach", *Sustainability: Science, Practice and Policy*, vol. 2, no. 2, pp. 1-8 (<http://ejournal.nbii.org>), 2006
- [25] A. Garner, G. A. Keoleian, "Industrial Ecology: An Introduction". University of Michigan National Pollution Prevention Center for Higher Education, 1995

## **Intention Behavior of Villagers in Adopting Telecommunication Technology: A Case Study of Using Cellular Phone in Indonesia**

**Budiarto Subroto\* and Mira Rochyadi\*\***

*\*Industrial Engineering Department, Faculty of Engineering  
Sahid University, Jakarta, Indonesia  
E-mail: budiarto01@yahoo.com*

*\*\*Graduate Program of Industrial Engineering and Management  
Bandung Institute of Technology, Indonesia*

### **ABSTRACT**

Telecommunication technology is proven able to increase the welfare of villagers. In Indonesia, there are still thousands of remote village which have not been reached by the facility of telecommunication technology. One of the barriers of telephone program in the village is the people's behavior towards the telecommunication technology of cellular phone. The main purpose of this study is to know what variables that can influence attitude, subjective norm and perceived behavioral control as well as to know how the influence of the variables towards the intention of villagers to own and use the telecommunication technology of cellular phone. The research findings which are obtained from double regression analysis are as follows: (1) attitude towards behavior and perceived behavior is the significant variable which influences intention and (2) the variable of perceived behavior control that is not proven significant can change the relationship between attitude and intention as well as subjective and intention.

### **Keywords**

Intention behavior, telecommunication technology, cellular phone

### **1. INTRODUCTION**

The role of Information and Communication Technology (ICT) at present is very vital, especially when the trend of world's economy changed from industrial era into information era, from the resource-based economy into knowledge-based economy (Stiglitz, 2006). Currently, people who have access to the latest information are the ones who can conquer the economy (Yunus, 2007). In many literatures, it was found that the telecommunication technology had an influence to the progress and welfare of a country or community (Hardy, 1980; Hudson, Heather & Parker, 1990; Bayes, 2001; Yunus, 2007). Unfortunately, not all people can enjoy the advanced telecommunication technology. Those who live in the villages and remote area often have no access to telecommunication technology. This leads a bigger gap between life in village and in city. Therefore, the inaccessibility of information also causes lack of knowledge for villagers in health and education sectors. It is common if the information accessibility for villagers became one of points of action resulted in the World Summit on Information Society (WSIS) at the end of 2003. One of the points states that the plan is to connect villages and provide telematics facility, including telecommunication and internet in the late year of 2015.

Researches about villagers' behavior in Indonesia towards telecommunication technology are interesting to be conducted due to several reasons. The first is that there has not been any well implemented village telephone program in Indonesia. From the total of 67,797 villages in Indonesia, there are only 24,000 villages which have already got telecommunication service (Donny and Mudiarto, 2006). The government has failed in implementing the village telephone program which was conducted in 2003 for more than 3,000 villages in Indonesia. From several barriers reported by Department of Communication and Information of the Republic of Indonesia (2007), besides the weak system and technology, there is also an indication that the behavior of villagers in adapting the technology has become one of the problems that cause the program unsuccessful. Therefore, it is needed to undertake a research about villagers' behavior towards telecommunication technology. Moreover, the government plans to provide USO village telephones for more than 40,000 villages in Indonesia in the year of 2007 until 2009.

The second reason in undertaking this research is to emphasize the business model (Godong, 2006; Siswanto, 2006) which is based on the Village Phone Model successfully implemented in Bangladesh and Uganda (USA Grameen Foundation, 2005). Meanwhile the other model has more emphasis on technology and policy of national telecommunication industry (Langi, 2005; Bandung et. al., 2006). In fact, within the telecommunication system, one of the most important issues is the telephone user. Venkatachalam and McDowell (2002) state that the need of telecommunication technology of cellular phone that is now commonly offered to people live in cities is not the same as the one that is needed by villagers. Learning how villagers'

behavior towards telecommunication technology of cellular phone will help policy makers, both the government and the company managers to make the best decision for regulations and marketing strategy of telecommunication service for villagers. Therefore, learning villagers' behavior towards telecommunication technology becomes an interesting topic to study.

## 2. KNOWING INTENTION BY USING THEORY OF PLANNED BEHAVIOR

Researchers have been trying to improve behavior models in order to explain people behavior in all aspects of life. At the early development of the theory of behavior, attitude is believed as the most influential variable towards intention and person's behavior. In 1991, Ajzen added perceived behavioral control variable into a TRA model to accommodate a person's self confidence in behavior with all the limitations. This model is later known as *the Theory of Planned Behavior* (TPB). In this model, there are three factors which influence consumer's intentions, namely: (1) the belief of the possibility of the effect towards certain behavior and evaluation from the effect of that behavior (*behavioral beliefs*), (2) the belief of other people's normative hope and motivation to achieve that hope (*normative beliefs*) and (3) the belief of the existence of the factors which can support or interrupt behavior to happen and how big the influence of those factors (*control beliefs*). Behavioral beliefs create attitude towards the behavior (positive or negative attitude towards the behavior), *normative beliefs* create *subjective norms* and *control beliefs* create *perceived behavioral control*.

In the research conducted to explain behavior of lower-middle business people in Chile in adopting the e-commerce technology (Nasco et. al., 2007), it is found that *attitude* and *subjective norm* are proven have positive and significant influence towards *intention*. However, the constructed *perceived behavioral control* is not proven have significant influence. The research conducted by Nasco et. al. (2007) which states that *perceived behavioral control* (PBC) does not give significant influence to the formation of *intention* is very interesting to be investigated. The insignificant influence of PBC towards *intention* is also found in the research of adopting information technology by lower-middle managers in United States (Riemenschneider, Cyntia et. al., 2003). Referring to that condition, the researchers are interested in investigating the behavior of villagers towards cellular phone technology by using TPB model. In a research using TPB, Celuch et. al. (2007) suggests the next researchers to investigate possibility of variables in TPB whether they have capability to moderate relationship among the variables and *intention*. From the literary study, the researchers put PBC as a moderator variable that will influence relationship between *attitude* and *intention*, and relationship between *subjective norm* and *intention*. Furthermore, the research model can be seen in the following Figure 1.

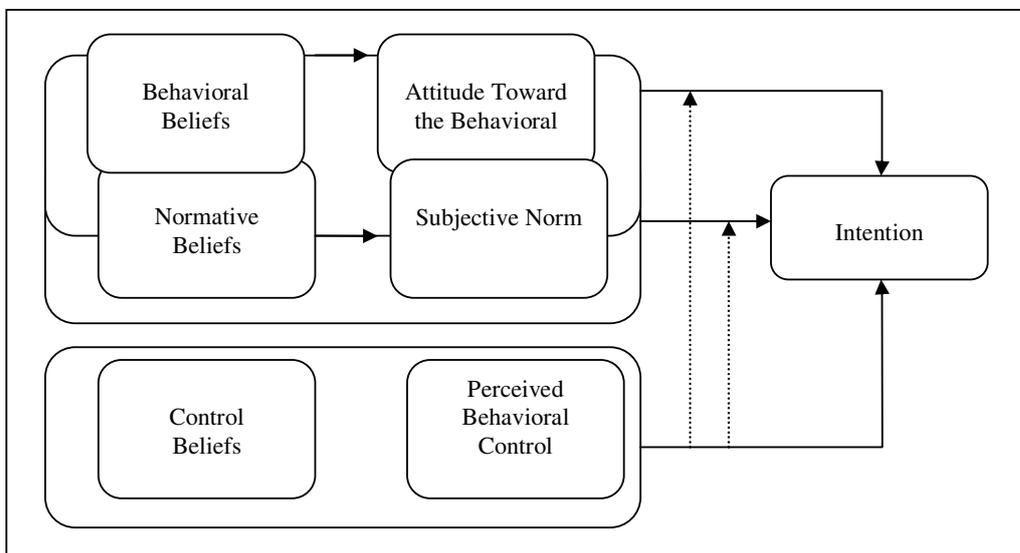


Figure 1: Research Model

## 2.1 Measuring the Construction of TPB

A guideline to elaborate construction of each variable in the Theory of Planned Behavior has been provided by Ajzen. By direct and indirect measurement for emphasizing each measurement must be arranged based on unique behavior of each population which is going to be researched at early research (Ajzen, 2006; Francis, Jillian et. al., 2004). In arranging construction of each variable, an early research was conducted in the form of interview survey to 30 villagers come from Cikadut Village and Mekarmanik Village in Cimenyan Residency, Bandung Region. The early research was conducted to know what factors of the villagers that represent three variables, namely *Attitude towards Behavior Beliefs*, *Subjective Norm Beliefs* and *Perceived Behavior Control Beliefs*. In each proposed question, the researchers have prepared options of answer and let respondents to write down their own opinion. To know the attitude towards behavior of the villagers, the researchers also ask several questions related to advantages and disadvantages felt by the villagers when using telecommunication technology of cellular phone, such as the advantage to be able to communicate easily, to save money and time as well as to increase self confidence. In *subjective norm* variable, the question is related to the closest persons who influence the respondents in making the decision to own and use the telecommunication technology. Meanwhile, for *Perceived Behavior Control* variable the respondents were asked about the factors supporting or avoiding them to use telecommunication technology.

Results of early research about the constructed variables were elaborated more in the form of questionnaire. The answer of the questions which are approved by 75% of the respondents was then written in questionnaire. Total of closed-questions is 46 which consist of 8 questions related to respondents' profile and other 38 closed-questions on Likert scale (ordinal) ranging from 1 until 5 which indicate: strongly agree, agree, no opinion, disagree and strongly disagree. The scoring range is more appropriate to be used for villagers instead of a wide range of scoring that can confuse respondents.

## 2.2 Research Hypothesis

From the background of research it can be described that there is a strong pull to connect all villages in Indonesia with telecommunication network. This is not only the agenda for the government but also the ones for private companies. It can be seen by wider coverage of telecommunication network to small villages by telecommunication operators in Indonesia. Despite the high number of villages in Indonesia which has not been reached by telephone, there are several villages, especially in the island of Java have almost been reached by telecommunication service (Department of Communication and Information of the Republic of Indonesia, 2007).

Referring to general principle of relationship of each variable in TPB stated by Ajzen (2006), the research hypothesis which is arranged based on the relationship between *attitude toward behavior* variable (AB) and *intention* (I) is:

H1: The attitude of villagers towards telephone has positive influence to their intention to own and use telecommunication technology of cellular phone.

The research hypothesis for the relationship between subjective norm (SN) and intention (I) is:

H2: Subjective norm of villagers towards cellular phone has positive influence to their intention to own and use telecommunication technology of cellular phone.

Variable relationship of perceived behavior control (PBC) in this research is investigated by two models, i.e. independent variable (see figure 2.4) and moderator variable. The research hypothesis for independent variable is:

H3.1: Perceived behavior control of villagers towards cellular phone has positive influence to their intention to own and use telecommunication technology of cellular phone.

Meanwhile, the research hypothesis for moderator variable is:

H3.2: Perceived behavior control of villagers towards owning and using cellular phone influences the relationship between attitude and intention as well as the relationship between subjective norm and intention of villagers towards their intention to own and use telecommunication technology of cellular phone.

## 3. RESEARCH METHOD

### 3.1 Arrangement of Research Instrument

Stages of conducting this research are based on the research guideline of TPB proposed by Ajzen (1991). The first stage is to identify population of the research (villagers who have not owned telephones), to determine behavior or intention which are going to be investigated (intention to own and use telecommunication technology), and to undertake early research to reveal specific elements needed in the questionnaire. The early survey was conducted in two different villages in Bandung region.

Referring to the early research, questionnaire that consists of 8 questions which represent behavioral beliefs about the advantage of owning a cellular phone was made. Other 6 questions represent normative beliefs of closest social environment upon having cellular phone and 11 questions represent control beliefs of obstacles to have a cellular phone. Each belief is measured to calculate how big is the value of constructed attitude, subjective norm and perceived behavioral control. The value of attitude towards behavior norm is obtained from behavioral beliefs and outcome evaluation ( $A_B = \sum b_i e_i$ ). Meanwhile, the constructed subjective norm resulted from normative beliefs and motivation to comply ( $SN = \sum n_i m_i$ ) and the constructed perceived behavior control is obtained from control beliefs and perceived power ( $PBC = \sum c_i p_i$ ). Besides the 25 questions above, there are 13 direct questions to measure attitude, subjective norm, perceived behavioral control and intention. The options to answer are measured by 5 Likert scales, ranging from Strongly Agree, Agree, No Opinion, Disagree and Strongly Disagree. Considering that the research population is the villagers in West Java Region, the questionnaire is translated into Sundanese language by a translator in order to ease respondents to understand the questions.

### 3.2 Respondents

Research respondents come from 6 different villages in districts located near the border of Bandung City, West Java. This research uses purposive sampling technique. Technique of obtaining data is in-depth interviewing to the respondents directly. This way is enable the researchers to obtain answer of each question in the questionnaire and also observe the villagers as the research objects directly.

## 4. RESEARCH FINDINGS

### 4.1 Demography

Number of respondents is 143 persons with 76 males (53.9%) as majority. The ages of the respondents are mostly ranging from 17 to 25 years and from 36 to 40 years. Only a few of them have higher education. One person has a bachelor degree (BA) education and another one has a diploma degree. Majority of female respondents are housewives (27.7%), while other professions which also have a high percentage is private employees (16.3%) and business people (17.7%).

### 4.2 Factor Analysis

One of the requirements to operate data by using factor analysis and regression is that the data must be metric with minimum interval scale (Hair et. al., 2006). To fulfill the requirement, data tabulation which come from the questionnaire are changed by using Method of Successive Interval (MSI). By using this method, the data is arranged into order data and analyzed by using MSI program in MS Excel in order to become interval scale to fulfill the basic requirement in analyzing data using factor analysis and double regression. The value of *beliefs* is obtained from multiplication of each comment upon *beliefs* (b) given by the respondents with an evaluation (e).

McCarthy et. al. (2003) in his research about meat consumers' behavior by using Theory of Reasoned Action (TRA) as an early model of TPB, stated that the construction made by the early research that the uni-dimensions should be tested first by using factor analysis. Besides, the reliability of the questions must be seen to measure research construction based on Cronbach Alpha.

Results of the analysis factor can be seen in Table 1. From the table, it can be known that the constructed attitude towards behavior consists of 2 questions in which each question is related to the feeling caused by cellular phone and that the cellular phone is a good gadget. Because there are only 2 questions, the construction of the Cronbach Alpha value is not measured. In the construction of subjective norm, 4 questions are grouped into two factors in which each factor has two questions. The first question is related to the belief upon the influence of friends' opinion in buying cellular phone and the card, while the second question is related to the belief of family in buying cellular phone and the card. Cronbach Alpha used for these questions is 0.821. For the construction of *perceived behavioral control* and *intention*, each has 3 questions with Cronbach Alpha values 0.580 and 0.629.

### 4.3 Regression Analysis and Correlation: Double Linear Regression

To elaborate relationship of variables in this research model, double regression analysis is used as a method. The results of factor analysis which have been done in the following stage are used as a basis of data grouping for each identified variable. By SPSS 15 analysis, it is found in the respondents' histogram that 3 outliers are not included in the analysis. So, the total of analyzed respondent data is 138 persons. This number is still far below the minimum sample of Hair (2006) which mentions

100 samples as a minimum sample for regression analysis, or 5 times bigger than research variables or 15 to 20 times bigger than research variables for a better result.

In this study, the double linear regression analysis is conducted for four times. The first is the relationship that influences attitude (AB). It is found that the people's belief to benefits of telephone is to save the time (AB2) is the most significant predictor ( $\beta = 0.278$ ,  $p < 0.05$ ) comparing with the people's belief that the phone allows them to communicate easily (AB1) and save the cost (AB3). This also shows that villagers believe strongly that the telephone help them save time needed to give information than their belief that the phone can allow them to communicate easily and save the cost. Meanwhile, the positive correlation between AB2 and the attitude can be interpreted that the more convince the villagers to the benefits of cellular phone in saving time, the better attitude they have towards the cellular phone.

Table 1: Loading factor and reliability of each construction

The Components of TPB Model	Loading Factor	Cronbach Alpha*
<b>Attitudes toward behavior</b>	1	
Telephone creates happy feeling	0.819	
Telephone is a good thing	0.819	
<b>Subjective Norm</b>	1	0.821
Belief to the influence of friends' opinion in buying telephone card	0.910	
Belief to the influence of friends' opinion in buying cellular phone	0.839	
Belief to the influence of family's opinion in buying cellular phone	0.808	
Belief to the influence of family's opinion in buying telephone card	0.746	
<b>Perceived Behavior Control</b>	1	0.580
There is no barrier to have a telephone	0.828	
Having a telephone is an easy thing	0.755	
If you want to have a telephone, then you must own it	0.623	
<b>Intention</b>	1	0.629
Efforts to have a telephone	0.831	
Commitment to have a telephone	0.757	
Intention to have a telephone	0.682	

\*The calculation of Cronbach Alpha is only for constructed variables with minimum three questions

The second double linier regression is conducted in the beliefs that it can influence subjective norm (SN). The analysis results show that the villagers have a belief that friend (SNF1) and family (SNF2) influence them in buying cellular phone and the card. These two factors show positive influence to subjective norm, i.e. the higher their belief to their family and friends, the higher their subjective norm will be. Meanwhile, by the double linier regression to see relationship on the perceived behavioral control (PBC), it is found that only one belief which is proven significant ( $\beta = -0.233$ ,  $p < 0.05$ ), i.e. the belief to long distance to buy and use cellular phone (PBC4). The other 5 beliefs are not significantly proven. The long distance that the villagers have to buy cellular phone and the cards has a negative influence to their self confidence (PBC) to have cellular phone. It can be inferred from the relationship that the more convince the villagers to get cellular phone and the cards, the less their self confidence will be to buy and have cellular phone.

To test the TPB model, the double linier regression is conducted in the relationship between *attitude toward behavior* (AB), *subjective norm* (SN), *perceived behavior control* (PBC) and *intention* (I). This study found that the villagers' intention is significantly influenced by their positive attitude towards cellular phone and their self confidence to have cellular phone. The influence of surrounding environment towards the villagers' intention to have cellular phone is not significantly proven.

Besides testing the TPB model, there is also a test to know the relationship of villagers' self confidence that can change the relationship between attitude and intention and the relationship between *subjective norm* and *intention* (PBC as a moderator variable). It was found in the test that *perceived behavior control* cannot influence the relationship between *attitude* and the *intention* to have cellular phone. The only relationship that can be changed by adding the villagers' self confidence factor (PBC) is the relationship between *subjective norm* which come from the influence from friends and the intention. Before *perceived behavior control* is used as a moderator variable, friends' opinion has positive influence to the intention to have cellular phone. After the self confidence factor is added into the model, the influence of friends' opinion becomes negative. This is interesting to be analyzed because when the villagers are more confident to be able to have cellular phone, in fact friends' opinion becomes a factor that can weaken the intention to have cellular phone.

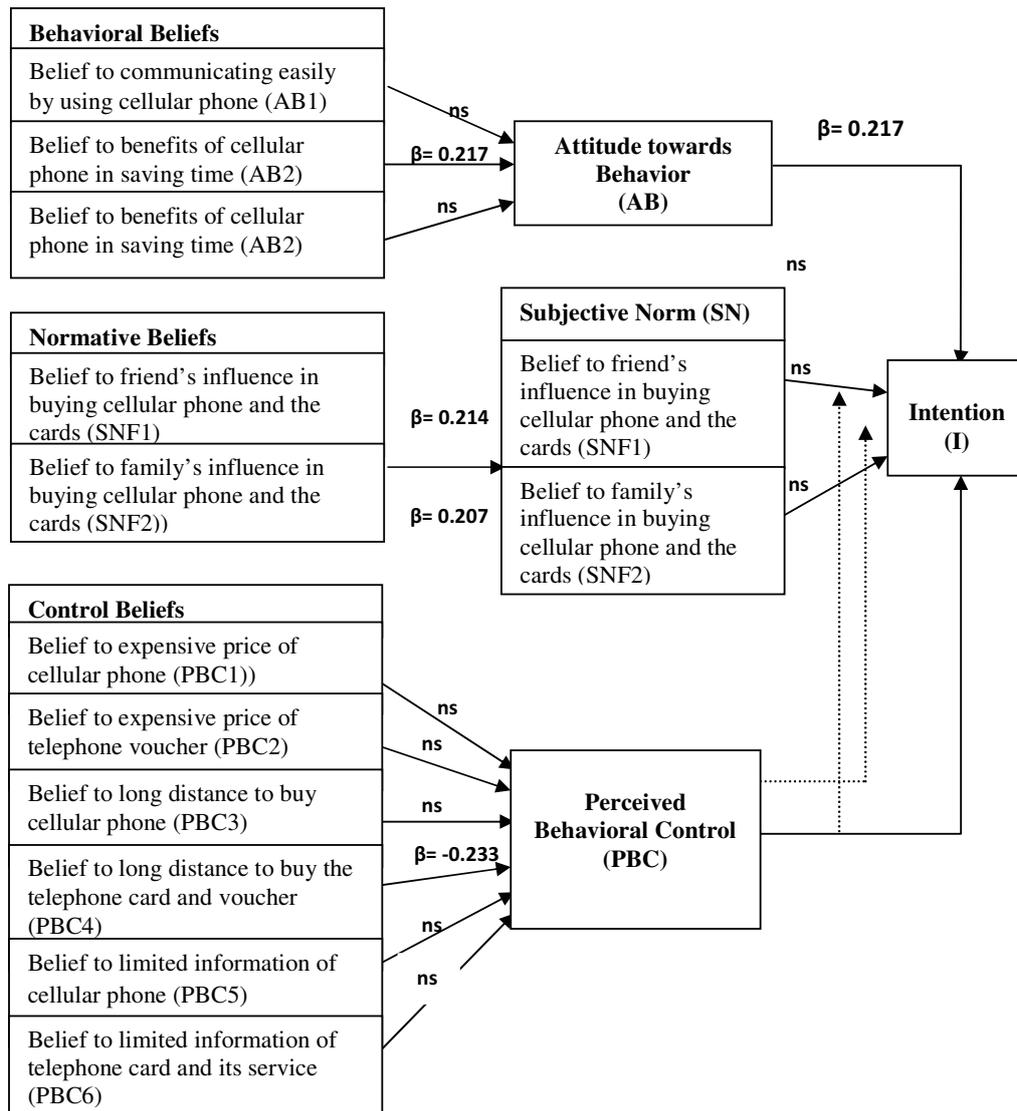


Figure 2: Final results of double regression

The researchers use relationship limitation that can be found possibly due to the inaccurate parameter. Consequently, the respondents tend to be confused in interpreting the proposed questions. The bias or confusion of the concept of PBC variables is also mentioned by Armitage and Conner in Nasco (2007). Therefore, the conclusion is not very convincing.

On the practice, this study can be an input for Indonesian government, especially Department of Communication and Information which become the policy makers in telecommunication sector to have an approach to attitude and self confidence of the people to village telephone. By concerning the factors which are proven having influence, the government is expected to arrange a policy that can accommodate the wants and behaviors of villagers.

## 5. CONCLUSION AND SUGGESTION

It can be inferred from figure 2 that the results of analysis using double regression can explain the variants of TPB model which is an enhancement of TRA model as follows: (1) 16% intention variants of villagers to buy and use telecommunication technology of cellular phone, and other 84% is caused by other factors. Even though it is significant, the intention variants have not been able to be explained yet; (2) the differential of the model consists of several *beliefs* variables which does not have a significant influence to explain the latent variables (figure 5.1). This is because the TPB model is an advanced model of

TRA which is included in multi attributes group. Therefore, this model possibly has problems in a situation where the dimension analysis is used by discrete data.

In previous researches on benefits of technology (Nasco et. al., 2007, Riemenschneider et. al., 2003), it is found that PBC does not significantly influence *intention*. So, in the case of villager's intention to buy and use village telecommunication technology, the SN dimension does not significantly influence intention. In this case study, it is also proven that the suggestion from Celuch (2007) to investigate further on the moderator relationship among variables cannot be proven. In other words, proposed hypothesis is rejected.

Findings of the study are still not optimal yet. It is expected that there will be an advanced research on villagers' behavior by using the same theory and model. In spite of the fact that the study still needs to be continued, there is a finding shows that there is a moderator relationship between PBC variable and SN, though the influence is not very significant. These findings are beneficial as an early point for further investigation in the next researches.

## REFERENCES

- [1] Ajzen, Icek., The Theory of Planned Behavior, *Organizational Behavior and Human Decision Process* 50, 1991, p 179-211
- [2] Ajzen, Icek, Behavior Intervention Based on The Theory of Planned Behavior, Brief Description on the Theory of Planned Behavior, 2006
- [3] Ajzen, Icek & Fishbein, Martin., The Influence of Attitudes on Behavior, <http://people.umass.edu/ajzen/tpb.html>
- [4] Ajzen, Icek, Constructing a TPB Questionnaire: Conceptual and Methodological Considerations, January 2006.
- [5] Armitage, C.J., Conner, M., Efficacy of The Theory of Planned Behavior. A Meta Analytic Review, *British Journal of Social Psychology*, Volume 40, Number 4, December 2001, pp. 471-499 (29)
- [6] Bandung, Yoanes, Langi, Armein Z. R., Complementary of IntServ and DiffServ for Qos Guarantees in Rural Next Generation Network (R-NGN), Pro. ICI CI, August 2005
- [7] Bayes, Abdul, Infrastructure and Rural Development: Insight from a Grameen Bank Village Phone Initiative in Bangladesh, *Agricultural Economics Journal*, 2001
- [8] Celuch, Kevin, et al., Understanding Small Scale Industrial User Internet Purchase and Intentions: A Test of Two Aptitude Models, *Industrial Marketing Management* 36, 2007, p. 109-120
- [9] Department of Communication and Information: Policy on Provision of Rural Telecommunication Infrastructure, KPU/USO, 2007
- [10] Donny, BU., Mudiarjo, R., Digital Review Asia Pasific Indonesia Chapter, United Nation Development Program, ICT Watch, 2006
- [11] Fishbein, Martin, & Ajzen, Icek, Belief, Attitude, Intention and Behavior: An Introduction Theory and Research, Addition Wesley Publishing Company, 1980
- [12] Francis, Jilian J., et al, Constructing, Questionnaire Based on The Theory of Planned Behavior, Manual for Health Services Researchers, Quality of Life and Management Living Resources, May 2004
- [13] Gillholm, Robert, et al, The Effect of Choice on Intention Behavior Consistency, Goteborg Psychological Report 26, no 9, 1996
- [14] GODONG, Adrian, Business Model Development for Rural Telecommunication Service, ITB, 2006
- [14] Grameen Foundation USA, Village Phone Replication Manual, 2005
- [15] Hardy, Andrew P., The Role of The Telephone in Economic Development, IPC Business Press, 1980
- [16] Hair, J. F., et al, Multivariate Data Analysis, 6<sup>th</sup> edition, Pearson, Prentice Hall, 2006
- [17] Hawkins, Best & Coney, Consumer Behavior: Building Marketing Strategy, McGraw Hill, 2004
- [18] Langi, Armein Z. R., Franchising of Telecommunication Operation: New Strategy for USO Indonesia, Mei 2006
- [19] Liao, Chechen, et al, Theory of Planning Behavior (TPB) and Customer Satisfaction in The Continued Used of E-Service: An Integrated Model, *Computers in Human Behavior* 23, 2007, p. 2804-2822
- [20] Kanuk, I. Lazar, Schiffman, Leon G., Consumer Behavior, Prentice Hall, 2004
- [21] McCarthy, M., et al, Influencing Intention to Purchase Beef in The Irish Market, *Meat Science* 63, 2003, p. 1071-1080
- [22] Nasco, Suzanne A., Predicting Electronic Commerce Adoption in Chiean SMEs, *Journal of Business Research* 2007
- [23] Richardson, Don et al, Grameen Telecom's Village Phone Program In Rural Bangladesh: A Multi Media Case Study, Canadian International Development Agency (CIDA), 2000
- [24] Reimenschneider, Cyntia K., et al, Understanding IT Adoption Decisions in Small Business: Integrating Current Theories, *Information and Management* 40, 2003, p. 269-285
- [25] Siswanto, Joko, A Business Model of Village Phone for entrepreneurship development in Rural Areas of Indonesia, Bandung 2006
- [26] Smarkola, C., Efficacy of Planned Behavior Model: Beliefs that Contribute Computer Usage Intentions of Students teachers and experienced teachers, *Computer in Human Behavior* 24, 2008, p. 1196-1215
- [27] Salomon, Michel R., Consumer Behavior-Buying, Having and Being, Pearson, Prentice Hall, 2004
- [28] Van Hooft, Edwin A. J., et al, Job Search and The Theory of Planned Behavior: Minority-Majority Group Differences in The Netherlands, *Journal of Vocational Behavior* 65, 2004, p. 336-390
- [29] Venkatachalam, Shree, et al, What is broadband? Where is "Rural"?, *Government Information Quarterly* 20, 2002, p. 151-166
- [30] Yusuf, Muhammad, Bank for The Poor, Marjin Kiri, 2007

## Knowledge Sharing Attempt of Doctors in Teaching Hospital using Partial Least Squares (PLS) Analysis

Oktri Mohammad Firdaus<sup>a,c</sup>, T.M.A. Ari Samadhi<sup>b</sup>, Rajesri Govindaraju<sup>b</sup>, Kadarsah Suryadi<sup>b</sup>, Agus Mutamakin<sup>d</sup>, Kah Hin Chai<sup>e</sup>

<sup>a</sup>Ph.D. student Department of Industrial Engineering, Bandung Institute of Technology, Bandung 40132  
E-mail : oktri.firdaus@gmail.com; oktri.firdaus@widyatama.ac.id

<sup>b</sup>Department of Industrial Engineering, Bandung Institute of Technology, Bandung 40132

<sup>c</sup>Department of Industrial Engineering, Faculty of Engineering, Widyatama University, Bandung 40124

<sup>d</sup>Center for Clinical Epidemiology & Evidence-Based Medicine (CEEEM), Faculty of Medicine, University of Indonesia, Cipto Mangunkusumo Hospital, Jakarta 10430

<sup>e</sup>Department of Industrial and Systems Engineering, Faculty of Engineering, National University of Singapore, Singapore

### ABSTRACT

Communication among doctors in addressing a disease that involves the same disciplines and involves a wide range of different disciplines plays a very vital. Significant aspects of influence in the advancement of medical science are knowledge sharing activities as a form of follow-up communication activities. This study will examine knowledge sharing activities in the 5 (five) department in a teaching hospital in Indonesia. The method used to conduct surveys directly to the doctors who are selected as respondents by random sampling. The number of questionnaire were distributed to respondents as many as 200 pieces, while the questionnaires were returned and processed fruit totaled 192 with a net responses rate of 96%. This study shows that of the five hypotheses, there are three hypotheses supported. The conclusion of this study is that management support has no effect on intention to share knowledge, that doctors are mostly internal-driven, i.e. they share their knowledge because they enjoy doing it, not because management support this, and not that the knowledge involved is useful. This points to the difficulty of promoting knowledge sharing, that is, top management support or leadership may not be that effective (since the results show that management support has no effect) in driving knowledge sharing. Maybe what management can do is to ensure that they select doctors who are intrinsically motivated and like to help people.

### Keywords

*Knowledge sharing, doctors, partial least squares (PLS)*

## 1. INTRODUCTION

Health conditions in Indonesia had a very significant development in recent decades. For example, the infant mortality rate fell from 118 deaths per thousand births in 1970 to 35 in 2003, and life expectancy increased from 48 years to 66 years in the same period. This displayed a developmental impact of the expansion of the provision of public health facilities in 1970 and 1980, and the impact of family planning programs [1]. Indonesia's health ministry has improved although some remained problems and new challenges continue to increase [1]. The progress achieved including reduced infant mortality and increased life expectancy, but maternal mortality and child malnutrition remains a major problem. Demographic and epidemiological transition accelerated by rising incomes and an aging population. This shift resulted in a rapid increase in health care demands more and better. Indonesia's health system must answer this demand by improving the quality of services and diversified its funding of health [1]. Public health in Indonesia was influenced by many factors. These factors not only from the health sector such as health care and availability of health infrastructure, but also influenced by economic factors, education, social environment, heredity, and other factors. Public health situation can be reflected through morbidity, mortality and nutritional status [2].

Seen from the side a more micro level hospitals, there are several things that can affect the process of integration of health information systems in Indonesia and in other countries, namely concerning the relationship between the readiness of policymakers in the hospital, the patient data documentation system is good (medical record), human resources directly involved both doctors, nurses, midwives and pharmacists as well as other resources that are not directly involved as well as other supporting infrastructure such as server systems and the process of defining all business processes that occur in a hospitals [3]. To realize all of the above, then one of the factors that play a role is communication, direct communication

between all actors involved in the health world with emphasis on the sharing of useful information and knowledge (information and knowledge sharing) as well as through its medium well it software or hardware with respect to effective strategies in implementing information and communication processes for knowledge sharing [4].

## 2. LITERATURE REVIEW

The implementation of knowledge sharing can take place not only in the formal order, but also in the form of non-formal order is precisely the process of knowledge sharing can be run more effectively [5]. The process of knowledge sharing in the medical world especially among doctors is needed. This happens especially when a doctor with specific expertise found patients with a special case and is not in accordance with the area of competence, then the doctor will naturally consult other doctors are more appropriate competence. These conditions can be considered as the beginning of the process of knowledge sharing. The other thing is when a patient requires treatment not only by a doctor but by a team of physicians, the knowledge sharing process is in progress for this condition.

Previous research focused on the process of knowledge sharing in the field of health, among others References [6] with emphasis on the implementation of decision-making at a health clinic. References [7] discuss the role of information technology in changing society's view of health care. References [8] explained that more than the ability to see the role of knowledge management in healthcare to alter the characteristics of organizational capabilities and human resources, the quality of infrastructure and the decision making process. References [9] described the knowledge sharing behavior of physicians in a hospital. References [10] used deductive databases and database ontology in information integration process and the implementation of knowledge sharing in health care. References [11] using the media storytelling as knowledge sharing media treatment of a disease. References [12] emphasizes the importance of interdisciplinary science in solving problems in health care in particular a hospital. References [13] utilized bioinformatics and centralization-based health services in the process of knowledge sharing.

References [14] further highlight case studies of autism as the main chart roadmap to generate knowledge sharing specifically for people with autism. References [15] described the results of an investigation into the application of knowledge management system for the classification of disease. References [16] designed a process of knowledge sharing after the SARS outbreak. References [17] described the knowledge sharing behavior of consumers in an inter-organizational healthcare community. References [18] conducted research related to knowledge sharing in the hospital more specific. References [19] raised the issue of ease of access and reuse the knowledge and the knowledge sharing process with a case study on the health sector in the Caribbean region. References [20] developed a model of knowledge sharing for pediatricians using a Web 2.0 framework. References [21] stated that the community of practice (CoP) is the best solution in the process of sharing knowledge specific to the case in Kuwait. References [22] used statistical methods and perspectives from existing experience to improve the process of knowledge sharing.

References [23] conducted an analysis of knowledge management mechanisms that occur in health care portal. References [24] described the main factors that influence health professionals to adopt knowledge management. In the end references [25] provide brilliant idea, called the future of healthcare knowledge sharing, where there are several key trends that knowledge ownership, endorsment of informal channels, specialized communities, real-time knowledge sharing, consumer-generated knowledge, Mandated sharing of the "collective intelligence ", and improved access to knowledge.

From a full explanation before, we could conclude that with the increase in the number and type of disease in this world requires a qualified medical treatment. To produce high quality medical treatment, the required increase in the quality of research related to medical treatment. However, the increasing amount of research is not enough to be followed also by improving the quality of research that is not directly in dire need of good quality communication between physicians specializing in the dissemination of research results related to medical treatment. One of the main requirements to allow the dissemination of research results can be well established is the need for the process of knowledge sharing among doctors that would lead to the need to improve the effectiveness of the base of knowledge sharing among doctors.

This study tried to look at the relationship level interplay of intention to share knowledge that has been developed by several previous investigators through the Theory of reasoned Action (TRA), the Theory of Planned Behavior (TPB) and Technology Acceptance Model (TAM) with Knowledge Sharing Attempt (KSA) which is a positive contribution of references [26]. Some of the factors that have significant influence based on the analysis of the previous studies on intention to share knowledge are management support, enjoyment helping others, perceived usefulness and the interaction frequency. Broadly speaking, this research can be concluded has 4 (four) direct effects on intention to share knowledge, as well as the intention to share knowledge (ISK) is assumed to affect knowledge sharing attempt (KSA). There we propose the following hypotheses:

*H1. Management support is influenced to intention to share knowledge*

*H2. Enjoyment helping others is influenced to intention to share knowledge*

*H3. Perceived usefulness is influenced to intention to share knowledge*

*H4. Interaction frequency is influenced to intention to share knowledge*

*H5. Intention to share knowledge is influenced to knowledge sharing attempt*

Further explanation of the conceptual model of this study can be seen in figure 1 below.

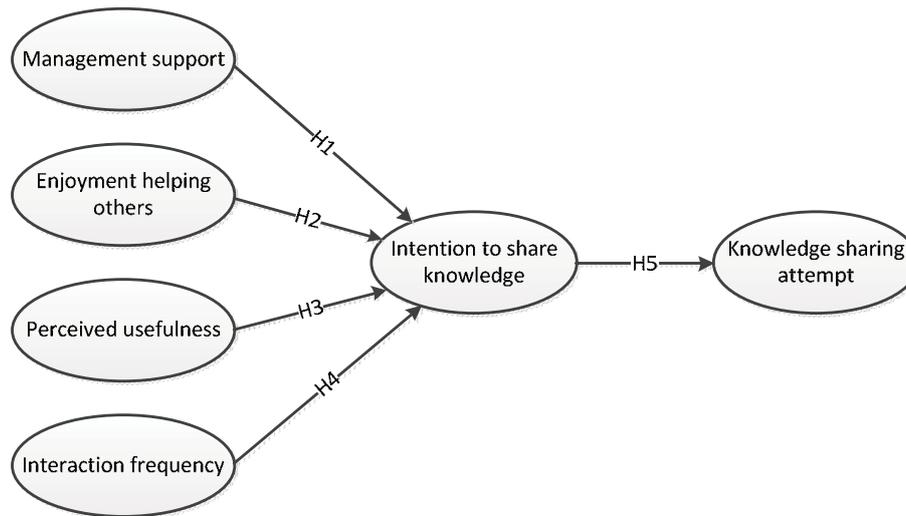


Figure 1: Conceptual Model

### 3. METHODS

In this study we used the survey method, this is caused by this research work was the focus of the current situation, and then shape the research questions about of who, what, where, how much / many, and does not require control over behavioral events [27]. This research questionnaire using closed questions. The main requirement of the respondents who would fill out this questionnaire is a medical specialist candidate (resident), specialist doctors who are continuing to be the consultants and specialists are a faculty member in the Faculty of Medicine and minimal working together in a hospital for at least 2 (two) years, the reason is that respondent assumed to be representative of the actual conditions in terms of knowledge, skills and experience they have in doing medical treatment. In addition to these criteria, the doctor is concerned with the doctor already knew each other well in the same part or different parts but has a level of interdependence is high especially in dealing with a problem of the patient as a team.

The survey was conducted by the method of paper-based questionnaire distributed directly to the respondents. The main part of the questionnaire in this study was a closed question that contains a list of questions with answers that are available and choose the answer that the respondent lived there [28]. The answer to a closed question questionnaire will be validated using appropriate statistical methods both in terms of descriptive statistics to multivariate statistics. The processes of distributing the questionnaire can only be done after the issuance of a certificate of ethical escaped examine the Health Research Ethics Committee Cipto Mangunkusumo Hospital/Faculty of Medicine University of Indonesia Jakarta. This is a major requirement in the field of health research in Indonesia can be implemented. The certificate is valid passes the review of conduct during the period of 1 (one) year and applied nationally in all hospitals located within the jurisdiction of the Republic of Indonesia. The questionnaire study using the 5 likert-scale with the explanation that the value of 1 indicates strongly disagree and a score of 5 indicates strongly agree. The respondents are sampled both of resident doctors and consultants from 5 different departments in teaching hospitals in Indonesia are Pediatrics, Obstetrics & Gynecology, Anesthesia, Radiology and Clinical Pathology. By using proportional random sampling method, a total of 200 pieces of research questionnaire is given directly to the resident and consultant. The number of questionnaire were returned as much as 199 pieces and questionnaires that can be processed as many as 192 pieces with a net response rate of 96%.

This study shows the following profile of the respondents, aged respondents consisted of 81 people (42,19%) aged under 30 years, 83 people (43,23%) between 31-45 years old, 24 people (12,5%) between 46-60 years old and 4 people (2,08%) aged over 60 years. By sex as much as 82 people (42,7%) were male and 110 (57,29%) were female. The respondents of this study is dominated by the resident with a total of 153 people (79,69%), the staff of as many as 9 people (4,69%), a fellow by 2 people (1,04%), 18 people (9,38%) consultant, head of division by 4 people (2,08%), as well as the professor as 6 people (3,13%). While the composition of the respondents from the five departments under study shows the results of 38 people (19,79%) came from the department of clinical pathology, 40 people (20,83%) from the department of pediatrics, radiology department of 39 people (20,31%), 37 people (19,27%) from the department of anesthesia, as well as 38 people (19,79%) from the department of obstetrics & gynecology. Meanwhile, recent information shows that 142 people (73,96%) have experience of 2-6 years as a doctor, 21 people (10,94%) experienced for 7-10 years, 11 people (5,73%) experienced for 11-15 years, and each group of 9 people (4,69%) for respondents with 16-20 years experienced and above 20 years.

#### 4. RESULT AND DISCUSSION

After all data was collected through the paper based questionnaire with a total of 192, performed the processing and analysis of data using the rules of PLS-SEM with using Smart PLS 2.0 software. The use of software Smart PLS 2.0 is not without controversy, in which the most basic things a matter of debate on the expert was mentioned that when using PLS Smart PLS 2.0 or other software, it cannot be measured Goodness-Fit Test [29]. But if we set aside the controversy beforehand, the actual use of PLS is quite helpful for the research that has little data, because the main rule of the PLS-SEM does not specify a minimum sample size that can be processed [29]. PLS-SEM also has the flexibility in the distribution of population, as well as formative and reflective structure has the power in the process of exploration [29]. The other thing that supports the use of PLS-SEM in the processing and analysis of research data is optimized PLS-SEM on prediction accuracy, and can maximize the value of the variance in the construct variables [30].

The next stage after it is determined that this study will use Smart PLS 2.0 for processing and analysis of data is test reliability. Indicators are widely used by the researchers for this is Cronbach's alpha [29]. Cronbach's alpha values of these will range from 0 to 1, where references [31] explained that the minimum of a variable is said to be reliable 0.7 for the early stages, but in its development some researchers suggest that the minimum is 0.8 or 0, 9 with the aim to increase the confidence of researchers that research instrument used is really reliable. Meanwhile, references [29] suggested that the threshold for each variable is said to be reliable at 0.5. Indicator test reliability than Cronbach's alpha this is a composite reliability or part of research called Dillon-Goldstein's Rho, its value is at least equal to Cronbach's alpha or possibly larger [29].

Indicator reliability used results of the calculation of loadings for all observed variables [29]. The main purpose of the indicator reliability is to check whether there is one or more observed variables of a variable construct that has no reliable indication [29]. The minimum value that can be said reliably is of 0.7 [29]. In the next stage is to test the validity of particular convergent validity, which would be a valid indicator of whether or not a variable is used indigo AVE (average variance extracted). AVE measures the amount of variance that is on variable constructs (latent) in relation to random measurement error [29]. Its value ranges from 0 to 1, and the minimum acceptance amounted to 0.5 [32]. The explanation can be seen in table 1.

Table 1: Indicator reliability

	AVE	Composite Reliability	R Square	Cronbachs Alpha	Communality	Redundancy
ATTEMPT	0,7981	0,9222	0,2222	0,8738	0,7981	0,1761
ENJOYMENT	0,7792	0,9134	0	0,8578	0,7792	0
INTENTION	0,7232	0,9473	0,4023	0,9334	0,7232	0,265
INTERACTION	0,7292	0,8893	0	0,8107	0,7292	0
MANAGEMENT	0,6439	0,8431	0	0,7216	0,6439	0
USEFUL	0,5494	0,8218	0	0,7155	0,5494	0

References [32] describes for discriminant validity verification can be done by using the value of the root of the AVE (average variance extracted) and replace the value 1 in the calculation of correlations between variables constructs. In principle, the value of the root of the AVE should be greater than the value of the correlation between variables and construct the other just said that the variable is valid constructs [32]. Table 2 shows the correlation values for all variables of the same construct was greater when compared with the value of the correlation between different variables.

Table 2: Discriminant validity

	ATTEMPT	ENJOYMENT	INTENTION	INTERACTION	MANAGEMENT	USEFUL
ATTEMPT	<b>0,8934</b>	0	0	0	0	0
ENJOYMENT	0,5492	<b>0,8827</b>	0	0	0	0

INTENTION	0,4713	0,6151	<b>0,8504</b>	0	0	0
INTERACTION	0,4148	0,4522	0,4108	<b>0,8539</b>	0	0
MANAGEMENT	0,4835	0,3793	0,2943	0,3851	<b>0,8024</b>	0
USEFUL	0,5334	0,5415	0,4055	0,4927	0,4922	<b>0,7412</b>

In this study to test the hypotheses on each direct antecedents we used SmartPLS 2.0 software with the generation of data through a bootstrapping procedure [33] & [34]. This research used the number 500 for each time bootstrapping run, there is no definitive reason to choose this 500 number. Previous researchers suggested that the amount of bootstrapping run as many as 500 shows a fairly optimal result for a study specifically related to behavioral research [35]. All tests of this hypothesis using a two-tailed (two-way), on the grounds that all the hypotheses are designed not made to have a tendency towards the positive and negative effects, but rather focus on the exploration of the relationship between the levels of one variable with another variable. Detailed descriptions of the results of hypothesis testing are in Table 3 and Figure 2.

Table 3 Hypotheses test result

Path/Hypothesis	Paper-based Questionnaire (n=192)	
	Path coefficient	t-value
MANAGEMENT → INTENTION	0,020	0,311
ENJOYMENT → INTENTION	0,518	<b>7,571**</b>
USEFULNESS → INTENTION	0,042	0,646
INTERACTION → INTENTION	0,0148	<b>2,333*</b>
INTENTION → ATTEMPT	0,471	<b>4,064**</b>

Note: \*: significant at  $p < 0,05$ ; \*\*: significant at  $p < 0,001$  (two-tailed)

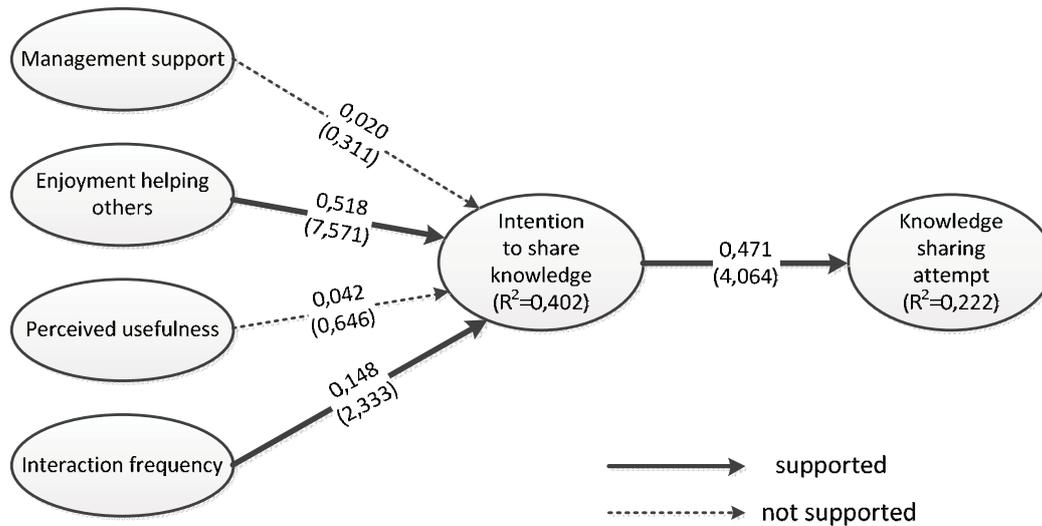


Figure 2: Full Model

## 5. CONCLUSION

Based on the hypothesis test for the data using the method of paper-based data collection questionnaire with a total sample of 192 pieces, acquired three (3) supported the hypothesis and 2 (two) hypothesis is not supported. Variables that are not declared "relationship" between the antecedents with constructs such as management support and perceived usefulness on intention to share knowledge. This indicates that management support has no effect on intention to share knowledge, that doctors are mostly internal-driven, i.e. they share their knowledge because they enjoy doing it, not because management support this, and not that the knowledge involved is useful. This points to the difficulty of promoting knowledge sharing, that is, top management support or leadership may not be that effective (since the results show that management support has no effect) in driving knowledge sharing. Maybe what management can do is to ensure that they select doctors who are intrinsically motivated and like to help people.

## REFERENCES

- [1]. World Bank (2010) : *Profil Sektor Pembangunan Manusia: Memperkuat Institusi Kesehatan dan Pendidikan di Indonesia*, World Bank Indonesia, Jakarta.
- [2]. Ministry of Health Republic of Indonesia (2010) : *Buku Profil Kesehatan Indonesia 2009*. Kemenkes RI, Jakarta.
- [3]. Abidi, S.S.R., (2001) : Knowledge management in healthcare: towards knowledge-driven decision support services, *International Journal of Medical Informatics*.
- [4]. Mei, Y.M., Lee, S.T., and Al-Hawamdeh, S., (2003) : Formulating a communication strategy for effective knowledge sharing, *Journal of Information Science*.
- [5]. Hall, H., (2001), Input-friendliness: motivating knowledge sharing across intranets, *Journal of Information Science*, 27 (3) pp 139-146
- [6]. Frosch D.L., & Kaplan, R.M., (1999) : Shared Decision Making in Clinical Medicine: Past Research and Future Directions, *American Journal of Preventive Medicine, Volume 17 Number 4*
- [7]. Fieschi, M., (2002) : Information technology is changing the way society sees health care delivery, *International Journal of Medical Informatics*.
- [8]. Bose, R., (2003) : Knowledge management-enabled health care management systems: capabilities, infrastructure, and decision support, *Expert Systems with Applications*.
- [9]. Ryu, S., Ho, S.H., & Han, I., (2003) : Knowledge sharing behaviour of physicians in hospitals, *Expert Systems with Applications* 25 (113-122)
- [10]. Nardon, F.B., & Moura, L.A., (2004) : Knowledge Sharing and Information Integration in Healthcare using Ontologies and Deductive Database, *Medinfo*.
- [11]. Bulow, P.H., (2004) : Sharing experiences of contested illness by storytelling, *Discourse Society Vol 15 (1) 33-53*
- [12]. Burnett, S.M., Williams, D.A., & Webster, L., (2005) : Knowledge support for interdisciplinary models of healthcare delivery: a study of knowledge needs and roles in managed clinical networks, *Health Informatics Journal Vol 11(2) 146-160*
- [13]. Lubitz, D.V., & Wickramasinghe, N., (2006) : Networkcentric healthcare and bioinformatics: United operations within three domains of knowledge, *Expert Systems with Applications* 30 (11-23)
- [14]. Oberleitner, R., Wurtz, R., Popovich, M.L., Fiedler, R., Moncher, T., Laminarayan, S., & Rieschl, U., (2005) : Health Informatics: A Roadmap for Autism Knowledge Sharing, *Medical Care and Compunetics Volume 2*.
- [15]. Hwang, H.G., Chang, I.C., Chen, F.J., & Wu, S.Y., (2008) : Investigation of the application of KMS for disease classifications: A study in a Taiwanese hospital, *Expert Systems with Applications* 34 (725-733)
- [16]. Chen, S.L., Chang, S.M., Lin, H.S., & Chen, C.H., (2008) : Post-SARS knowledge sharing and professional commitment in the nursing profession, *Journal of Clinical Nursing* 18 (1738-1743)
- [17]. Von Krogh, G., Kim, S., & Erden, Z., (2008) : Fostering the knowledge-sharing behavior of customers in interorganizational healthcare communities, *IFIP International Conference on Network and Parallel Computing*
- [18]. Juarez, J.M., Riestra, T., Campos, M, Morales, A., Palma, J., & Marin, R., (2009) : Medical knowledge management for specific hospital departments, *Expert Systems with Applications* 36 (12214-12224)
- [19]. Mansingh, G., Osei-Bryson, K.M., & Reichgelt, H., (2009) : Issues in knowledge access, retrieval and sharing – Case`studies in a Caribbean health sector, *Expert Systems with Applications* 36 (2853-2863)
- [20]. Abidi, S.S.R., Hussini, S., Sriraj, W., Thienthong, S., & Finley, G.A., (2009) : Knowledge Sharing for Pediatric Pain Management via a Web 2.0 Framework, *Medical Informatics*.
- [21]. Marouf, L., & Al-Attabi, F., (2010), *Community of Practice in the Kuwaiti Medical Sector: An Exploratory Study*.
- [22]. Ting, S.L., Kwok, S.K., Tsang, A.H.C., & Lee W.B., (2010) : CASESIAN: A knowledge-based system using statistical and experiential perspective for improving the knowledge sharing in the medical prescription process, *Expert Systems with Applications* 37 (5536-5346)
- [23]. Lee, C.S., Lian Goh, D.H., and Chua, A.Y.K., (2010) : An analysis of knowledge management mechanism in healthcare portals, *Journal of Librarianship and Information Science*.
- [24]. Chen, Y.H., Liu, C.F., & Hwang, H.G., (2010) : Key factors affecting healthcare professionals to adopt knowledge management: The case of infection control departments of Taiwanese hospitals, *Expert Systems with Applications* 38 (450-457)
- [25]. Fortin, F., Johnston, R., Phillips, M., and Sgrignoli, D., (2010) : *The Future of Healthcare Knowledge Sharing*, Healthcare Association Conference, Chicago, IL.
- [26]. Siemsen, E. (2005) : *Essay on Knowledge Sharing*, A Dissertation Faculty of University of North Carolina.
- [27]. Aulawi, H., (2010) : *Analisis Hubungan antara Knowledge Enablers, Perilaku Berbagi Pengetahuan dan Kemampuan Inovasi*, Disertasi, ITB, Bandung.
- [28]. Sekaran, U. (2011) : *Research Methods for Business*, John Wiley & Sons, Inc. New York.
- [29]. Chin, W.W. (1998) : *The partial least squares approach to structural equational modeling*. Modern methods for business research, 295-358.
- [30]. Barclay, D., Higgins, C., & Thompson, R. (1995) : The Partial Least Squares (PLS) approach to causal modeling: Personal computer adoption and use as an illustration, *Technology Studies Vol 2(2) pp. 285-324*.
- [31]. Nunnally, J.C. (1978) : *Psychometric Theory*, McGraw-Hill, New York, NY.
- [32]. Fornell, C., & Larcker, D.F. (1981) : Structural equation models with unobservable variables and measurement errors, *Journal of Marketing Research*, 18(2), pp.39-50.
- [33]. Gray, P.H. & Meister, D.B. (2004) : Knowledge sourcing effectiveness. *Management Science*, Vo. 50(6) pp. 821-834
- [34]. Subramani, M. (2004) : How do suppliers benefit from information technology use in supply chain relationships? *MIS Quarterly Vol. 28(1) pp. 45-73*.
- [35]. Tenenhaus, M. et al. (2005) : PLS path modeling. *Computational Statistics & Data Analysis*, 48(1): 159-205.

## Modeling a Feasible and Sustainable Business of Traditional Batik Home Industry

Sri-Bintang Pamungkas<sup>a</sup>, Gita Dwi Permata Sari<sup>b</sup>

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : sri.bintang@ie.ui.ac.id

<sup>b</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : gita.dwi@ui.ac.id

### ABSTRACT

*Hand stamping and hand writing in Batik industry is a famous culture characterized by Indonesia. The traditional Batik industry may hold great potential to boost economic growth. Most of the industry consists of generally small but labor-intensive firms. Unfortunately the development of technology and policy changes in the last 40 years have threatened their existence. Many of the traditional Batik firms are not able to compete with the Batik printing industry, and at the end they closed down their business. It happened especially in Laweyan, Solo, one of the central area of traditional Batik production of Central Java.*

*The objective of the study is to revive the traditional Batik industry in Laweyan back to its existence from its long time gone through an investment model of traditional Batik home industry. It will be proven that a small capital funding from banks is quite enough to rebuild profitable home industry Batik firms that make Laweyan regain its Traditional Batik Kingdom in Indonesia. The result of the study shows that the business model of Batik traditional home industry yields positive investment criteria. Industrial conditions mapping also indicates that a cluster model of the Batik industry has a potential of growing.*

### Keywords

*Traditional batik, feasibility, engineering economics, investment criteria, IE Matrix*

### 1. INTRODUCTION

Writing and stamping Batik by hand in a traditional way is putting special pattern with melting wax on “mori”, white fabric material, using tools called “canting” and “stamp”. Writing Batik with “canting” or stamping with “stamp” has been known since the ancient kingdom of “Majapahit” and currently recognized worldwide as Indonesian traditional cultural heritage; many of us believed this kind of technology has to be preserved rather than abandoned. During 1950-1970, traditional Batik became a mainstay of Indonesia textile products both locally and internationally, when the industry was growing rapidly. However when the government began to introduce a capital-intensive textile industry in 1970s, and the printing industry is allowed freely to exploit the traditional Batik patterns in the printing to produce similar products, called the printing Batik, which much faster and cheaper, then the traditional Batik industry began to collapse. The existence of Batik printing reduces much of the market share of traditional Batik [4].

Laweyan, a small village in Surakarta City suburb, is known as one of the central area of traditional Batik production in Central Java. Formerly there were 170 traditional Batik firms in 1980, but currently only 27 traditional Batik firms are left and those are small-and medium-scale enterprises (SME). In micro-economic level, the SME of a traditional Batik industry contributes as a source of income for craftsmen and small entrepreneurs; while that on a macro level, it may expected to contribute to the output production and employment in Indonesia [5]. However, uncertain economic conditions, such as imperfect competition, currently embrace, cause financial problems for the purchase of materials, for the production capacity and for the payment to Batik craftsmen of the industry.

References [3] added that SMEs in Indonesia faces many problems, mainly: (1) lack of technological knowledge; (2) lack of marketing know-how; (3) lack of managerial capacity; and (4) poor access to formal financial resources. It is difficult for SMEs, especially the traditional Batik industry, with its limited skill of human and financial resources to develop markets and arrange financially by themselves. Therefore, a special effort to provide source of funds for new investment and working capital to the traditional Batik industry has to be arranged and developed, to rebuild the industry back on its foot into the Great Laweyan of 1960s. Banks are effective in providing external resources for new and innovative activities, because banks can credibly commit in making additional funding available as the project develops [1].

Based on the reasons above, the issues in this study is of traditional Batik industry that has high economic and cultural value, but its existences is threatened by an imperfect market situation. Therefore, what is needed is designing a model of investment in the traditional Batik industry, where banks as capital funders are attractive to invest.

## 2. METHODOLOGY

This study uses the traditional Batik industry in Laweyan, Surakarta, as an object. Several firms that have been closed, some others which are still producing with very low capacity, and big firms which produce both the printing Batik and traditional Batik are studied and used to create a model. The analysis is done through descriptive qualitative and quantitative methods which are in the form of primary data and secondary data collected from owners of the firms. The study also collects data from the SME Industry Regional Department in Surakarta; and information from some Batik literatures.

This research approach involves several key steps:

Step 1: determine an economies scale of Batik firm, which will be used as representative model in this study, assumptions to be used, and input data in form of costs to be incurred.

Step-2: calculate cost of fixed asset and working capital required for investment in the model

Step-3: calculate annual production costs, including product price, and its annual sales projections.

Step-4: modeling a financial scheme through bank loans, including interest rate and debt service payments.

Step-5: arrange projected sources and uses of funds statement to see where and when an amount of funds to be placed

Step-6: calculate feasibility analysis using the techniques of financial analysis

Step-7: make sensitivity analysis to know how sensitive the business due to changes of factors

Step-8: draw a map of traditional Batik industry in Laweyan, based on internal and external environments.

Financial feasibility analysis of the model is based on some investment criteria [2], such as: Net Present Value (NPV), Benefit Cost Ratio (BCR), Discounted Payback Period (PBR), and Internal Rate of Return (IRR).

Net Present Value (NPV) is ratio between PV of net cash flow and PV of investment (capital outlays) over the life of the investment. NPV is as indicator of the feasibility of an investment: If the NPV >0, the investment is feasible to be implemented; if NPV <0, the investment is not feasible to be implemented. The NPV formula is as follows:

$$\text{NPV} = \sum_{t=1}^t \frac{CF_t}{(1+i)^t} - I_0 \quad (1)$$

Where:

CF<sub>t</sub> = annual cash flow in period t (Rp)

I<sub>0</sub> = initial investment in year-0

i = discount rate used to find the present value (%)

t = duration of investment (year)

IRR is a discount rate at which the net present value of costs of the investment equals the net present value of the benefits of the investment. It also used in capital budgeting to measure and compare the profitability of investments in a rate of returns. Generally IRR is compared with rate of capital or MARR, the Minimum Attractive Rate of Returns: If the IRR >MARR, the investment is feasible to be implemented; if NPV <MARR, the investment is not feasible to be implemented. The IRR formula is as follows:

$$IRR = i_1 + \frac{NPV_1}{NPV_1 - NPV_2} \cdot (i_2 - i_1) \quad (2)$$

Where:

NPV1 = net present value at a discount rate i1

NPV2 = net present value at a discount rate i2

i1 = discount rate first experiment

i2 = discount rate second experiment

Discounted Payback Period (DPP) is the number of periods (years) required to cover all capital expenditures incurred using proceeds of the net cash flow. If the discounted payback period is less than the maximum attractive period the project is acceptable, and vice versa. The DPP is calculated as follows:

$$DPP = \frac{I_0}{DCF} \times 1 \text{ years} \quad (3)$$

BCR is ratio between discounted of benefits and discounted of costs of an investment project. If the ratio is >1 then the investment means profitable; likewise, if the ratio is <1 then the investment is not profitable. The formulation of BCR is as follow:

$$BCR = \frac{\sum \text{Benefit}}{\sum \text{Cost}} \quad (4)$$

The SWOT Map of the condition of the traditional Batik industry in Laweyan Cluster is determined based on internal and external environments that can be generated to support the model of the traditional Batik home industry to be sustainable. Internal and external environmental factors are analyzed using internal factor table (IFAS) and the external factor table (EFAS) by the use of weighting and rating. The weighting is based on the relative strengths of other factors; where as the rating is based on the actual condition of the industry in response to those factors. Furthermore the results of matrix IFE and EFE assessment is mapped into IE matrix, a schematic diagram which is divided into 9 cells to determine the appropriate direction of the industry strategy

### 3. RESULTS AND DISCUSSION

#### 3.1. The Business Model of Traditional Batik Home Industry

The assumptions behind the model of the traditional Batik home industry are follows:

- The Model of traditional Batik firm is derived from a traditional Batik of small-scale industry in one of the Batik industry cluster in Surakarta
- The total area of land of the Model is about 500 square meters; with the building area is about 350 square meters. The building area mainly consists of area for both writing and stamping Batik; there are 10 work stations for writing Batik and 5 work stations for stamping. There are storage for materials, and workshop for repair and maintenance.
- Outside the building, there are several pools of 2 x 1.5 meters, to colorize the just waxed written and stamped cloth: usually two brown pools and one black pool. Other two or three pools with hot water are used to wash the wax out-of the cloth. Another area, outside the building, is use to dry-up the nearly finish Batik product, before each of the Batik product is ironed, folded and packed.
- The model produces both stamped Batik and written Batik; the maximum capacity production of which is 30 pieces per month for written Batik and 200 pieces per month for stamped Batik.
- There is a showroom inside and in front part of the building, 5x5 meters, for individual customers to visit, see and select the Batik product.
- Projections carried out for 10 years.

##### 3.1.1. The Production Process

The production process of making the traditional Batik is as follows:

- |   |   |
|---|---|
| 1. Cutting the cloth from its bundles into pieces of 2 meters long colorizing | 5. Sending to another pool for another colorizing |
| 2. Sending the pieces to work stations for wax writing and stamping           | 6. Sending to pool for washing-out the wax        |
| 3. Sending to pool for colorizing (dyeing)                                    | 7. Sun drying                                     |
| 4. Wax removing   | 8. Inspection and pocketing/packing               |

#### 3.2. Cost of Investment

Investment costs consist of cost of fixed asset investments (fixed assets) and working capital (working capital). This model assumes that the land and buildings already exist and is already owned. The cost additional buildings and facilities incurred are shown in Table 1

Working capital is one of the most important asset elements of the company. Due to the absence of working capital consist of raw materials needed to run the day-to-day production activities. Working capital is defined by entire current assets owned by firm subtracted by its current liabilities; they are shown in Table 2. As usually as it is, payment period of account receivables is 5 days, while for account receivables is 20 days, while for trade payables is 10 days. Inventory storage is given a period of 15 days.

#### 3.3. Annual Operation

##### 3.3.1. Sales Projection

Production adjusted for projected sales. The finish good inventory period is given in this business model is 20 days. Sales projection is assumed increasing 2.5% every year because sales of printing Batik cannot be prevented so as make little growth in sales of traditional Batik. The sales projection is shown in Table 3. Selling price is set for stamped Batik in first year is Rp 100.000 per piece and selling price is set for written Batik is Rp 600.000. There is an increase in price 5% every year.

Table 1: Fixed Asset Investment

Investment Cost	Cost
Building Facility	Rp 28.750.000
Production Equipment	Rp 25.325.875
Showroom Equipment	Rp 3.910.000
Pump and Installation	Rp 4.025.000
Licensing	Rp 1.725.000
<b>Total Investment Cost</b>	<b>Rp 63,735,875</b>

Table 2: Working Capital

Working capital	Cost year-1
<b>Current Asset</b>	
Cash and Account Receivables	Rp 6.666.667
Inventory	Rp 10.678.035
<b>Current Liabilities</b>	
Account Payable	Rp 6.766.785
<b>Total working capital</b>	<b>Rp 10.577.917</b>

Table 3: Sales Projection

Year	Written Batik		Stamped Batik	
	Sales (Unit)	Sales (Rp)	Sales (Unit)	Sales (Rp)
1	248	148.800.000	1.656	165.600.000
2	268	168.840.000	1.711	179.655.000
3	277	183.235.500	1.768	194.922.000
4	286	198.648.450	1.825	211.266.563
5	295	215.144.606	1.883	228.879.827
6	304	232.793.757	1.940	247.598.623
7	313	251.669.961	1.997	267.617.099
8	322	271.851.802	2.055	289.159.137
9	331	293.422.651	2.112	312.038.590
10	340	316.470.956	2.170	336.638.223

### 3.3.2. Annual Cost Allocation

Allocation of annual production costs consists of raw material cost, overhead costs, operational cost and wages that can be seen in Table 4. Both written Batik and stamped Batik have the same raw material, just a different quantity adapted to production capacity. The raw material is mori (white fabric), wax, dyes, Batik chemical and petroleum. There are 51 labor force (5 persons a pattern maker with the wage Rp 70.000/piece, 30 writing Batik makers with the wage Rp 330.000/piece, 10 stamp Batik makers with the wage Rp 20.000/piece, 5 dye workers with the wage Rp 500.000/month, 1 person sales force with the wage Rp 500.000/month) that is used in a business model of traditional Batik home industry.

Table-4: Annual Cost Allocation

Year	Material Cost	Overhead Cost	Operational cost	Wages	Total Annual Cost
1	94.411.865	15.259.928	3.144.000	168.240.000	281.055.793
2	102.533.204	15.722.924	3.301.200	177.266.700	298.824.028
3	116.021.721	16.132.499	3.309.060	186.692.310	322.155.590
4	126.004.827	16.562.554	3.309.453	196.541.579	342.418.413
5	137.028.074	17.014.111	3.309.473	206.840.735	364.192.393
6	147.805.206	17.488.246	3.309.474	217.617.567	386.220.492
7	160.208.100	17.986.088	3.309.474	228.901.520	410.405.182
8	173.178.982	18.508.821	3.309.474	240.723.790	435.721.067
9	186.415.549	19.057.692	3.309.474	253.117.423	461.900.137
10	201.600.090	19.634.006	3.309.474	266.117.424	490.660.994

Overhead costs are costs associated with the operation of the production of Batik such as electricity costs, water costs, maintenance costs, telephone costs, and indirect labor. Whereas operating cost consist of administrative and marketing costs, these costs are incurred for the operation and marketing of the product and is not associated with production activities. Percentage of cost increased 5% per year.

### 3.4. Financing

The source of funds used to finance fixed assets and working capital is from bank loan; the whole assets are used as collateral. For the calculation of the debt service an effective interest of 12% is used, in accordance with the retail investment interest rate in local Bank. The repayment of principal and interest of this business will run for 5 years. Funding projections are shown in the Table 5.

Table 5: Funding Projection

Bank Loan	Rp74.313.792				
Interest Rate	12%				
Period	5 years				
	<b>Year 1</b>	<b>Year 2</b>	<b>Year 3</b>	<b>Year 4</b>	<b>Year 5</b>
Principal Installment	14.862.758	14.862.758	14.862.758	14.862.758	14.862.758
Interest Payment	8.917.655	7.134.124	5.350.593	3.567.062	1.783.531
Total Installment	23.780.413	21.996.882	20.213.351	18.429.820	16.646.289

### 3.5. Sources and Uses of Funds Statement

Source and Uses Funds statement is designed to show how funds are obtained and how they are used. In the start up phase, the source of funds comes from a bank loan amount of Rp 74.313.792 (nearly Rp 75 million) while the use of the fund is to buy fixed assets and finance working capital to support the production process. When the business enters production phase, the source of fund comes from earnings after taxes (EAT) and depreciation. EAT is generated from revenue subtracted by all of costs, depreciation, interest payment and tax. Tax is set in this business at 10%, in accordance with the government regulation. The depreciation method used in this model is a straight line. Another use of funds is to replacement of some equipments. In addition, the funds is also used to repayment of the bank loan. The difference of the sources of funds and uses of funds become surplus by the end of the year and can be used for next year's capital. Table 6 shows the sources and uses funds projection.

### 3.6. Feasibility Analysis

To evaluate the feasibility of the investment of the business model of traditional Batik home industry, some investment criteria such as NPV, IRR, Payback Period and BCR are used. The positive cash flow of the business shown from the difference between the total source of funds and the total uses of funds indicates the yearly operation of the business can be conducted well. With the use of MARR of 14%, regarding a risk of 2% above the rate of interest of 12%, shows that a positive NPV of Rp 169.928.565 (nearly Rp 170.000.000) is reached. At the same time, the IRR of 37% is considered high enough compared to MARR. The BCR of 3.2 means that the business feasible to run. Another indicator showed by the Discounted Payback Period of 4.2 (5 years) compared to an economic operation of the business of ten years is a good indicator that the business may be run well.

### 3.7. Sensitivity Analysis

Sensitivity analysis is used to determine how sensitive is the profit ability of the traditional Batik model to any change on its main variables. The variables include the prices of traditional Batik product, the raw material costs, and the direct labor wage. Basically the selling price of the traditional Batik product and the raw material cost varies, not stable and cannot be controlled, because there are no specific standards; they may increase or decrease according to market conditions and business strategy. Labor wage in this has a great proportion of the production cost; therefore its sensitivity must be examined.

Based on Figure 1, it can be seen, that the business is able to standstill for the decrease of selling price up to 8%. The increase in raw material costs up to 26% still give rise to a positive NPV; while the increase in labor costs up to 17% still bring a positive NPV.

Table 6: Sources and Uses Funds

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
<b>Sources of Fund</b>											
EAT	-	8,857,510	25,156,775	32,459,798	44,410,196	57,117,271	71,628,312	84,867,304	99,634,497	116,078,606	133,076,979
Depreciation	-	14,584,875	14,584,875	14,584,875	14,584,875	14,584,875	14,584,875	14,584,875	14,584,875	14,584,875	14,584,875
Bank Loan	74,313,792	-	-	-	-	-	-	-	-	-	-
<b>Total Source</b>	<b>74,313,792</b>	<b>23,442,385</b>	<b>39,741,650</b>	<b>47,044,673</b>	<b>58,995,071</b>	<b>71,702,146</b>	<b>86,213,187</b>	<b>99,452,179</b>	<b>114,219,372</b>	<b>130,663,481</b>	<b>147,661,854</b>
<b>Uses of Funds</b>											

Fixed Asset	63,735,875	-	2,360,375	5,419,375	22,266,875	5,419,375	6,270,375	25,325,875	2,360,375	5,419,375	22,266,875
Bank Loan Installment	-	14,862,758	14,862,758	14,862,758	14,862,758	14,862,758	-	-	-	-	-
Incremental Working capital	-	10,577,917	5,997,761	1,788,276	1,713,738	1,291,653	1,849,171	1,572,113	1,569,423	2,185,404	1,810,207
<b>Total Uses</b>	<b>63,735,875</b>	<b>25,440,675</b>	<b>23,220,894</b>	<b>22,070,409</b>	<b>38,843,371</b>	<b>21,573,786</b>	<b>8,119,546</b>	<b>26,897,988</b>	<b>3,929,798</b>	<b>7,604,779</b>	<b>24,077,082</b>
<b>Surplus</b>	10,577,917	(1,998,290)	16,520,756	24,974,264	20,151,700	50,128,360	78,093,641	72,554,190.39	110,289,574	123,058,702	123,584,771
Beginning Year Value	-	10,577,917	8,579,626	25,100,383	50,074,646	70,226,346	120,354,706	198,448,347	271,002,537	381,292,111	504,350,813
End Year Value	10,577,917	8,579,626	25,100,383	50,074,646	70,226,346	120,354,706	198,448,347	271,002,537	381,292,111	504,350,813	627,935,584

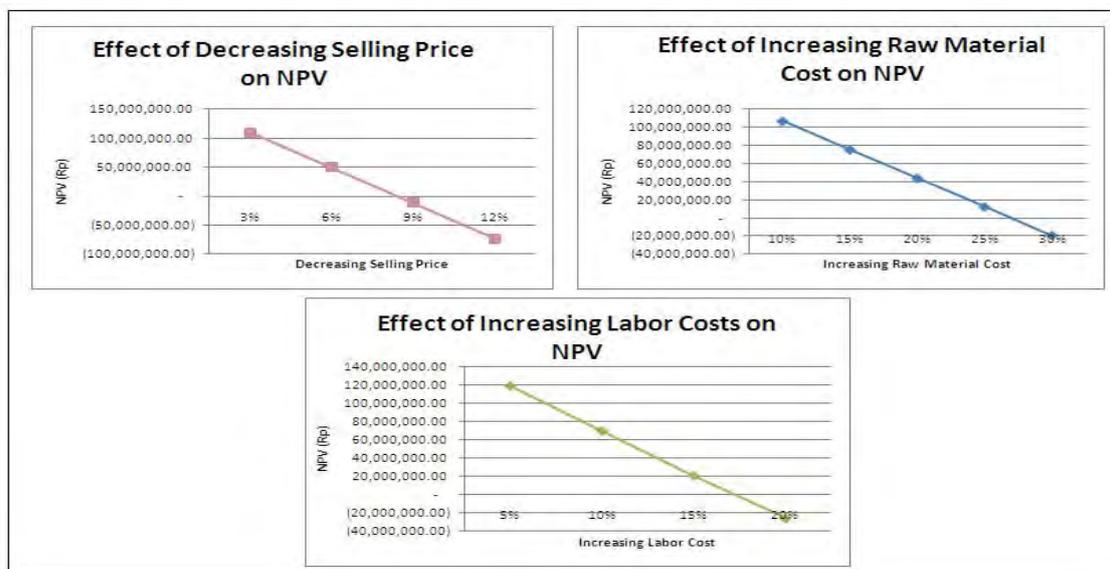


Figure-1:Sensitivity Analysis

### 3.8. Mapping the SWOT of the Traditional Batik Industry in Laweyan Cluster

Traditional Batik Industry SWOT Mapping is conducted to determine the appropriate strategy to support traditional Batik home industries to be a sustainable industry. The Internal and External factors are generated based on observations, interviews and a review of some literatures. The weighting of the factors (from 1.0 for poor to 4.0 for outstanding) is given by 5 business owner of small-scale traditional Batik industry in Surakarta then processed using the calculation method of AHP (Analytical Hierarchy Process) , and the ratings are given by the Head of SME industry Department in Surakarta. rating scale ranging from 4 (outstanding) to 1 (poor) based on the effect of these factors to the current conditions. Rating for strengths and opportunities are positive (if there is a greatest effect of opportunities and strength, given the rating 4, but if the smallest effect factor of opportunities and strengths, given the rating of 1), while providing rating weaknesses and threats are the opposite. Table 7 and Table 8 shows the IFE and EFE matrix of traditional Batik industry.

Table 7: IFE Matrix

Internal Strategy Factor	Weight	Rating	Weight X Rating
<b>Strength Factor</b>			
Having trained and skilled craftsmen	0.1090	4.0	0.4360
Cohesive business management	0.0690	3.0	0.2070
Strong relationship between Batik entrepreneurs	0.0710	3.7	0.2627
Unique patterns and models	0.1600	4.0	0.6400
High quality handmade products	0.0850	3.7	0.3145
<b>Weakness Factor</b>			
Lack of craftsmen regeneration	0.1540	1.7	0.2618
Difficulty getting raw materials	0.0980	2.7	0.2646

Limitation of capital	0.1400	2.0	0.2800
Traditional financial management	0.1140	3.0	0.3420
<b>TOTAL</b>	<b>1.000</b>		<b>3.009</b>

Table 8: EFE Matrix

External Strategy Factor	Weight	Rating	Weight X Rating
<b>Opportunity Factor</b>			
Increasing demand of Batik	0.0678	3.7	0.249
High appreciation for culture	0.0756	3.3	0.252
Market share is still wide	0.0770	4.0	0.308
Support of local government	0.0587	3.3	0.196
Advances in technology and communications	0.1311	3.0	0.393
<b>Threat Factor</b>			
Instability economic condition	0.1506	1.3	0.201
Development of Batik printing industry	0.2143	1.0	0.214
Existence of substitute products	0.0393	2.3	0.092
Global market conditions	0.0929	3.0	0.279
Many Competitors	0.0926	2.3	0.216
<b>TOTAL</b>	<b>1.0000</b>		<b>2.400</b>

Based on the assessment of the weighting and the ratings, the value of IFE matrix is 3.0 and the value of EFE matrix is 2.4. Then the value is mapped into internal and external matrix (IE Matrix), in which the position of the traditional Batik industry of Laweyan is located in position IV of Figure 2, namely a position of “developing and growing stage condition”. This means, that a suitable strategy to support the traditional Batik industry of Laweyan includes intensive strategy that contains market penetration, market development, product development; and integration strategy, both forward integration, backward integration, and horizontal integration.

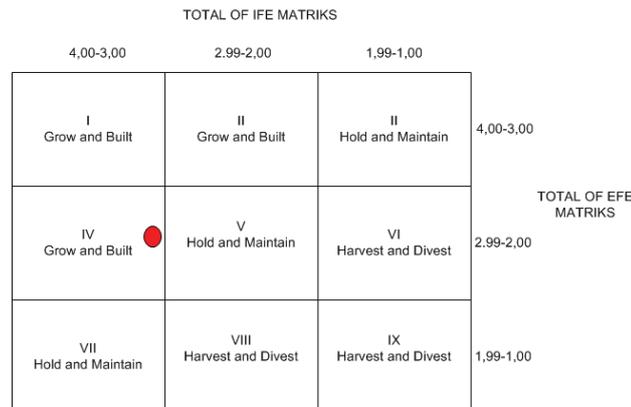


Figure 2: IE Matrix of traditional Batik industry of Laweyan

#### 4. CONCLUSION

From the research results obtained the following results:

1. The value of investment for this business model is nearly Rp 75 million, with capital funding from banks for 5 years and 12% interest rate per year.
2. The results of the projected calculations for 10 years with the amount of MARR is 14%, Show that the business model of Batik home industry is feasible to run, with a value of NPV is nearly Rp 170 million; IRR is 37%, BCR is 3.2; and the Discounted Payback Period is about 5 years.
3. If the government can bring some kinds of financial facilities to the traditional Batik Industry, such as, grace period of two years, tax holiday also for two years, and investment tax credit for at least 10%, better NPV, IRR, BCR and DPP will be reached.
4. The results of sensitivity analysis show that the decrease in selling price of 8% is allowable for a positive NPV; the same thing happens also for the increase in raw material costs to 26%, and increase in labor wages to 17%.
5. Based on the mapping position, Batik Laweyan is in a developing and growing condition. Suitable strategy to survive in this industry is an intensive strategy and integration strategy.

6. To see Laweyan regain its traditional Batik Kingdom in Indonesia a mass investment of 15 to 20 billion Rupiahs are needed.

#### **REFERENCE**

- [1] Beck, Thorsten, "Industry growth and capital allocation: does having a market-or bank-based system matter?" *Journal of Financial Economics* , pp.147–180, 2002
- [2] Brigham, Eugene.F. & Michele C. Erhardt. (2006). *Financial Management Theory and Practice*. Thomson Learning Inc.
- [3] Hayashi, Mitsuhiro, "The role of subcontracting in SME development in Indonesia micro-level evidence from the metalworking and machinery industry," *Journal of Asian Economic* 13, 2002
- [4] Kusumawardhani, Fajar. *Sejarah Perkembangan Industri Batik Tradisional di Laweyan Surakarta Tahun 1965-2000*. Surakarta. 2006
- [5] Sudantoko, Djoko. *Pemberdayaan Industri Batik Skala Kecil di Jawa Tengah*. Semarang. 2008

## Analysis of the Effectiveness of Kompas Newspaper Advertising Based on Size and Color Factors Using Eye Tracking Method

Erlinda Muslim<sup>a</sup>, Boy Nurtjahyo<sup>b</sup>,  
Adissa Andam Dewi<sup>c</sup>, Aisyah Iadha Nuraini<sup>d</sup>, Tegar Septyan<sup>e</sup>

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : erlinda@eng.ui.ac.id

<sup>b</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : boymoch@eng.ui.ac.id

<sup>c</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : adissa\_ti08@yahoo.com

<sup>d</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : aisyah.iadha@ui.ac.id

<sup>e</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : tegar.septyan@ui.ac.id

### ABSTRACT

Various types of goods/services promotion performed by the company to introduce their products, a form of promotion is through advertising. There are several media to place an advertisement, in which newspaper has several advantages than other media. Competition among companies is requiring them to choose an effective advertising. This research focuses on looking at the effectiveness of some of the most popular advertisement in the newspaper-using eye tracking methods. The study was conducted by looking at two factors, size (3 columns and 4 columns) and color factors (color and black & white). Sixty subjects performed four combination of newspaper advertising using Eye Tracker. Every combination is performed by 15 subjects. The next step is used questionnaire to validate the data. This result of questionnaire is similar to results from data viewer software. The results showed that size factor (3 columns and 4 columns) or the interaction between them, do not affect significantly the duration of fixation. The significantly affect the duration of fixation is a factor of color (black & white and color).

### Keywords

*Advertising, Newspaper, Eye Tracking, Ergonomics*

### 1. INTRODUCTION

Along with the progress of time in all areas of life, especially in the field of information and communication technology has caused the development of the media to be very rapid. In the face of future challenges that are very difficult, a clear concept and rigorous competitive strategy are needed and supported by the resources and all the potential owned to be able to deal with it. Marketing strategy which aims to win the competition is needed in order to survive in market. Strategy that can be used by producers in order to market its products is the marketing communications through advertising or advertising program.

Lots of advertising media are well known by people, such as the print media (newspapers and magazines), electronic media (television, radio, computer), and outdoor media (exhibitions, calendar, etc.). In Indonesia, newspaper has an important role for advertisers because nationally, advertising cost of newspaper is second place after television.

Indonesia's leading newspaper is Kompas newspaper. Being a leading newspaper in Indonesia, Kompas has the highest rating among the others. Kompas is one of two Indonesian newspapers which are audited by the Audit Bureau of Circulations (ABC). For advertisers, newspapers rating is a driving factor for choosing them in newspapers where they will advertise their products. Kompas newspaper is one of consumer choice.

Kompas provides advertising rates that is varied according to the type of advertising. The difference of this is caused by its characteristics and value on each type of advertising. Kompas has two types of advertisement, regular and Klasika. Regular has 7 columns and Klasika has 9 columns. Each of it has a type of advertising with sizes, colors, and costs that were different.

The newspaper sells advertising space to advertisers in millimeters column (mmc). An advertisement with a 4-column width and height of 100 mm will have extensive advertising space 400 mmc (4 columns x 100 mm). Thus the cost to be paid advertiser is calculated by multiplying the broad of advertising space based on mmc with advertising rate (rate card) per mmc. The newspaper also provides two alternative colors, namely black and white (BW) and Full Color (FC), which both of them have different prices.

Advertisers who want to advertise their products and services are categorized as display advertising. Size of display advertisement which is favorite by advertisers is 3 columns x 270 mm and 4 columns x 270 mm. The fees are charged for BW at Rp 105,000 per mmc and FC RP 147,000 per mmc.

Because of the high interest of the newspaper advertiser and the fees charged to advertisers, the study was conducted to see the effectiveness of sizes and colors as a recommendation for advertisers using eye tracking. The size and color factor is one of the important factors that determine decision-making of customer so this study focuses on those factors. Small size or larger size of advertising has different purpose. Small space advertisement can be used effectively to build frequency [1]. According to Huang (1993), the color choices made in standardization efforts are integral to industrial product success [2].

The eye tracking methods used in this study are increasingly being applied in the field of marketing and consumer behavior, particularly in advertising [3]. The eye-tracking device has become one of the most important human-machine interfaces in which eye movements are related to the information-processing demands of a task [4].

The size will be in the two trials, display size of 4 columns x 270 mm (color BW and FC) and 7 columns x 115 mm (color BW and FC). Based on the purpose of this study, the title of this paper is Analysis of the Effectiveness of Kompas Newspaper Advertising Based on Size and Color Factors Using Eye Tracking Method.. The research question of this reserach is abut the correlation between size and color of advertising with the visibility of advertising.

## 2. METHODS

### 2.1 Subjects

The number of subjects for the four combinations of newspaper advertisement is 60. Each combination requires 15 subjects. The criteria of the subjects are as follows:

1. Male or female
2. Aged between 18-22 years
3. Subject did not know the theme of the research
4. Subject is not color-blind
5. Subject did not have difficulty on vision, like nearsighted or farsighted and other

### 2.2 Display of Newspaper Advertisement

Newspaper advertisement used in this study is beverage products because it is a general product. There are four combinations of newspaper advertisement, they are combination 1 (black and white advertisement with a small size), combination 2 (color advertisement with a small size), combination 3 (black and white advertisement with large size), and combination 4 (color advertisement with large size). The visualization of these combinations can be seen in Figure 1.



Combination 1

Combination 2

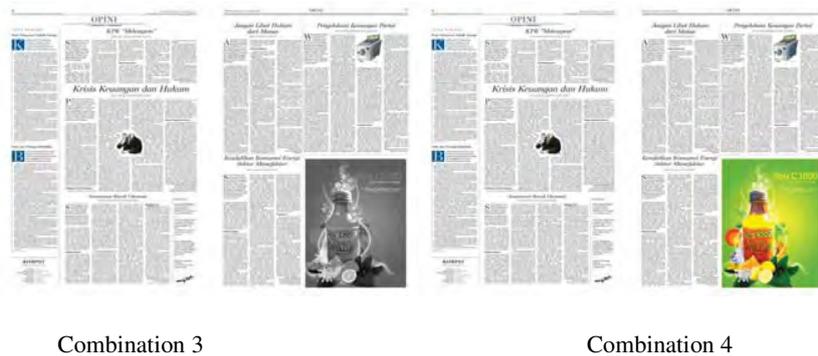


Figure 1: Newspaper Advertisement

### 2.3 Equipments

Eye tracker is a device used to track the movement of eyes. The tracking of eyes movement is needed in order to know whether eyes is doing brief stop (fixation) or rapid movement (saccades) on object seen by the eyes. These two of movement is used to access attention of subject on the picture [5]. This study uses the EyeLink II Head Fixed Eye Tracker. Its main components are EyeLink II Host PC, EyeLink II Display PC, EyeLinkII PCI Card, and EyeLinkII Headband. The eye tracker is combined with Experiment Builder as media execution. EyeLink II Display PC monitor used is a HP 19 "rectangle and CPU. The scope of view of the human eye is limited to 30° so there is a minimum distance between the monitor with the eye, which is 70.53 cm.

### 2.4 Analysis Framework

Data obtained from a combination of 1-4 will be processed using fixation maps, interest area, and statistical tests. Data of fixation map explain about the intensity of the sight of all subjects. Data of interest areas explain about the intensity vision of the respondents in area advertising. The statistical test used to look the factors that significantly affect the dwell time is ANOVA. The interaction between these two factors can be seen in the Estimated Marginal Mean.

## 3. RESULTS

### 3.1 Fixation Map and Interest Area

The colors on the fixation map indicate duration of eye fixations. Duration of fixation is indicated by green, yellow, and red color. Green color indicates the lowest duration while red indicates the highest duration.

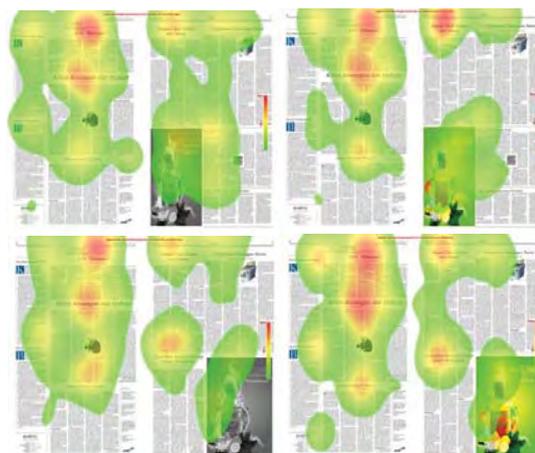


Figure 2: Fixation Map, Combination 1-4

Based on fixation map in Figure 2, the intensity of all subjects' sight can be seen in this figure. Examples of combinations 1, the area of advertisements contains intensity of yellow color that means some subjects see any advertisement in newspapers. Percentage of subjects ever seen in a newspaper advertisement can be seen from the area of interest. This percentage means the

effectiveness of the advertising of newspaper which has been combined. Percentage of subjects ever seen in newspaper of combination 1 is 7.37%, a combination 2 is 7.68%, a combination 3 is 6.01%, and a combination 4 is 7.81%. This percentage shows the time spent by subjects who saw newspaper advertisement than all the time spent to see the entire newspaper.

Based on the results of the data viewer, the value effectiveness of each combination has been obtained. Its value is 7.37% for black and white advertisement in 3 columns type, 7.68% for colored advertisement in 3 columns type, 6.01% for black and white advertisement in 4 columns type, and 7.81% for colored advertisement in 4 columns type. Based on those values, the colored advertisement in 4 columns type has the greatest value of effectiveness, and then the colored advertisement in 3 columns type in second position, black and white advertisement in 3 columns type in third position, and black and white advertisement in 4 columns type in fourth position.

### 3.2 Statistic Test

Before the results of statistical processing are analyzed, it must be ensured that the data processed are Normal. Normally test is conducted to ensure processed data are normal because statistical processing requires normalize data. The test shows that the data is normally distributed (refer to Figure 3).

Normal P-P Plot of Regression Standardized Residual

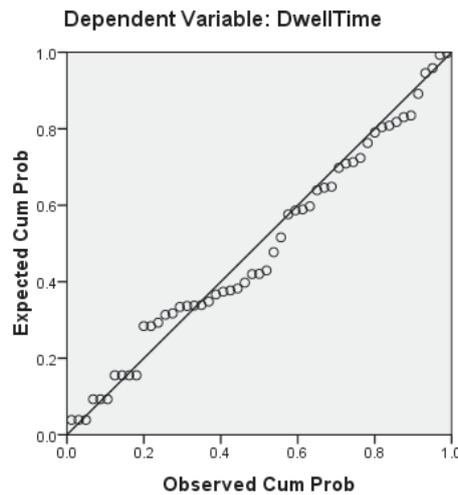


Figure 3: Normal Probability Plot

After the data has passed normality test, further analysis can be carried out to see a significant factor affecting the Dwell Time. The analysis was done by looking at the table of ANOVA and Coefficient table.

**ANOVA<sup>b</sup>**

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.328E7	2	6641676.966	4.972	.011 <sup>a</sup>
	Residual	6.679E7	50	1335835.240		
	Total	8.008E7	52			

a. Predictors: (Constant), Warna, Ukuran

b. Dependent Variable: DwellTime

Figure 4: ANOVA Table

F value was obtained 4.972 with a significance level 0.011 (refer to Figure 4). Since the significance level is less than  $\alpha$  (0.05), it can be said that the size and color simultaneously affect fixation duration (Dwell Time).

**Coefficients<sup>a</sup>**

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-722.649	698.303		-1.035	.306
	Ukuran	511.913	317.629	.208	1.612	.113
	Warna	870.241	317.629	.354	2.740	.008

a. Dependent Variable: DwellTime

Figure 5: Coefficients Table

Based on the coefficients table in Figure 5, a significance level of size is 0.113, which means the size factor does not significantly affect the level of Dwell Time because the significance level is less than  $\alpha$  (0.05). However, a significance level of color is 0.008, which means the color factors significantly affect Dwell Time. Based on the level of significance of the color factor is lower than  $\alpha$  ( $0.008 < 0.05$ ) then  $H_0$  is rejected.

**Tests of Between-Subjects Effects**

Dependent Variable: DwellTime

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1.337E7 <sup>a</sup>	3	4457423.924	3.274	.029
Intercept	9.668E7	1	9.668E7	71.023	.000
Ukuran	3448492.551	1	3448492.551	2.533	.118
Warna	1.006E7	1	1.006E7	7.389	.009
Ukuran * Warna	88917.838	1	88917.838	.065	.799
Error	6.670E7	49	1361282.534		
Total	1.772E8	53			
Corrected Total	8.008E7	52			

a. R Squared = .167 (Adjusted R Squared = .116)

Figure 6: Test of Between-Subject Effects

Based on the Figure 6, the level of significance of the interaction between the size and color is 0.799. The level of significance is much greater than  $\alpha$  (0.05) which means that the interaction between the factors was not significant to the Dwell Time. The lack of interaction can be seen in Figure. 7. Green and blue lines do not intersect which means there is no interaction between the two factors.

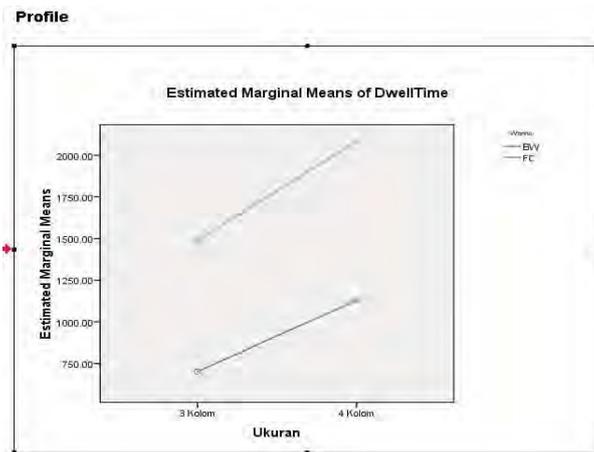


Figure 7: Estimated Marginal Means of Dwell Time

#### 4. DISCUSSION

The purpose of this research is analyzing the effectiveness of sizes and colors as a recommendation for advertisers on the visibility of customers. In combination 1 (black and white advertisement with a small size), some subjects see the advertising and the others see the news or the title. In combination 2 (color advertisement with a small size), most of the subjects see and know about the advertising. In combination 3 (black and white advertisement with a large size), most of the subjects do not see and know about the advertising. In combination 4 (color advertisement with a large size), the result is similar to combination 3.

Based on the values of effectiveness are obtained, most of the subjects' interests to the color advertising and the largest one. Experiment test showed that there is significance effect of size and color of advertisement in newspaper. This finding might justify the higher rate of consumer attractiveness about using color and larger size. Previous study is about advertising using game online [6] which the advertising has a motion together with the game. As the result, there are different factor influences static and dynamic advertising. In game, the advertising must have motion to attract the consumers. However, in newspaper, the static advertising still gives interest for customers. For further study, economy analysis, content of advertising, and type of display advertising can be added as factors to analysis the effectiveness of advertising in newspaper.

## 5. CONCLUSION

Based on the values of effectiveness are obtained ratings from highest to lowest, there are color advertisement in 4 columns type, color advertisement in 3 columns type, black and white advertisement in 3 columns type, and black and white advertisement in 4 columns type. The results of the processing of questionnaire and data viewer have same values. Subjects not only see, but also know what advertisement on newspaper images. The statistical results showed that the interaction between the factor and the size factor does not affect Dwell Time (the time spent looking at the advertisement) of advertisement was significantly. Color factor is the most affecting factor in Dwell Time advertisement. Color factor is affecting the awareness of subjects so it can be an option for advertisers when choosing the type of advertisement in newspapers.

## ACKNOWLEDGMENT

The author gratefully acknowledges the data collection using tools from ergonomic center Universitas Indonesia.

## REFERENCES

- [1] Raitt, Suzanne, "Effective newspaper ads", Toronto Star
- [2] Irvine Clarke III, Earl D Honeycutt Jr, "Color usage in international business to business print advertising", *Elsevier: Industrial Marketing Management*, vol. 29, issue 3, pp. 255-261, May 2000.
- [3] He Da, Lai Weinhua, Chen Lingmin, "An eye tracking research on the print ads viewing by college student", *Electrical and Control Engineering (ICECE)*, 2011, Conference Publications.
- [4] Chern Shenglin, Chia Chin Huan, Chao-Ning Chan, Mau-Shiun Yeh, Chuang-Chien Chiu, "Design of computer game using an eye tracking device for eye's activity rehabilitation", *Elsevier: Optics and Laser in Engineering*, vol. 42, issue 1, pp. 91-108, July 2004.
- [5] Yarbus, A.L, "Eye movement and vision", New York: Plenum, 1967.
- [6] Handoko, H, "Observation of effectiveness of static in-game advertising for game spectators using eye tracking method", Depok: Universitas Indonesia, 2011.

# **Innovation and Malcolm Baldrige: Effect of Strategic Planning, Customer Focus and Operations Focus toward Result of Performance Excellence and Sustainability**

**Khristian Edi Nugroho Soebandrija**

*Industrial Engineering Department, Faculty of Engineering, Bina Nusantara University, Jakarta 11480  
E-mail : Knugroho@binus.edu and Khristianedi@yahoo.com*

## **ABSTRACT**

Innovation and Malcolm Baldrige Criteria have been indispensable for enhancement of Human Life and Environment. This paper relates the concept, theoretical aspects and managerial implications of Innovation and Malcolm Baldrige for the benefit of Human Life within unit analysis of individual, company and nation toward global benefit. As scope of problem and in scope of a nation, Indonesia, in the last 5 until 10 years, has been experiencing difficulties in competing with other nations. As scope of objectives, Methodology and Discussion in this paper emphasize on generalized concept of Innovation and Malcolm Baldrige to mitigate and eventually has objectives to eliminate scope of the problem pertaining the competitiveness difficulties. Furthermore, in term of generalized concept of innovation of three pillars of Global Competitiveness Index (GCI) and Professor Clayton M. Christensen, and seven criteria of Malcolm Baldrige National Quality Award (MBNQA) in Business, Health Care and Higher Education. In term of Malcolm Baldrige Criteria 2011-2012; in this paper, Confirmatory Factor Analysis (CFA) was utilized to investigate constructs' reliability and validity, while Structural Equation Modeling (SEM) were utilized to examine relationship among constructs that relate effect of Strategic Planning, Customer Focus and Operations Focus toward Result of Performance Excellence and Sustainability.

## **Keywords**

*Innovation, Malcolm Baldrige, Strategic Planning, Operations Focus, Performance Excellence, Sustainability*

## **1. INTRODUCTION**

Indonesia in the last 5 until 10 years, has been experiencing difficulties in competing with other nations. According to Global Competitiveness Index (GCI), GCI 2010-2011, Indonesia undergone 10 point increase from Rank 54 into 44. Yet, in GCI 2011-2012, Indonesia undergone 2 point decrease from Rank 44 into 46, that constitute an alert for the incoming years. In this situation, Performance Excellence and Sustainability are deemed Indispensable, not to mentioned the Strategic Planning, Customer Focus and Operations Focus. That relate to Innovation and Malcolm Baldrige. As scope of objectives, Methodology and Discussion generalized concept of Innovation and Malcolm Baldrige to mitigate and eventually has objectives to eliminate scope of the problem pertaining the competitiveness difficulties. The mentioned of generalized concept of innovation of three pillars of Global Competitiveness Index (GCI) and Professor Clayton M. Christensen, and seven criteria 2011-2012 of Malcolm Baldrige National Quality Award (MBNQA) in Business, Health Care and Higher Education. The details of Malcolm Baldrige Criteria is also identified and elaborated by Sadikin (2011) in "Seri Manajemen Mutu Bunga Rampai" and Blazey (2011) in Insights to Performance Excellence 2011-2012. Although the Baldrige criteria and framework are widely accepted in practice, there is surprisingly little theoretical and empirical evidence of their validity (Ford and Evans, 2000). Several studies presented empirical analyses of the original Baldrige Criteria in the manufacturing environment and provided evidence that the performance relationships observed in the Baldrige causal model were supported in US firms. Most recently, York and Miree (2004) examined the relationship between TQM and financial performance, using a sample of Baldrige Award winners; they replicated a second sample of state quality award winning companies with three different sets of financial performance measures. Baldrige quality award winners generally had better financial performance than their peers after and before winning a quality award.

## **2. LITERATURE REVIEW**

### **Innovation**

An innovation is an idea, practice or object that is perceived as new by the entity adopting it, according to Rogers (2003). The concept of innovation implies the idea that something is added to something else that already exists, or that something that exists is given up. The argument is that adding and/or taking away are ways to improve a state of affairs. As indicated by Jalonen (2012), Despite positive connotations associated with the concept of 'innovation', it should be noted that the potential

value integral to innovation may or may not be realised in the future. Fernandes (2012) has further elaborated the value construct that deals with two wide variables: value form and value materialization. The value form varies from tangible to intangible. The value materialization is concerned with the simplicity or complexity of the process utilized to create value. Mehrabani (2012) has further enhanced the mentioned Value Constructs in term of Knowledge Management and Innovation Capacity. Tipu (2011) has further classified the Innovation Management, as entity that consider the i. Process of Innovation, ii. Factors Affecting Innovation, Protection of Innovation, iii. Measures of Innovation, and iv. Types of Innovation. Unlike Tipu, Muscio (2010) has segregated the Innovation according to three big categories, which are : i. Business Innovation Needs, according to Product or Process Innovation, ii. Technology, according to Pure Technology, or Other Technology ( New Materials, Machinery, ICT or Environmental ).

**Innovation and Performance**

Innovation and Performance has been discussed in Scientific Analysis of Entrepreneurship and SMEs (SCALES, 2007, p. 44 and 47). SCALES segregate important determinants of Innovation Input and Innovation Output, that are expressed in the following equations.

Determinants of Innovation Input

$$y_i = \alpha + \sum_{j=1}^J \beta_j x_{ij} + \varepsilon_i \tag{1}$$

Determinants of Innovation Output

$$y_i = \begin{cases} \alpha + \sum_{j=1}^J \beta_j x_{ij} + \varepsilon_i & \text{if } y_i^* = \alpha + \sum_{j=1}^J \beta_j x_{ij} + \varepsilon_i > 0 \\ 0 & \text{if } y_i^* = \alpha + \sum_{j=1}^J \beta_j x_{ij} + \varepsilon_i \leq 0 \end{cases} \tag{2}$$

$$y_i = \begin{cases} \alpha + \sum_{j=1}^J \beta_j x_{ij} + \varepsilon_{2i} & \text{if } y_i^* = \alpha + \sum_{j=1}^J \beta_j x_{ij} + \varepsilon_{1i} > 0 \\ 0 & \text{if } y_i^* = \alpha + \sum_{j=1}^J \beta_j x_{ij} + \varepsilon_{1i} \leq 0 \end{cases} \tag{3}$$

The mentioned equations are discussed in detail in the session of Discussion and Analysis and The above introduction pertaining the Determinants of Innovation, is further elaborated in the overview by SCALES (2007, p. 10) in the following model:

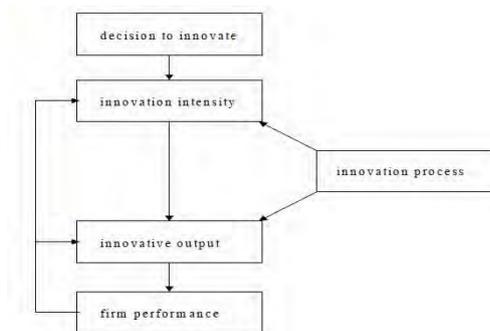


Figure 1 Overview of Innovation Process

**Innovation – Productivity Relationship**

The empirical evidence for Innovation – Productivity Relationship, has been discussed by Hall (2011, p. 11) that provided a detailed review of the studies that have attempted to estimate a quantitative relationship between firm-level productivity and innovation measures explicitly.

In term of Equation, the empirical of evidence has been visualized in the following equation that is resulted from two other equations and its original equation. The mentioned equations are discussed in detail in the session of Discussion and Analysis

$$r_{it} = \left( \frac{\eta + 1}{\eta} \right) (a_{it} + \alpha c_{it} + \beta l_{it}) + \left( \frac{\gamma(\eta + 1) - \varphi}{\eta} \right) k_{it} \tag{4}$$

### Global Competitiveness Index

The *Global Competitiveness Report* ([www.weforum.org/gcr](http://www.weforum.org/gcr)) remains the most respected assessment of national competitiveness, providing a useful portrait of a nation's economic environment and its ability to achieve sustained levels of prosperity and growth. For a portrayal that represents reality as accurately as possible, the World Economic Forum draws its data from two sources: international organizations and national sources, and its own Executive Opinion Survey (Survey). The Survey is a one-of-a-kind tool for capturing vital information that is not otherwise available at a global level. The data gathered thus provide a unique source of insight and a qualitative portrait of each nation's economic and business environment, as well as an understanding of how

it compares with the situation in other countries. The World Economic Forum has conducted its The World Economic Forum has conducted its annual Survey for over 30 years, modifying it over time to capture new data points essential to the Global Competitiveness Index (GCI) and other Forum indexes. It has also expanded the scope of its sample, achieving this year a record of over 15,000 surveys from 142 economies between January and June 2011.

© 2011 World Economic Forum | [www.weforum.org/gcr](http://www.weforum.org/gcr)

Country/Economy	GCI 2011-2012		GCI 2010-2011	
	Rank	Score	Rank	Change
Tunisia	40	4.47	32	-8
Poland	41	4.46	39	-2
Barbados	42	4.44	43	1
Italy	43	4.43	48	5
Lithuania	44	4.41	47	3
Portugal	45	4.40	46	1
Indonesia	46	4.38	44	-2
Cyprus	47	4.36	40	-7
Hungary	48	4.36	52	4
Panama	49	4.35	53	4
South Africa	50	4.34	54	4

Figure 2 : GCI and Indonesia's Rank of GCI 2011-2012 Versus 2010-2011

### Malcolm Baldrige National Quality Award

The seven criteria in the MBNQA are hypothesized to have a particular relationship to each other ( Badri et al, 2005, p. 1123 ). Although the Baldrige criteria and framework are widely accepted in practice, there is surprisingly little theoretical and empirical evidence of their validity (Ford and Evans, 2000). Several studies presented empirical analyses of the original Baldrige Criteria in the manufacturing environment and provided evidence that the performance relationships observed in the Baldrige causal model were supported in US firms. Most recently, York and Miree (2004) examined the relationship between TQM and financial performance, using a sample of Baldrige Award winners; they replicated a second sample of state quality award winning companies with three different sets of financial performance measures. Baldrige quality award winners generally had better financial performance than their peers after and before winning a quality award.

Posterior to the discussion on Innovation, there are further discussion based on the title of this paper; Innovation and Malcolm Baldrige: Effect of Strategic Planning, Customer Focus and Operations Focus toward Result of Performance Excellence and Sustainability. The subsequent discussion in Figure 3, convey the further overview aspect of seven criteria within the MBNQA.



Figure 3: Malcolm Baldrige 2011 – 2012 Criteria

### 3. METHODOLOGY

Methodology and Discussion in this paper emphasize on generalized concept of Innovation and Malcolm Baldrige to mitigate and eventually has objectives to eliminate scope of the problem pertaining the competitiveness difficulties. Furthermore, in term of generalized concept of innovation of three pillars of Global Competitiveness Index (GCI) and Professor Clayton M. Christensen, and seven criteria of Malcolm Baldrige National Quality Award (MBNQA) in Business, Health Care and Higher Education.

In term of Malcolm Baldrige Criteria 2011-2012; in this paper, Confirmatory Factor Analysis (CFA) was utilized to investigate constructs' reliability and validity, while Structural Equation Modeling (SEM) were utilized to examine relationship among constructs that relate effect of Strategic Planning, Customer Focus and Operations Focus toward Result of Performance Excellence and Sustainability.

#### Structural Equation Modeling

The literature reviews of this paper are originated from International Journal about SEM (Written in English) and Books about SEM (Written in English and Bahasa Indonesia). The highlighted International Journal among others is **Structural Equation Modeling: A Multidisciplinary Journal**, while the highlighted Books about SEM, among others are authored by Hoyle (2012), Kline (2011), Schumacker and Lomax (2010), Rencher and Christensen (2012), Hair, Black, Babin, Anderson (2010), Ariefianto (2012), Wiyono (2011), Wijaya (2009), and Wijanto (2008). A Multidisciplinary Journal (SEM: AMJ), is the main reference for this project paper. First article on the mentioned journal refers to article of Wu and Kwok (2012) on Using SEM to Analyze Complex Survey Data. Second article refers to Preacher, Zhang and Zyphur (2011) on Alternative Methods for Assessing Mediation in Multilevel Data. Third article refers to Crayen, Geiser, Scheithauer, and Eid (2011) on Evaluating Interventions with Multimethod Data: A Structural Equation Modeling Approach. Books on SEM Concept; this SEM Concept refers to the following discussion on Variables in SEM, Measurement and Structural Models, Measurement and Structural Errors, Mathematical Notation, and Introduction to LISREL 8.8. The books that convey the mentioned discussion are authored by Hair, Black, Babin, Anderson (2010), Byrne (1998) and Wijanto (2008). Books on SEM Procedures; this SEM Procedures refer to the following discussion on Specification, Identification, Estimation, Testing and Re-specification. In addition to the book that is authored by Schumacker and Lomax (2010), The books that convey the mentioned discussion are authored by Hair, Black, Babin, Anderson (2010), Byrne (1998) and Wijanto (2008).

### 4. DISCUSSION AND ANALYSIS

#### Innovation

This paper relates the concept, theoretical aspects and managerial implications of Innovation and Malcolm Baldrige for the benefit of Human Life within unit analysis of individual, company and nation toward global benefit. With the consideration of that unit of analysis, the Figure 1 has indicated the details of that unit of analysis on Know How, in term of Focus Firm, Competitive Environment and Macro Environment Sections and Subsections. Precisely, it elaborates the IT and Organizational Performance from 3 Unit of Analysis. Not to mention the Concept of Disruptive Innovation by *Professor Clayton M. Christensen*.

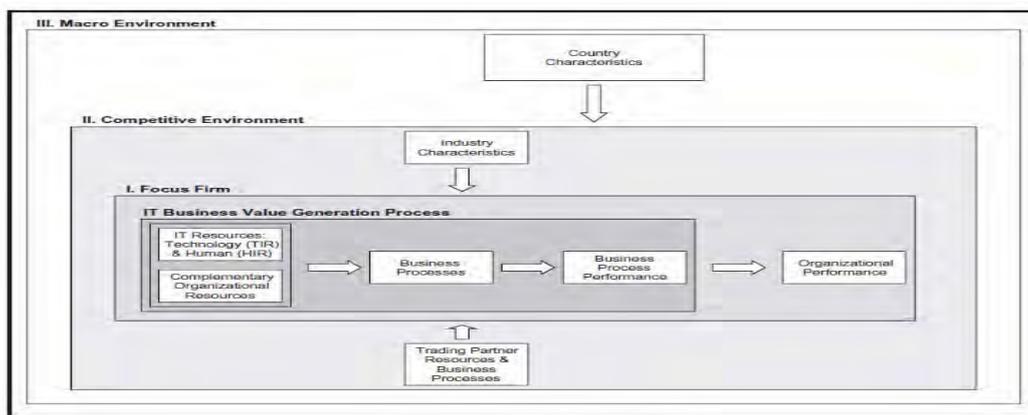


Figure 4: IT and Organizational Performance from 3 Unit of Analysis.

Determinants of Innovation Input, from Equation (1)

SCALES (2007, p. 44) elaborates the mentioned Equation, by stating that The variable of interest is innovation intensity, the total amount of time all employees spend on innovative activities, as a percentage of total available time<sup>1</sup>. The whole set of innovation

and firm-performance variables, including the sectoral dummies, are used as explanatory variables in the innovation equation. With  $y_i$  denoting innovation intensity for firm  $i$  and  $x_{ij}$  the value of explanatory variable  $j$  for firm  $i$ , with  $\epsilon_i \sim N(0, \sigma^2)$ . The explanatory variables that are included in the model are displayed, for which an expected sign is filled. The sectoral dummies are added in the model. A constant term  $\alpha$  is included. Equation (1) could have been modelled as a Tobit model, which takes account of zero shares of innovation input. The standard linear-regression model seems most appropriate to model the innovation-input equation, using ordinary least squares (OLS) as estimation method.

Determinants of Innovation Output, from Equation (2)

SCALES (2007, p. 47) elaborates the mentioned Equation, by indicating that use the share of new products or services in total turnover as innovation-output indicator and dependent variable. Since a number of firms have zero innovative output, simply estimating a linear regression model by OLS leads to biased estimates. Tobit models are better suited to model such a dependent variable (Greene, 2000; Franses and Paap, 2001). We consider two types of Tobit models, named type-1 Tobit model and type-2 Tobit model (Amemiya, 1985). For the type-1 Tobit model, a latent variable  $y_i^*$  is introduced. It takes a value of 0 if firms have no innovative output, and 1 if firms have innovative output. This latent variable is used in the model according to Equation (2).

According to discussion by Hall (2011, p. 11), The Equation (5) is deemed as the original equation, while Equation (6) and (7) are the building block for Equation (4).

$$Q = AC^\alpha L^\beta K^\gamma \tag{5}$$

$$q_{it} = a_{it} + \alpha c_{it} + \beta l_{it} + \gamma k_{it} \quad i = \text{entity}, t = \text{time} \tag{6}$$

$$q_{it} = \eta p_{it} + \phi k_{it} \quad \phi > 0 \tag{7}$$

Hall (2011, p. 7) mentioned that What is meant by the term “productivity” is fairly easy to understand although difficult to measure: it is the quantity of output that can be produced using a given level of inputs. If productivity is to be used as a measure of innovation, there is an implicit assumption that increases in output not accompanied by increases in inputs are due to innovative activity. Equation (5) constitutes relationship between output and the level of inputs using a production function. Hall (2011, p. 7) indicated that  $Q$  is output,  $C$  is the level of capital stock, and  $L$  is labor (and potentially other noncapital inputs).  $A$  is the overall level of productivity which may vary across entities. That is, because of organizational differences, frictions, or other constraints, entities with identical levels of  $C$  and  $L$  may not be able to achieve the same level of output  $Q$ . By algorithm mechanism, then the Equation (5) is transformed into Equation (6), and eventually is rewritten according to the shifted demand. Precisely, Hall (2011, p. 7) mentions the following reason: much of innovative activity is directed towards new products and product improvement, it is useful to rewrite the demand equation to allow the knowledge stock to shift the demand curve facing the firm. Assuming that the knowledge stock has a positive coefficient implies that the effect of increased knowledge or innovative activity is to shift the demand curve out by making the firm’s products more attractive to its customers, at a given price.

Equation (4) is obtained based on the equation for revenue. Hall (2011, p. 11) indicates that this equation shows that knowledge stock  $K$  is likely to contribute to revenue and therefore to measured productivity growth via two channels: directly by increasing the efficiency of production and indirectly by shifting the demand curve for the firm’s products outward (note that  $\eta$  is negative so that  $-\phi/\eta$  is positive). It is usual to think of these two channels as process and product innovation. For full identification of the system implied by equation (4), it would be desirable either to have data on individual firm output prices to allow separate estimation of  $\eta$  and  $\phi$  or to have some information on the components of  $K$  that might be directed toward processes and/or products. At the simplest level, one can gain some idea of the relative importance of the two types of innovation for productivity using the innovation dummy variables available from the various innovation surveys. An implication of the foregoing model is that process innovation will have ambiguous effects on revenue productivity, whereas the effect of product innovation is likely to be positive.

### Global Competitiveness Index

Figure 5 in term of Indonesia’s Stage of Development, is an indispensable aspects to be considered in order to maintain and improve Indonesia’s Stage of Development of Stage 2: Efficiency driven. Furthermore, it is indispensable to consider the GCI, According to Global Competitiveness Index (GCI), GCI 2010-2011, Indonesia undergone 10 point increase from Rank 54

into 44. Yet, in GCI 2011-2012, Indonesia undergone 2 point decrease from Rank 44 into 46, that constitute an alert for the incoming years.

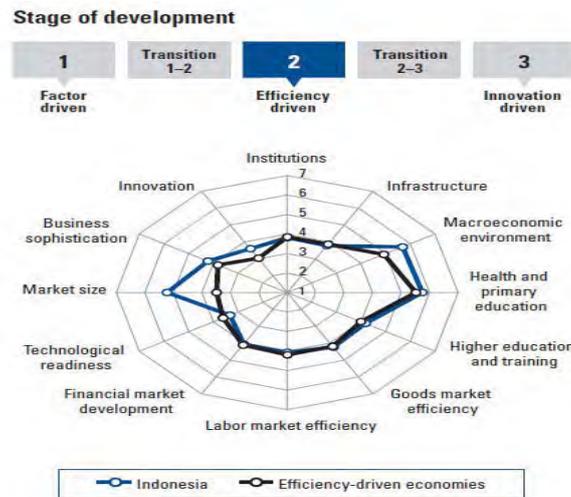


Figure 5: GCI 2011 – 2012 and Indonesia’s Stage of Development

### Malcolm Baldrige National Quality Award

Referring to Figure 1 pertaining the overview of Innovation Process, then Malcolm Baldrige is important to be considered, in any unit analysis that has been mentioned in the aspect of, theoretical aspects and managerial implications of Innovation and Malcolm Baldrige for the benefit of Human Life within unit analysis of individual, company and nation toward global benefit. Precisely, the Malcolm Baldrige refers to Effect of Strategic Planning, Customer Focus and Operations Focus toward Result of Performance Excellence and Sustainability. Data collection is conducted using both Primary and Secondary Method. For Primary Method, the interview process is conducted, along with the survey that relate to the Management of The Company. For Secondary Method, the analysis is referring to the Annual Report from the listed company in Jakarta Stock Exchange ( [www.idx.co.id](http://www.idx.co.id) ). Other information is originated from the Indonesian Quality Award Foundation ( IQA ) [www.indonesianqualityaward.org](http://www.indonesianqualityaward.org) that since 2006 has conducted and provided the Indonesian Quality Award, including the Recent Award in November 2012; Indonesian Quality Award VIII 2012. The highlighted discussion is referring to the “Growth” for both category of institution.

Excellent “Growth” for Middle Level Institution

1. **PT Krakatau Medika** Bronze Award ( Early Improvement )
2. **Universitas Bina Nusantara** Silver Award ( Early Improvement )
3. **PT Krakatau Engineering** Gold Award ( Good Performance )

Excellent “Growth” for Big Level Institution

1. **PT Aneka Tambang ( Persero )** Bronze Award ( Good Performance )
2. **PERUM PERUMNAS** Silver Award ( Good Performance )
3. **PT Semen Tonasa** Gold Award ( Early Improvement )

Innovation and Malcolm Baldrige, and its relations with Effect of Strategic Planning, Customer Focus and Operations Focus toward Result of Performance Excellence and Sustainability are deemed indispensable. Precisely, the Growth that has been shown in by both Middle and Big Institution. SCALES (2007, p. 31) specified the Innovative Activities that lead to the Growth.

### 5. CONCLUSION

An innovation is an idea, practice or object that is perceived as new by the entity adopting it , according to Roger (2003). The concept of innovation implies the idea that something is added to something else that already exists, or that something that exists is given up. The argument is that adding and/or taking away are ways to improve a state of affairs. It is indispensable to refer to the Figure 1 Pertaining Overview of Innovation Process, not to mention the determinants of Innovation Input and Output, and eventually the Innovation – Productivity Relationship, along with their Equations from Equation (1) until Equation (7). Referring to Figure 1 pertaining the overview of Innovation Process, then Malcolm Baldrige is important to be considered,

in any unit analysis that has been mentioned in the aspect of, theoretical aspects and managerial implications of Innovation and Malcolm Baldrige for the benefit of Human Life within unit analysis of individual, company and nation toward global benefit. Precisely, the Malcolm Baldrige refers to Effect of Strategic Planning, Customer Focus and Operations Focus toward Result of Performance Excellence and Sustainability. Figure 5 in term of Indonesia's Stage of Development, is an indispensable aspects to be considered in order to maintain and improve Indonesia's Stage of Development of Stage 2: Efficiency driven. Furthermore, it is indispensable to consider the GCI, According to Global Competitiveness Index (GCI), GCI 2010-2011, Indonesia undergone 10 point increase from Rank 54 into 44. Yet, in GCI 2011-2012, Indonesia undergone 2 point decrease from Rank 44 into 46, that constitute an alert for the incoming years.

Although the Baldrige criteria and framework are widely accepted in practice, there is surprisingly little theoretical and empirical evidence of their validity (Ford and Evans, 2000). Several studies presented empirical analyses of the original Baldrige Criteria in the manufacturing environment and provided evidence that the performance relationships observed in the Baldrige causal model were supported in US firms. Most recently, York and Miree (2004) examined the relationship between TQM and financial performance, using a sample of Baldrige Award winners; they replicated a second sample of state quality award winning companies with three different sets of financial performance measures. Baldrige quality award winners generally had better financial performance than their peers after and before winning a quality award.

## REFERENCES

- [1] Amemiya (1985). *Advanced Econometrics*, Blackwell, Oxford. SCALES (Scientific Analysis of Entrepreneurship and SMEs).
- [2] Ariefianto, M.D. (2012). *Ekonometrika. Esensi dan aplikasi dengan menggunakan EViews*. Jakarta. Penerbit Erlangga.
- [3] Badri, M.A, Selim, H., Alshare, K., Grandon, E.E, Younis, H., Abdulla, M. The Baldrige Education Criteria for Performance Excellence Framework. Empirical Test and Validation. *International Journal of Quality & Reliability Management*. Vol. 23, No. 9, p. 1118 - 1157
- [4] Blazey, M. L. (2011). *Insights to Performance Excellence 2011-2012. Understanding the Integrated Management system and Baldrige*. Milwaukee. American Society for Quality. Quality Press.
- [5] Byrne, B.M. (1998). *Structural Equation Modeling with LISREL, PRELIS, SIMPLIS*. Lawrence Erlbaum Associates.
- [6] Byrne, B.M. (2010). *Structural Equation Modeling with AMOS. Basic Concepts, Application, and Programming*. 2<sup>nd</sup> Edition. New York. Routledge. Taylor & Francis Group.
- [7] Crayen, C., Geiser, C., Scheithauer, H., Eid, M. (2011). Evaluating Interventions with Multimethod Data: A Structural Equation Modeling Approach. *Structural Equation Modeling: A Multidisciplinary Journal*. 18:497-524.
- [8] Fernandes, M.T (2012), "Value Construct towards Innovation", *International Journal of Innovation, Management and Technology*, Vol. 3, No. 1, pp 10 – 19.
- [9] Franses, P.H., and R. Paap (2001). *Quantitative Model in Marketing Research*, Cambridge. University Press, Cambridge. SCALES (Scientific Analysis of Entrepreneurship and SMEs).
- [10] Greene, W.H. (2000). *Econometric Analysis*, 4th ed., Prentice Hall, New Jersey. SCALES (Scientific Analysis of Entrepreneurship and SMEs).
- [11] Hair, J.F., Black, W.C., Babin, B.J., Anderson, R.E. (2010). *Multivariate Data Analysis: A Global Perspective*. 7<sup>th</sup> Edition. New Jersey. Pearson Education.
- [12] Hall, B.H. (2011) Using productivity growth as an innovation indicator. University of Maastrich and UC Berkeley. Report for the High Level Panel on Measuring Innovation, DG Research, European Commission
- [13] Jalonen, H. (2012). The Uncertainty of Innovation : A Systematic Review of Literature. *Journal of Management Research*. 4(1), 1 – 48
- [14] Mehrabani, S.E, Shajari, M., Iran, D. (2012), "Knowledge Management and Innovation Capacity", *Journal of Management Research Vol. 4, No. 2, pp 164 – 177*
- [15] Muscio, A., Nardone, G., Dottore, A. (2010). "Understanding Demand for Innovation in the Food Industry", Emerald Group Publishing Limited, ISSN 1368-3047, MEASURING BUSINESS EXCELLENCE, Vol. 14, No. 4, pp. 35 – 48
- [16] Rogers, E. M. (2003), "Diffusion of Innovations (5th ed.)". Free Press, New York, NY.
- [17] Tipu, S.A.A (2011), "Academic Publications on Innovation Management in Banks (1998–2008): A Research Note", *Innovation : Management, Policy and Practice*. Vol. 13, No.2, pp. 236 – 260.
- [18] SCALES (2007). *Innovation and Performance*. SCALES (Scientific Analysis of Entrepreneurship and SMEs).
- [19] York, K. and Miree, C. (2004), "Causation or covariation? An empirical re-examination of the link between TQM and financial performance", *Journal of Operations Management*, Vol. 22 No. 3, pp. 291-311.
- [20] Hoyle, R.H. (2012). *Handbook of Structural Equation Modeling*. New York. Guilford
- [21] Kline, R.B. (2011). *Principles and Practice of Structural Equation Modeling*. 3<sup>rd</sup> Edition. New York. Guilford.
- [22] Preacher, K.J., Zhang, Z., Zyphur, M.J. (2011). Alternative Methods for Assessing Mediation in Multilevel Data. The Advantages of Multilevel Structural Equation Modeling. *Structural Equation Modeling: A Multidisciplinary Journal*. 18: 161-182.
- [23] Rencher, A.C., Christensen, W.F. (2012). *Methods of Multivariate Analysis*. 3<sup>rd</sup> Edition. New Jersey. John Wiley & Sons, Inc.

- [24] Sadikin, I. (2011). Seri Manajemen Mutu. Bunga Rampai Kriteria: Malcolm Baldrige National Quality Award ( MBNQA ). Edisi VII: 2011-2012. Bandung . Lembayung Center.
- [25] Schumacker, R.E., Lomax, R.G (2010). A Beginner's Guide to Structural Equation Modeling. 3<sup>rd</sup> Edition. New York. Routledge. Taylor & Francis Group.
- [26] Wijanto, S. H. (2008). Structural Equation Modeling dengan LISREL 8.8. Konsep & Tutorial. 1<sup>st</sup> Edition. Yogyakarta. Graha Ilmu.
- [27] Wijaya, T. (2009). Analisis Structural Equation Modeling Menggunakan AMOS. Yogyakarta. Universitas Atmajaya Yogyakarta.
- [28] Wiyono, G. (2011). Merancang Penelitian Bisnis dengan alat analisis SPSS 17.0 & Smart PLS 2.0. 1<sup>st</sup> Edition. Yogyakarta. UPP STIM YKPN.
- [29] Wu, J.Y and Kwok, O.M (2012). Using SEM to Analyze Complex Survey Data: A Comparison between Design-Based Single-Level and Model-Based Multilevel Approaches. *Structural Equation Modeling: A Multidisciplinary Journal* . 19: 16-35
- [30] [www.weforum.org/gcr](http://www.weforum.org/gcr) accessed on 1st September 2012
- [31] [www.idx.co.id](http://www.idx.co.id) accessed on 10th September 2012
- [32] [www.indonesianqualityaward.org](http://www.indonesianqualityaward.org) accessed on 15th September 2012

# Partnership Strategy to Build Technopreneurship as a Mean to Achieve the Entrepreneurial University

**Tiena Gustina Amran**

*Faculty of Engineering, Magister Program of Industrial Engineering Department,  
University of Trisakti, Jakarta 11440  
Tel : (021) 5663232 ext 8177. Fax : (021) 5605841  
E-mail : tiena\_amran@yahoo.com*

## ABSTRACT

The Entrepreneurial university achievement goes together with community's development in social, economy, politics, environment, and national defense in the Indonesian society. Commitment made by the faculty heads are a priority in achieving vision and missions which resulting in contributions from the qualified lecturers and creative students of the Industrial Engineering Department. This continuous improvement was done in each semester in the form of modules. From the academic side, students are assigned a manufacturing industry planning project for 4 semesters, consisting of 30 modules like industrial planning, production process, and real business development. Maira Technopreneurship Business Incubator (MTBI) is created to accommodate students' products and help them market and manage their business by creating a business incubator. Partnership is conducted with business innovation center focusing on developing business network with regards on professional ethics and legal aspects, as well as social towards other parties like the small and medium enterprises. The innovation center also connects university with researchers and industrial professionals so that this partnership not only developing knowledge, but also developing business products. Based on this partnership and tests, product development and innovation can be obtained and students will obtain an experience of working in the real business environment before their graduation day.

## Keywords

*Entrepreneurship, business plan, industry, partnership*

## 1. INTRODUCTION

University graduates dominate the number of unemployed in Indonesia. The workspace available just could not absorb the annually growing number of university graduates because some of them were not ready to be involved with "the real" job. Based on the Statistical Bureau (*Badan Pusat Statistik*)'s data on August 2012, there are 7.2 million open unemployment with Open Unemployment Rate (*Tingkat Pengangguran Terbuka/TPT*) of 6.12%. The university graduates dominated this rate by 12.12% consisted of 6.21% college level and 5.91% undergraduate level. The rate for vocational school graduate was 9.83%, high school graduate was 9.80%, junior high school 7.76% and elementary school and below 3.64%.

Another reason is the uneven balanced between the number of university level workers needed compared to the number of university, both public and private. The growing number of students in a university did not always mean the increasing quality level of its graduates. This also one of the reasons why there was an increasing number of unemployment of the university graduates. The university party stated that the industry did not put enough trust to recruit science and technology graduates with high grades, and they were placed as operators. The university believed that this underestimated their position. The Ministry of Employment explained the necessity to prepare ready to work graduates as well as those with entrepreneurial spirits. University graduates were in great needs to be ready to get into work both in hard and soft skills from their logical reasoning to their entrepreneurial and leadership skills. Therefore, the graduates did not always need to depend on the industry's employment needs. Nation wise, the ratio of entrepreneurs to the Indonesian people has only reached the 0.18% from the targeted 5%-7%.

Trisakti University consisted of 9 Faculties, 36 Departments, Graduates and Doctoral Programs with around 30 thousand student's body in several campus locations in Jakarta. In its vision, it was stated "To become one of the leading international quality universities in developing knowledge, science, technology, and art as well as entrepreneurship to increase the living quality and culture that pay respect to the diversity and local wisdom of Indonesia."

As a result to that challenge, the Industrial Engineering Department created an organization to accommodate students' products and help them market and manage their business by creating a business incubator called Maira. The aims of this business incubator are:

1. To be an organization where students with entrepreneurial spirits can gather and discuss with each other.
2. To gather individuals with business ideas.
3. This business incubator was supported by the industry, alumni, government, and the non-profit organizations.
4. To create more employment to reduce the unemployment rate.
5. University-related incubator. This incubator aimed to commercialize science, technology, and intellectual rights of the researches' findings. The Industrial Engineering Business Incubator offered beginner companies an access to the department's laboratory, computers, library, and professional services in Industrial Engineering or other subjects.
6. This incubator was directly supported by the department in collaboration with other entrepreneurial concerned parties.

### Maira Technopreneurship Business Incubator (MTBI) Model Development

University-Based Incubator assisting the growth of spin-off firms through a dedicated facility providing subsidized space, consultation and other help to encourage entrepreneurship is a worldwide phenomenon. MTBI will have relationship and cooperation with the following parties:

1. Various Majors in the Trisakti University environment

MTBI gives and shares inputs on the expertise of academic staff and support to a variety of departments in Trisakti University, especially faculties, RICE, alumni, small medium Industries. It also creates synergy with Community Development and other units in Trisakti University which will act as "knowledge forum developer/manager."

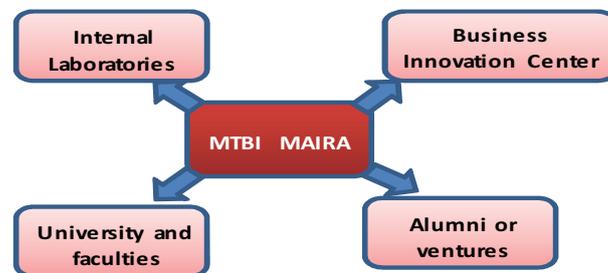


Figure 1: Trisakti University Industrial Engineering Dept. MTBI Model

2. Business Innovation Center (BIC)

BIC was built on 2008 and placed under the Indonesian Ministry of Research and Technology (RISTEK). This center holds the same mission as Ristek in building, promoting, and motivating the use of local generation's innovations through the synergy between A-B-G-M Academics, Business, Government and *Masyarakat* (People); so that in its turn, will pose a strategic role in the development of the national competitiveness in the global economic era. BIC will pose as an organization for innovators, researchers, academicians, and professionals to create a commercial and practicability outlook for their innovations. BIC will act as a bridge between the commercial and researcher party so that they are ready to positively synergize. Until today, BIC has published 510 products. The partnership between the Industrial Engineering Department and BIC involves the act to pro-actively supporting and inviting students, lecturers, and researchers to build the Indonesian competitiveness and independence through successful innovations.

3. Internal Laboratories

In the early stages a number of laboratories in the Industrial Engineering department run on their own based on their own modules. Now, MTBI acts as an integrator in the Manufacturing Industrial Design/MID (*Perancangan Industri Manufaktur/PIM*) throughout the laboratories like the production system, simulation and computation, statistics and quality engineering, design and work analysis, plant layout, and organizational design lab. A synergy with other faculty and department like the Art and Design Faculty, Electrical, Mechanical, and Informatics Engineering Departments were also conducted to design an ICT system that will expand the coverage of the Industrial Engineering student's product.

4. Outside parties

To play the role in creating a relationship between technopreneurs and other agencies such as SMI from the Ministry of Industry and Trade, the Ministry of Cooperation, Financial organizations and organizations like PNPM Mandiri, BPPT, Ristek, etc that are directly involved with the development of technopreneurs in the country.

### The Entrepreneurial University

Incubation is part of a global model for the management of knowledge and technology in regional development, with the university as an entrepreneur. The university has potentially flexible resources, giving it the ability to take on new missions, especially in times of crisis. The former exemplifies incubation as a strategy to revive a declining industrial region; the latter an instance of developing a 'green field' site, a region largely lacking in industry. Ideally, the incubator is part of a broader

strategy of academic and regional co-development and a web of informal and formal university–industry ties. Such ties can be initiated through creation of a formal structure, such as an incubator or a liaison office, or may arise from continuing relationships between professors and former students. In either case, the most productive regime of university–industry relations will comprise both elements (Henry Etzkowitz, 2002).

University is a natural incubator that sometimes plays an informal entrepreneurial role in the incubation of companies. Institutions in each sector (academy, government and industry) play hybridized roles that seem to move them away from classical understandings of each, for instance, entrepreneurial academics, academic industrialists, business strategy in government, and so on.

## 2. METHODOLOGY

### Manufacturing Integration Design

In the university level, the development towards becoming an entrepreneurial university was determined through the annually assessed Strategic Plan as a part of the Operational Plan. The success indicator in each faculty and major can be measured from the laboratory’s performance and the students’ practicum modules. In the Industrial Engineering Department, the MTBI integration to the MID was conducted as followed:

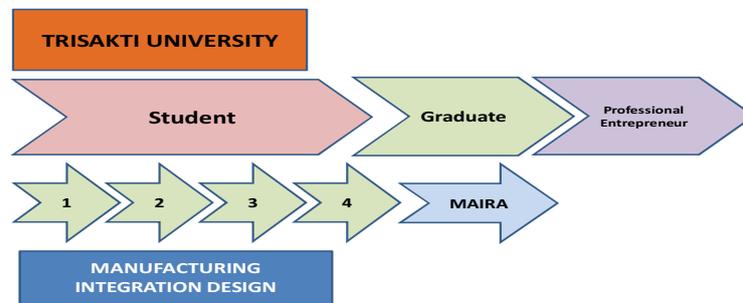


Figure 2: Manufacturing Industry Integration Design

Table 1: Integration between MID and MTBI

Characteristics	MID1	MID2	MID3	MID4 and Industrial Business Fair (IBF)	MTBI
Length of module	6 modules	9 modules	8 modules	7 modules 3 workshop	Selected products
Project/task	Design and report	Design and report	Design and report	Product and Business Plan Design	Enter the incubator
Scope	Shop floor	Shop floor	Factory facilities	Campus and public markets	Public potential market
Timeframe	6 months	6 months	6 months	6 months	Depend on the market
Learning	Supervised with room	Supervised with room	Supervised with factory	Supervised with room for self - development	Self-directed
Resources	Readily available within the department			Obtained on own initiative	joint venture
Credit unit	2 credit	2 credit	1 credit	2 credit	
Deliverables	Structured assignments, interim and final assessment by intensive department			Structured periodic reviews, final report and presentation	Project outcome, final report and presentation
Team	Six students per modules with same scopes	6 students per modules with same scopes	6 per modules with same scopes	Six students per modules with differences scopes	Maximum 4 per team
Supervision	Lecturers and assistants as member of laboratory	Lecturers and assistants as member of laboratory	Lecturers and assistants as member of laboratory	Facilitated by 7 lecturers, 3 practitioners, with 3 possible mentor	Facilitated by two lecturer with consultants

### 3. RESULTS AND DISCUSSION

#### 3.1. Industrial Engineering's Body of Knowledge in PIM Practice

##### 3.1.1. Experiential learning

Students in their small groups were tutored by several laboratory assistants in every stage:

- MID 1 stage: conducting the Product and Process Design (need identification, sketching, quality planning, and process mapping)
- MID 2 stage: conducting Operation Planning (work system improvement using experiments, forecasting, production planning, production main schedule, machine and operator requirements).
- MID 3 stage: conducting the facility planning design and cost calculation.
- MID 4 stage: conducting the business planning beyond the campus scope.
- Industrial Business Fair (IBF) & Maira TBI: developing business by involving the elements of Business, Academics, Government, and the Society.

##### 3.1.2. Outcomes focus approach

The result of MID 1 will be an input for MID 2, and same goes for MID 3. In MID 4, a business plan was prepared to see the market's opportunity for the idea that was developed based on the group's interest and guided by the supervisors from the academic, professional, corporate, and BIC party.

##### 3.1.3. Assessment of Tasks

The following section will highlight the advantages and benefit of the tasks assessment.

##### a. The product chosen is a manufacture project, even though service is also allowed

- Real life: to dig an idea from daily activities and needs.
- Problem solver: to provide a new solution inspired from creative idea brainstorming.
- Environment: to consider the environmental moral and ethics as well.

##### b. Encourages active learning

Shopping idea to find the inspiration, the idea and the implementation product or service as a problem solution in the society based on the MID knowledge in campus. Conduct discussions with professionals and academicians to develop shopping idea into mapping some alternatives solution.

##### c. Develop autonomous learning skill (4L)

Learn, analysis of the information will be collected to identify patterns and insights

Look, observe people to discover what they do rather than what they say

Ask, enlist people's participation to elicit information relevant to the project

Try to create simulation to help empathizes with people and to evaluate proposal design

##### d. Opportunity for self-assessment

1. Value proposition: value created by product or services
2. Customer segment: reason of existence for an organization, no business last without loyal customer behinds them.
3. Customer relationship: clearly define the type of relationship that the customers desire
4. Key partners: customers are the network that help a business model to be effective
5. Channels: the way to engage in product and service relationship function with the customer with quality, cost, delivery, after sales service and flexibility in mind
6. Key activities: the most important activity for an organization to run its business model
7. Key resources: consists of 4 points which are human, physical, intellectual, and financial resources
8. Cost structures: describes the implementation of the key activities by utilizing key partnership which definitely need cost
9. Revenue stream: a series of activities which seek for value so that the customer is willing to pay and also to accommodate the preferred paying method by the customer

##### e. Learning through feedback

1. Point Of Sales as revenue and result
2. Free market demand is the demand from the customer after Industry Business Fair (IBF) event to be marketed. At the time, the students are expected to start to process their company's legal entity

##### f. Selection and Nurturing

MTBI invited professionals, consultants, ventures, and those who were attracted to the product or prototypes to develop the products.

- Market demand
- Product function
- Future product technology
- Product continuity
- Capital aid
- Networking aid
- Information Computer Technology
- Company's Legal Status

### 3.1.4. Results and Improvement

From 2006 to present, 6 IBF has been conducted and in 2011 2 batches of the students, consisting of various teams, who have created 2 products (the poncho jacket and alarm pillow) was obtained.

Table 2: Summary of the project.

Origin	Platform	Number
Self-initiated	Web	1 alarm pillow
Partnership with industry		1 Rain coat

## 4. CONCLUSION

The MTBI Program in Trisakti University is an effort to support its vision and mission as an entrepreneurial university. Challenges and beyond, there are some obstacles: rare individuals with enough passion, those who are not only after academic tasks and valuing them as something to get an employment before graduation, the low importance of intellectual rights in the university, the large number of failure in the product's integral aspects that differ from their initial aims, unsuccessful in the commerce world.

## ACKNOWLEDGMENT

Industrial Engineering Department Trisakti University that sponsored to the International Seminar Quality in Research 2013.

## REFERENCES

- [1] Clark Tim, Alexander Osterwalder and Pigneur Yves, *Business Model You*, PPM Manajemen, 2012.
- [2] Henry Etzkowitz, *Incubation Of Incubators: Innovation As A Triple Helix Of University-Industry-Government Networks*, Science And Public Policy, Volume 29, Number 2, page 115-128, Beech Tree Publishing, April 2002.
- [3] *Modul Perancangan Industri Manufaktur I Perencanaan Produk dan Proses*, Laboratorium Sistem Produksi, Rekayasa Kualitas, Jurusan Teknik Industri Universitas Trisakti, 2012.
- [4] *Modul Perancangan Industri Manufaktur II Pengendalian Proses Dan Perancangan Organisasi*, Laboratorium Sistem Produksi, Sistem dan Simulasi, Desain Sistem Kerja dan Ergonomi, Perancangan Organisasi, Rekayasa Kualitas Jurusan Teknik Industri Universitas Trisakti, 2012.
- [5] *Modul Perancangan Industri Manufaktur III Perencanaan Tata Letak Pabrik*, Laboratorium Sistem Produksi, Sistem dan Simulasi Jurusan Teknik Industri Universitas Trisakti, 2012.
- [6] *Modul Perancangan Industri Manufaktur IV Perencanaan Bisnis*, Laboratorium Sistem Produksi, Sistem dan Simulasi, Desain Sistem Kerja dan Ergonomi, Perancangan Organisasi, Rekayasa Kualitas Jurusan Teknik Industri Universitas Trisakti, 2012.

# Conceptual Model for Evaluation the Impact of Transit-Oriented Development Initiatives to the Income Growth of MRT Operating Company

Akhmad Hidayatno, Tyonardo Cahayadi, Irvanu Rahman

*Systems Engineering Modeling and Simulation Laboratory  
Industrial Engineering Department, Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : akhmad@eng.ui.ac.id, tyonardo.cahayadi@gmail.com*

## ABSTRACT

The planned mass rapid transit development in Jakarta as a huge public infrastructure project must balance between massive cost investments with every possible sources of income opportunity. In order to do this, early on in the design, the MRT Jakarta Company with the Government of Jakarta must exploit the presence of each MRT station. This is because each station will bring a significant impact to the surrounding area, especially at walking distance radius. This Transit Oriented Development (TOD) perspective must be able to capture the value added to the area around the station and provide opportunities for additional revenue, especially the non fare box (NFB) revenue for the company. However, it is not clear how the causal relationships between MRT station development and NFB revenue generation. This paper offers a conceptual model of this relationship that would help the shareholders and stakeholders understand these important relationships and devise an appropriate strategy.

## Keywords

*Mass Rapid Transit, Urban Planning, Transit Oriented Development, Conceptual Model.*

## 1. INTRODUCTION

Public Infrastructure with massive investment would require income opportunities from different sources possible. Revenue from public infrastructure comes from usually three sources: income from ticket fare, income from subsidies, and non fare-box (NFB) revenue. NFB revenues are advertisements, property rent, kiosks and other income not linked directly with ticket sales (fare-box or FB). Finding factors that could affect the income dynamics between these three sources of income would provide more understanding on how all three are actually related.

All public infrastructures in general may affect the development and the value of property in an area, which open up the opportunities of NFB. Grass (1992) indicates that public infrastructure has a profound influence on the pattern of urban development and spatial distribution of urban property values [1]. The existence of a station in general would provide benefit to the surrounding environment within walking distance radius, which is known as part of the Transit Oriented Development. PT MRT Jakarta (MRTJ) must capture this predicted growth of NFB income opportunities. MRTJ is the state owned company who has the responsibility of developing, operating and maintaining this first urban rail-based mass rapid transit (MRT) line in Indonesia.

Understanding this relationship between station and NFB growth is important for determining the long term corporate financial strategy of MRTJ. In order to attract more passengers, the ticket price must be affordable. This would require subsidy from the city government. There is not yet clear contract agreement regarding this between Jakarta Government and MRTJ. This agreement could greatly affect the cost structure managed by both parties. For MRTJ this could significantly alter their corporate strategy.

Conceptual modeling, which would be based on system dynamics methodology, could show qualitatively the complexity of variables on this issue. This paper offers a conceptual model of this relationship that would help the shareholders and stakeholders understand these important relationships, and have a common understanding as the background on developing an agreement for MRTJ and Jakarta's City Government.

## 2. LITERATURE REVIEW

The impact of railway station proximity on property value has received wide attention in the economic literature. Several empirical studies tried to quantify this effect. However, the Conclusions are not uniform (Debrezion, 2004) [2]. The presence of a station in an area, will give a great impact of surroundings environment. Naturally, railway stations have an effect on both land value and land use patterns (Ferguson et al, 1988) [3]. The pattern of the effect can be seen as volcano shaped, shown in Figure 1.



Figure 1: Volcano Shaped Value Pattern of Land Value and Station Location

Source: (Steer Davies Glee, 2011) [4]

All public transportation infrastructures in general may affect the development and the value of property in an area. Public infrastructures produce pattern of urban development and spatial distribution of urban property values. This happens because the infrastructure is providing accessibility to an area so that residents from other areas far away can have access to reach the site.

Public transportation infrastructure that provides accessibility definitely impacts an area such as sewer, highway, bus station, train station. Damm then capitalized these services into urban property values [5]. With the accessibility, a place said to be interesting. As a location becomes more attractive, as a result of certain characteristics, demand increases. This results in increase of price

Another effect of the station is also influenced by any of the facilities provided by the station, as said by Bowes, The number of parking lots in or near the station and the proximity of the railway station to the Central Business District also increase of the impact of the station on property value [6].

In addition to the increase in terms of value, the presence of a station also provides other effects. When some of the development of property often focused on area besides highway road, or when on the sides there are fancy and dense commercial buildings, but behind on the second layer would be found lots of underprivileged housing on a way different scale from the first layer from the roadside. The theory on land prices and settlement that indicates a higher accessibility of a location leads to a dense settlement [2]. Area on station's walking distance provide place that has great accessibility for both commercial commuter use and residential use. Naturally, railway stations have an effect on both land value and land use patterns [7].

Station that gives access to a particular area would give movement of passengers in large numbers, especially when the particular area provides great money flow activities. High population movement would create a development of retail activities but at the same time may attract criminality [6]. This indicates that definitely a station would provide a growing retail area.

[8] The center for Transit Oriented Development (TOD) in Berkeley identified several ways that station location, transit accessibility can benefit land owners, improve marketability of new residential units, office and retail space, open up valuable new sites for development, prompt up zoning and higher density development, command higher sales prices and rents, making higher density construction more financially feasible, encourage cities to support new infrastructure and public facility. The development of station area can grow naturally with a possible threat of unstructured sprawling areas. The other better alternative is by orientating the development along the transit stations through regulation, rights allocation, and incentives by the government. This concept of development is known as Transit Oriented Development TOD [9]. The keywords from TOD definitions are mixed-use development, pedestrian walking, multimode interchange access, high density, and transit stations [10]. The TOD initiatives must be adopted by the MRTJ early in the development of the project to make sure that they could capture the business opportunity created by future growth of the surrounding MRT stations.



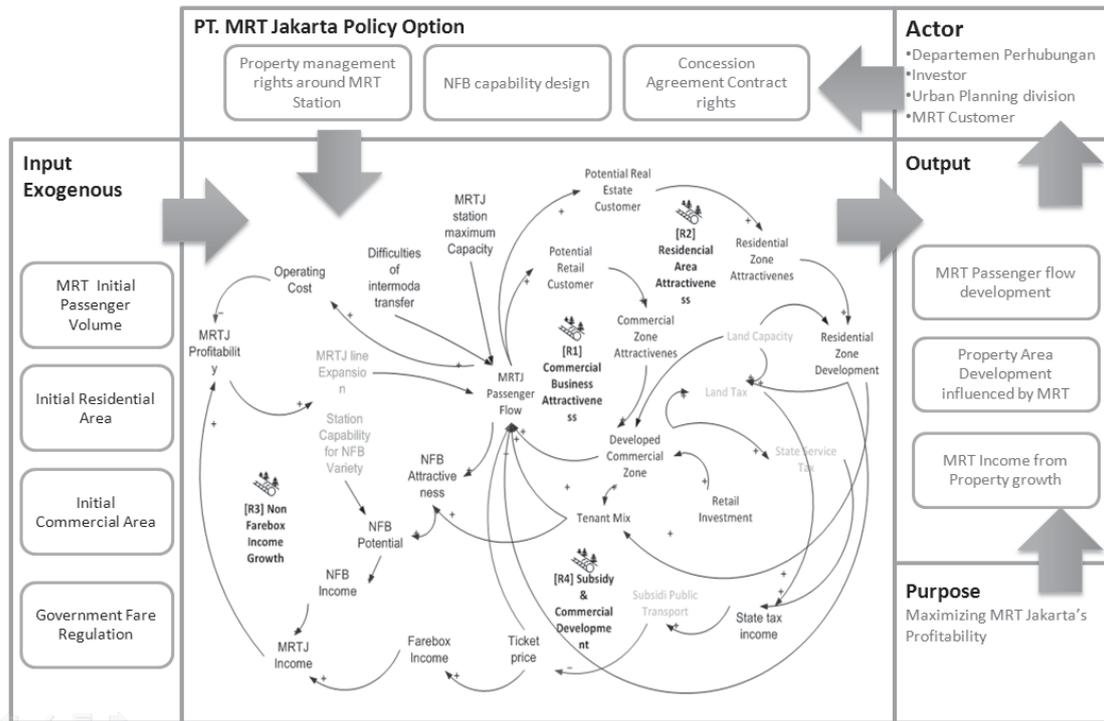


Figure 2: System Diagram

Using MRTJ Company is the primary actor in this analysis, this research identifies the purpose of the conceptual model is to gain insights on how to maximize MRT Jakarta’s profitability, especially from NFB business development. Based on shareholders' interviews, there are three outputs needed to accomplish this goal: passenger flows, property area development and property growth. The actor represents the interest of major stakeholder that could influence the MRTJ policies. Some of the possible explanation of variables interaction.

Figure 3 shows that the presence of the MRT station would affect development of two major area types: commercial area and residential area. Commercial area includes office, retail shopping, dining or leisure. In this conceptual model, the primary focus for area development is the passenger flows. The bigger the passenger flow, the area surrounding the station would be more attractive for development. At the same time, more developed area would attract more people to visit hence increasing the passenger flow, creating a positive feedback loop. The commercial area and retail area loops are R1-Commercial Business Attractiveness reinforcing loop. R2-Residential Area Attractiveness represents the reinforcing loop feedback for the development of residential area.

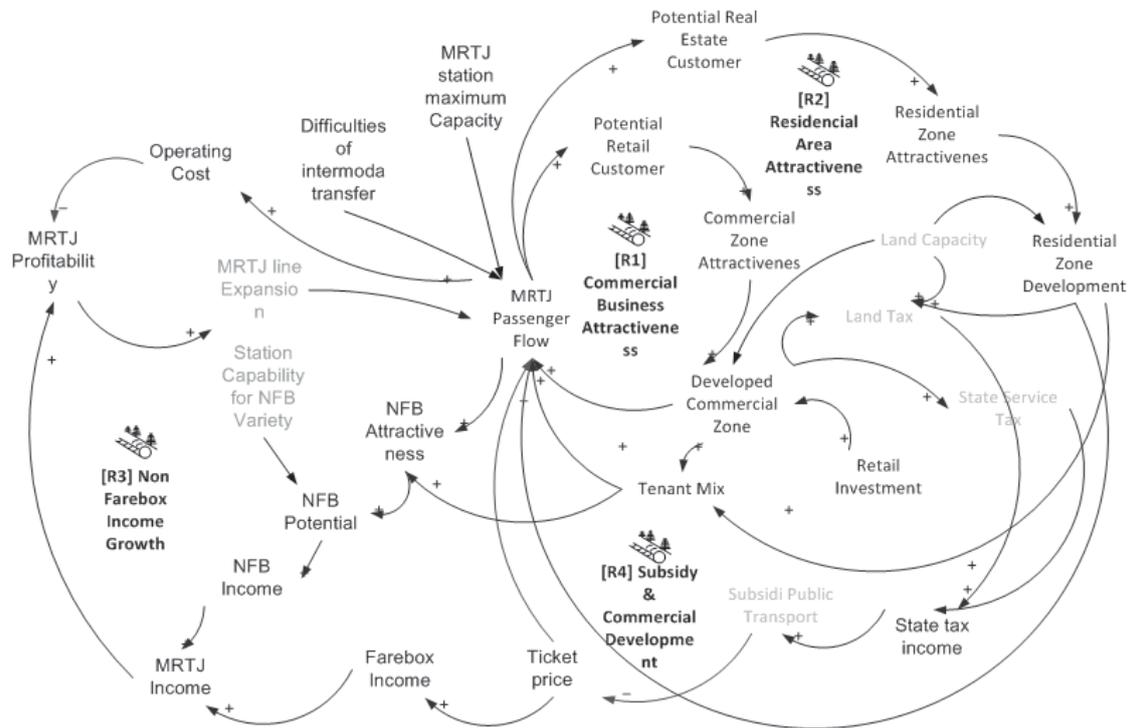


Figure 3: Causal Loop Diagram of TOD Impacts to NFB Income

However, all shareholders agree that with current state of building development in Jakarta and land availability, they would choose an integrated multi use area. Therefore, finding the right tenant-mix-ratio in the surrounding area of the station between commercial (including retail) and residential area would be the key for developing the NFB business. Each area types would have different dynamic effects on increasing passenger flow.

With the increase of passenger flow and influence by tenant mix, MRTJ can capitalize by developing the NFB business and increase their NFB income, shown as R3-NFB income growth. The increase of passenger flow would also increase the operating cost and could reduce MRTJ profitability.

The existence of MRTJ stations would benefit the government of Jakarta from an increasing state various tax, which includes land building tax and service tax. These increase tax along the MRT corridor will support the city government on providing affordable transportation cost to public by giving subsidy to passenger (R4-Subsidy & Commercial Development). The city government will be pressured by the public to make the ticket price as low as possible for the public, usually well below the normal price to cover the operational and investment expense. In addition, the amount of NFB income could never cover the lack of fare-box (FB) income required for breakeven, without government subsidy. This relationship provided the means for MRTJ on negotiating the amount of ticket price subsidy from the city government.

Using the conceptual model, the source of subsidy is shown clearly with the increase annual tax revenue from the development of areas surrounding all the future 15 MRT stations. This would make easy for MRTJ to negotiate the subsidy and create a more complete corporate strategy.

## 5. CONCLUSION

Public transportation development is always in constant pressure to provide affordable price to increase the accessibility of the general public. Greater mobility would be good for the city economy in the long run. However, the feasibility of this development will be questionable if there is a limited income available to cover the expenses. Using the transit development oriented perspective; the conceptual model developed in this paper could show the interrelationships of variables that open up the possibilities of NFB income growth. This growth came from the increasing economic value effects of MRTJ stations.

As part of an ongoing research, this conceptual model is the basis of a system dynamic model. The future final model combine with a financial model, would analyze the most influential variables in maximizing the profitability of the MRTJ. However, the current conceptual model could easily be use as a tool for explaining the positive impact loop of MRT stations development, passenger flow, government subsidy and the growth of NFB business. This would help MRTJ to prepare its corporate strategy in the long run.

## REFERENCES

- [1] Grass, R. G., 1992 The estimation of residential property values around transit station sites in Washington, D.C., *Journal of Economics and Finance*, 16, 139-146.
- [2] Debrezion, G., Pels, E., & Rietveld, P. (2004). *The Impact of Railway Stations on Residential and Commercial Property Value*. Tinbergen Institute Paper.
- [3] Ferguson, G. B., & Mark, J. (1988). *The Pre-Service Impacts of the Vancouver Light Rail Transit System on Single Family Property Values*, in J.M. Clapp and S. D. Editors. Elsevier.
- [4] Steer Davies Glee. (2011). *The Value of Station Investment: Research on Regenerative Impacts*. London: Steer Davies Glee.
- [5] Damm, D., S. R. Lerman, E. Lerner-Lam, and J. Young, 1980. Response of urban real estate values in anticipation of the Washington Metro, *Journal of Transport Economics and Policy*, 14, pp. 315-355.
- [6] Bowes, David R., and Keith R. Ihlanfeldt, 2001. *Identifying the Impacts of Rail Transit Stations on residential property values*. Elsevier.
- [7] Ferguson, B., M. Goldberg and J. Mark, 1988. *The Pre-Service Impacts of the Vancouver Light Rail Transit System on Single Family property values*, in: J.M. Clapp and S. D. Messner (Eds) *Real Estate Market Analysis: Methods and Applications*, pp. 78-110. New York: Praeger
- [8] Gihring, Thomas. 2009. *The Value Capture Approach To Stimulating Transit Oriented Development and Financing Transit Station Area Improvements*. *Victoria Transport Policy Institute*. Washington.
- [9] Dittmark, Hank and Gloria Ohland. *The New Transit Town: Best Practices in Transit-Oriented Development*. 2003. Island Press.
- [10] Transit Cooperative Research Program (TCRP). *Transit-Oriented Development and Joint Development in the United States: A Literature Review (TCRP Research Results Digest 52)*. 2002. Federal Transit Administration US.
- [11] Sterman, John D. 2000. *Business Dynamics: System Thinking and Modeling for A Complex World*. Boston: The McGraw Hill Companies, Inc.

# An Inventory Model on Damaged Product with Calculating Crashing Cost and Variable Lead Time

**Inaki Maulida Hakim**

*Department of Industrial Engineering,  
Faculty of Engineering,  
University of Indonesia, Depok 16424  
E-mail : inakimhakim@ie.ui.ac.id*

This paper about an inventory model especially on items had deterioration. Company has a policy to always fulfillment customer demand with specified service level. High technology product is one of single item for final product ordered from suppliers that have a number of requirements, inventory total cost and different lead time where this paper explain lead time have a pattern are variable lead time. Company always have inventory planning with exceeded product to anticipation product rejects caused decreased function product or damaged and had passed product life time. This paper developed an inventory model for high technology product to determine lot size optimal caused reject and damaged. To solve this problem, the first step is developed a mathematical model based on reference's model, and then solve the model analytically. Finally an inventory model for high technology product by calculating damage cost and variable lead time was derived by this research.

## **Keywords**

*Variable lead time, deterioration, high technology, crashing cost.*

## **1. INTRODUCTION**

Inventory item is one that is often done on every company and almost every company to do so. As the manufacturing industry supplies often found in the form of raw materials, semi-finished goods and finish good product. One of is the reason the company must maintain and exercise control over inventory is physically or economically impossible to get the goods immediately upon existing demand. Without the supplies then led to the waiting customers, while the real condition of the customer does not want to wait too long. For this reason the company felt the need to keep inventory to meet customer needs in unexpected ways (Hadle and Within,1963).

Good inventory system can be seen from the performance or the performance of the system inventory on hand. There are two main criteria to measure the performance of the inventory system are: (1) a high level of customer service (service level) and minimum inventory costs (Fogarty,1991). The emergence of inventory in the system is the result of a mechanism to meeting consumer demand. Consumer demand can't be met immediately at the time it depends on the stock. If inventory does not exist then consumers have to wait, as a result consumers are looking for companies to be able to meet the demand of consumers. As a result the company into profit shortfall, therefore, management becomes important. Deterioration product is defined as a commodity that is damaged or lost most of the value of quality as a result of declining utility or benefits when compared to the initial conditions. Wholesaler can be faced with a potential market but in the environment of uncertainty associated with the purchase price, expiry age and level of demand as a result of deterioration. This condition encourages wholesalers to take the right decisions related to inventory policies specifically how much needs to be ordered and when ordered back in order to get the maximum benefit.

In this paper refer to the previous paper Kee Chen Kuo and Ching-Ter Chang (2007), entitled Inventory model with seasonal demand with variable lead time and resource constraint, then developed taking into account the presence of defective single item in the product from the supplier, items referred to reject goods. As a result, the damaged goods inventories, the total cost will change by considering the cost of the damage. For the development of this paper refers to the model of Wu and Ouyang (2001).

## **2. THE PROBLEM FORMULATION**

This model is intended to address issues concerning the phenomenon of how many companies need to be able to meet the demand from customers so that the company can earn a profit and inventories to minimize the total cost of the measure of performance in this study.

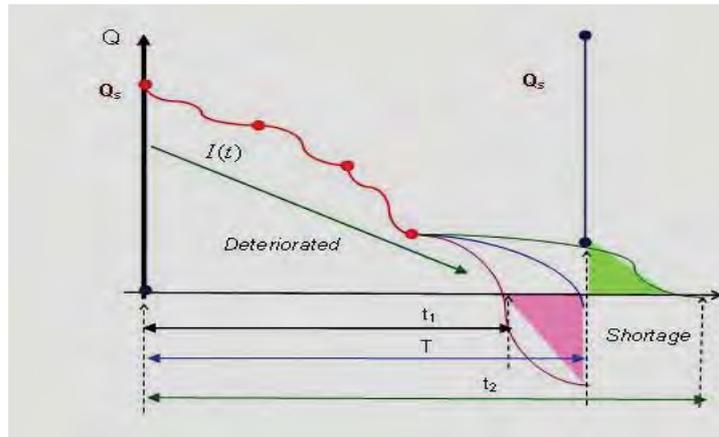


Figure 1 Inventory System Model For Deterioration Product

In the real side conditions if the inventory system is applied then there is the cost of inventory. General cost inventory for items that are not damaged consists of purchase cost, ordering cost and holding cost. Although on defective items (perishable items) on the total cost of inventory to add the cost of damage items. Due to the perishable items usually have life time so that the product caused the loss of value due to quality out of date, damaged and so the result of deterioration.

Decision variable in this model are :

1. While ordering lot size (Q)
2. when ordered (r) and
3. safety stocks (ss)

Assumption was used in this paper are :

1. Demand during planning time horizon is probabilistic and normally distribution.
2. Reorder point calculated from demand expectation during lead time plus safety stock (ss). When safety stock calculated from k multiplied demand deviation standard during lead time. When k as safety stock factor. Then r shown in formula 1.

$$r = DL + k\sigma \sqrt{L_i = L_{\max} - \sum_{j=1}^i (b_j - a_j)} \quad (1)$$

3. Number of items damaged on lot size Q is random variable binomial with parameter Q and p, when  $(0 \leq p \leq 1)$  is probability damaged items. When order coming to all item was inspection and each damaged items will be return to supplier and item sent on next lot size.
4. When process on in control condition assumptions not produce damaged items or number of items damaged = 0.
5. Set up cost and deterioration not calculated.

6. Lead time has n component when  $(L_{\min} = \sum_{i=1}^n a_i \leq L \leq \sum_{i=1}^n b_i = L_{\max})$ . (2)

Each first component has duration minimum ( $a_i$ ) and duration normal ( $b_i$ ) and crashing cost each periode unit ( $c_i$ ).

Crashing cost and lead time component will be shown Table 1.

Table 1: Lead time Data

Component of Lead time	Normal Duration (Day)	Duration Minimum (Day)	Crasing Cost (IDR/Day)
1	16	2	0.40
2	16	2	1.20
3	10	3	5.00

7. Annually demand following normal distribution with average D and deviation standard.

8.  $L_i$  = Long of lead time each component 1,2 .....I where  $L_i = L_{\max} - \sum_{j=1}^i (b_j - a_j)$

and crashing cost given as  $L_i < L \leq L_{i-1}$ .

Where :

$$R(L) = c_i(L_{i-1} - L) + \sum_{j=1}^i c_j(b_j - a_j) \quad (3)$$

- R(L) : lead time crashing cost per cycle
- j,i : index from number component of lead time j,i = 1,2,...,n
- c<sub>i</sub> : crashing cost unit each day of lead time component i
- a<sub>i</sub> : minimal duration lead time i
- b<sub>i</sub> : normal duration component of lead time i

9. Ordering cost constant every order and holding cost constant.
10. Shortage cost equivalent with number of items not fulfillment plus with marginal profit every units.
11. Systemic cost and order cost was ignored in calculated total cost.

### 3. THE MATHEMATICAL MODEL

Criteria Performance from development model in this paper is minimize total inventory cost consist of order cost ( $O_p$ ), holding cost ( $O_s$ ), shortage cost ( $O_k$ ), damaged item product cost ( $O_d$ ), and crashing cost ( $O_c$ ). In consequence the total cost in this inventory system can be written as:

$$O_T = O_p + O_s + O_k + O_d + O_c \quad (4)$$

Every cost component described as follows :

1. Ordering cost ( $O_p$ )

Ordering cost calculated from order quantity (D) during planning horizon divided with lot size (Q) multiplied every order. In consequence order cost in this inventory system can be written as:

$$O_p = A \frac{D}{Q} \quad (5)$$

2. Holding Cost ( $O_s$ )

Holding cost calculated from holding cost (H) multiplied with average lot size  $\left(\frac{Q}{2}\right)$  plus safety stocks (ss). In consequence holding cost in this inventory system can be written as:

$$O_s = H \left( \frac{Q}{2} + k \sigma \sqrt{L_i} \right) \quad (6)$$

3. Shortage cost ( $O_k$ )

Shortage cost calculated from number of shortage per cycle (N) multiplied with shortage cost per units ( $\pi$ ). In consequence shortage cost in this inventory system can be written as:

$$O_k = \pi N \quad (7)$$

Shortage becoming if number of demand during lead time (x) more than reorder point (r), on  $x=r$  until  $x = \infty$ . Finally shortage per cycle can be written (Nur Bahagia, 2006) :

$$\begin{aligned} N &= \int_r^{\infty} (z - r) \cdot f(z) \cdot dz \\ &= S_L [f(z_\alpha) - z_\alpha \psi(z_\alpha)] \end{aligned} \quad (8)$$

In consequence shortage cost in this inventory system can be written as:

$$O_k = \pi \cdot S_L [f(z_\alpha) - z_\alpha \psi(z_\alpha)] \quad (9)$$

4. Damaged Item Product Cost ( $O_d$ )

Damaged item product cost calculated from number damaged items per cycle ( $N_d$ ) multiplied damaged item product ( $c_d$ ) per unit defective on finish product can be happened lost, base on assumption then number damaged items ( $N_d$ ) in every cycle is

$$N_d = \begin{cases} 0 & \text{if } \tau \geq t \\ \theta P(t-\tau) + \int_0^{t-\tau} 2(1-x) \cdot dx & \text{if } \tau < t \end{cases} \quad (10)$$

Base on power series theorem, then  $e^{-\lambda t}$  value can be approached with  $e^{-\lambda t} = 1 - \lambda t + \frac{(\lambda t)^2}{2!}$ .

Then number damaged item product per cycle is :

$$\begin{aligned} N_d &= (\theta P + 2P) \left\{ t + \frac{1}{\lambda} \left( 1 - \lambda t + \frac{(\lambda t)^2}{2!} e^{-\lambda t} - 1 \right) \right\} + P \left\{ t^2 + \frac{2\lambda t}{\lambda^2} + \frac{2(1 - \lambda t + \frac{(\lambda t)^2}{2!} - 1)}{\lambda^2} \right\} \\ &= (\theta P + 2P) \frac{\lambda t}{2} + P - 2t^2 \\ &= \frac{\lambda}{2} (\theta + 2) P t + 2P t^2 \end{aligned} \quad (11)$$

In order to obtained in lot size ( $Q$ ), then  $t$  variable  $t$  change became :

$$t = \frac{Q}{P} \rightarrow P t = Q \quad (12)$$

Then be obtained number damaged item per items is :

$$N_d = \frac{\lambda}{2} (\theta + 2) P t + 2P t^2 \quad (13)$$

Damaged product in one year is number of damaged product per cycle ( $N_d$ ) multiplied with number cycle (frequency) in one year ( $f$ ).

$$\begin{aligned} (N_d)_{year} &= Q \left\{ \frac{\lambda}{2} (\theta + 2) P t + 2P t^2 \right\} \times \frac{D}{Q} \\ &= \left\{ \frac{\lambda P (\theta + 2) + 4Q}{2P} \right\} D \end{aligned} \quad (14)$$

In consequence damaged item product cost in this inventory system can be written as:

$$O_d = c_d \left\{ \frac{\lambda P (\theta + 2) + 4Q}{2P} \right\} D \quad (15)$$

5. Crashing Cost ( $O_c$ )

Crashing cost is cost out came per time unit for shorted lead time product coming, product crashing from normal duration and minimum duration component of lead time process from supplier. Crashing done for accelerate product order arrival from supplier. Arrival time from product have different component of lead time. Where :

$$L_i = L_{\max} - \sum_{j=1}^i (b_j - a_j)$$

$L_i$  =long of lead time each component 1, 2, ...,  $i$  and calculate

$R(L)$  given as  $L_i < L \leq L_{i-1}$

$$\text{Then, } R(L) = c_i (L_{i-1} - L) + \sum_{j=1}^i c_j (b_j - a_j)$$

(16)

Then to calculated crashing cost ( $O_c$ ) is demand devided lot size ( $q_o$ ) , then multiplied with R to L in  $R(L)$  function.

$$O_c = \frac{D}{q_o} R(L) \tag{17}$$

**4. SOLUTION MODEL**

To obtain decision variable Q optimal and r done with use optimization concepts. Optimization used to find first derivative from total cost ( $T_c$ ) with lot size (Q). Where

$$\begin{aligned} N &= \int_r^{\infty} (z - r) \cdot f(z) \cdot dz \\ &= S_L [f(z_\alpha) - z_\alpha \psi(z_\alpha)] \end{aligned} \tag{18}$$

Then to find  $\alpha$  , can be obtained is :

$$\alpha = \frac{H \cdot Q_o}{c_d D} \tag{19}$$

Decision variable in this paper are optimal lot size (Q), reorder point (r) and safety stocks (ss). To find each decision variable can be written :

$$1. \quad Q^* = \sqrt{\frac{2P(A + \pi S_L [f(z_\alpha) - z_\alpha \psi(z_\alpha)] + R(L))}{D\{HP + 4c_d D\}}} \tag{20}$$

$$2. \quad r^* = DL + z_\alpha S_L \tag{21}$$

$$3. \quad ss = z_\alpha S_L \tag{22}$$

**5. NUMERICAL EXAMPLE**

To illustrate the present model, the following examples are considered. The problem to be solved for damaged item product. In table 2 explained parameter used in mathematical model to solve decision variable.

Table 2: Parameter

Parameter	Unit	Quantity
D	Unit/year	10000
S	Unit/week	2000
H	IDR/unit/year	100000

A	IDR/order	1000000
$C_d$	IDR/unit/year	50000
$\pi$	IDR/unit	100000
$\alpha$	5%	1
$Z_\alpha$		0.05
$\theta$	%	1.65
$f_{z\alpha}$		0.1023
$\Psi_{z\alpha}$		0.0206
P		100000

Parameters are already known then included into mathematical model to solve problem, where to find decision variable. Another total inventory cost, decision variable in this inventory model are lot size (Q), reorder point (r) and safety stock (ss).

Table 3: Calculating Inventory Total Cost

i	Li	R(L)	r	ss	Q	OT
0	6	0	2275	1121	2029	223251019
1	4	5.6	1684	915	1840	192890901
2	2	22.4	1032	647	1594	153504749
3	1	57.4	650	458	1420	125830246

From calculating above then can be have decision that lead time needed is one week get minimum inventory total cost. Then having result optimal inventory policy.

## 6. DECISION

Inventory problem discussed in this paper is inventory problem in real world case, especially in high tech industries having variable lead time. The numerical example were shown to evidence the usefulness of the proposed model to find minimum total inventory cost and decision variable. Then inventory in this paper have assumption not use back order or lost sale in calculating inventory total cost. So future reach can be development inventory total cost with calculating shortage cost into model with variable lead time and calculating shortage cost into model with variable lead time for lost sale case.

## REFERENCES

- [1] Chang, C., T. "An efficient linearization approach for mixed-integer problems". *European Journal of Operational Research* 123 (2000) 652-659.
- [2] Chang, C., T. "A modified goal programming model for piecewise linear functions". *European Journal of Operational Research* 139 (2002) 62-67.
- [3] Chang, C., T. 2005. "A linearization approach for inventory models with variable lead time". *International Journal of Production Economics* 96 (2005) 263-272.
- [4] Chang, C.T. "A seasonal demand inventory with variable lead time and resource constraints". *European Journal of Operational Research* 31 (2007) 2433-2445.
- [5] Chang and Dye, S.Y. "An EOQ Model for deteriorating with time varying and partial backlogging". *The Journal of the operational research society* vol 50, no 11. Pp. 1176 - 1182, 2007.
- [6] Hadley, G., Within, T.M (1963), *Analysis of Inventory Systems*, Prentice Hall, Inc., Englewood Clift, N.J
- [7] Nur Bahagia, Senator, *Sistem Inventori*, Penerbit ITB, 2006.
- [8] Shah H., Mehta, J. Niketa. "An Inventory model for deteriorating items with exponentially increasing demand and shortages under inflation and time discounting. *Investigacao Operational*. 23 (2003) 103-111.
- [9] Sutopo. "On a stochastic inventory model for deteriorating commodity under stock dependent selling rate", 2008, *Proceeding APIEMs*.
- [10] Tarun et al. 2009. "An EOQ model for perishable items with power demand and partial backlogging". *IJQM*. Volume 15, number 1. 2009. pp 65-72.

# Fuzzy Lead Time Application to Material Requirement Planning Piano UP B1 PE

Nunung Nurhasanah<sup>a</sup>, Mubarakhatun Khoeriyah<sup>b</sup>

<sup>a,b</sup>Faculty of Science and Technology  
 University of Al Azhar Indonesia, Jakarta 12110  
 Tel : (021) 727 92753 ext 5003. Fax : (021) 724 4767  
 E-mail : nunungnurhasanah@uai.ac.id

## ABSTRACT

All the manufacturers are always tries to fulfill fluctuating and uncertain market demand in satisfy the customer needs. PT. XYZ is a music equipment manufacturing, especially piano. Over the last 2 years piano type UP B1 PE has the highest sales.

This research aims to estimate the length of lead time an optimal ordering of raw materials and raw materials requirement planning for next 5 months. Estimated lead time of ordering raw materials made using two methods, namely fuzzy techniques and Monte Carlo simulations. Both methods will then be compared using statistical techniques two side independent test using a significance level of 0.05 to determine the shortest lead time of ordering raw materials. To plan the requirement of raw materials use techniques of material requirements planning (MRP) because this method can be implemented in the company.

The results showed that the lead time of ordering raw materials using fuzzy techniques is smaller than the Monte Carlo simulation. To plan raw material piano UP B1 PE companies must begin planning on 6 November 2010 are for a component Treble Bridge. While the raw materials requirements planning piano UP B1 PE will end on June 23, 2011 as many as 26 types of components

## Keywords

*Lead time, material requirement planning, order, fuzzy, simulation*

## 1. INTRODUCTION

All manufacturers always try to fulfill fluctuating and uncertain market demand accurately according to customer needs. With a good material requirement planning, the company can make the process of production according to customer demands. PT. XYZ an industry in the field of manufacturing of pianos. There are two types of pianos is produced by this company which are Grand type and UP Right type. Based on the historical data, known that the number of piano UP Right types has a higher rate of sales than Grand piano type. We choose B1 PE for the highest sales of piano UP right type.

In material requirement planning estimated delivery times of raw materials from suppliers who has planned is often does not match with the actual time that have set. There are several ways that can be used for estimate the lead time of ordering raw materials, 2 of them using fuzzy techniques and Monte Carlo Simulation. The problems occur at this time in the PT. XYZ is company do not have a good method for their material requirement planning. PT. XYZ do not apply a special method in planning of raw materials, currently company only calculate it manually. Planning done by setting the amount of production during a few period for be used as reference in planning ordering raw materials for the next period.

Based on background, the problem can be formulated as follows:

1. Which most method appropriate for determining the estimate lead time of ordering raw materials piano UP B1 PE using fuzzy technique or Monte Carlo Simulation?
2. How the sequence of raw materials requirements planning appropriate to piano UP B1 PE?

The objectives to be achieved in this research are:

1. Estimating the optimal lead order of arrival raw material piano UP B1 PE on time so that piano production process can went well.
2. Plan right number and the time needs for raw materials for piano UP B1 PE in order to fulfill the production targets that have been set.

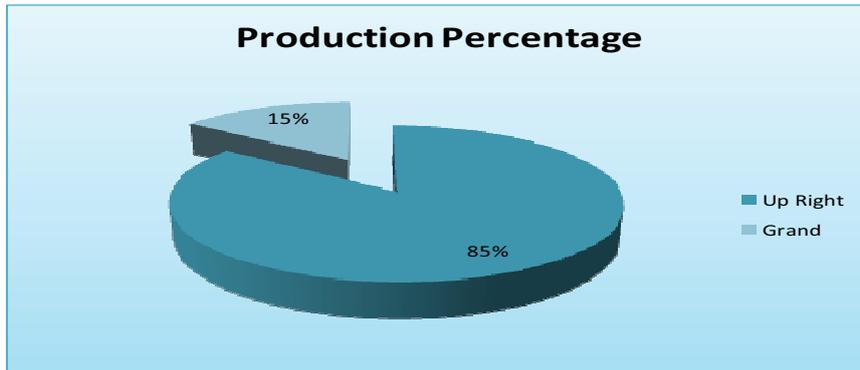


Figure 1 : Production Percentage of PT. XYZ

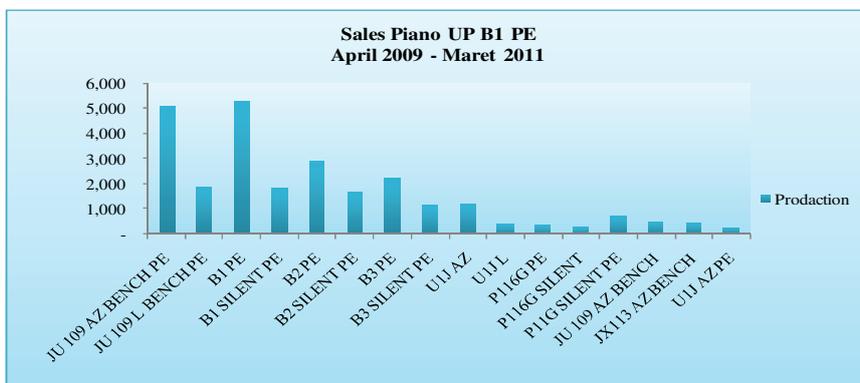


Figure 2 : Graph of Total Sales Up Right Piano Period April 2009 to March 2011

## 2. LITERATURE REVIEW

Earlier studies were can be used as a source of literature conducted by [1] with title Application of Fuzzy Lead Time to a Material Requirement Planning System. Discussion of this research is the application of fuzzy techniques for estimating the lead time of ordering in material requirements planning. Estimated lead time ordering using fuzzy techniques will be compared with Monte Carlo simulation. Monte Carlo simulations created using a random number between 1 to 10.000 for 20 independent samples. To compare both methods used 2-way ANOVA statistical techniques. The results showed the fuzzy technique has the raw material ordering lead time is shorter compared to the Monte Carlo simulations

## 3. RESEARCH METODOLOGY

Estimating lead time is conducted to determine lead time optimal to be used for planning ordering raw material piano UP B1 PE. Estimating lead time done in 2 ways with fuzzy technique and Monte Carlo simulations. Both methods will be tested with statistical technique to choose the best method in estimating a lead time of ordering raw material B1 piano UP PE.

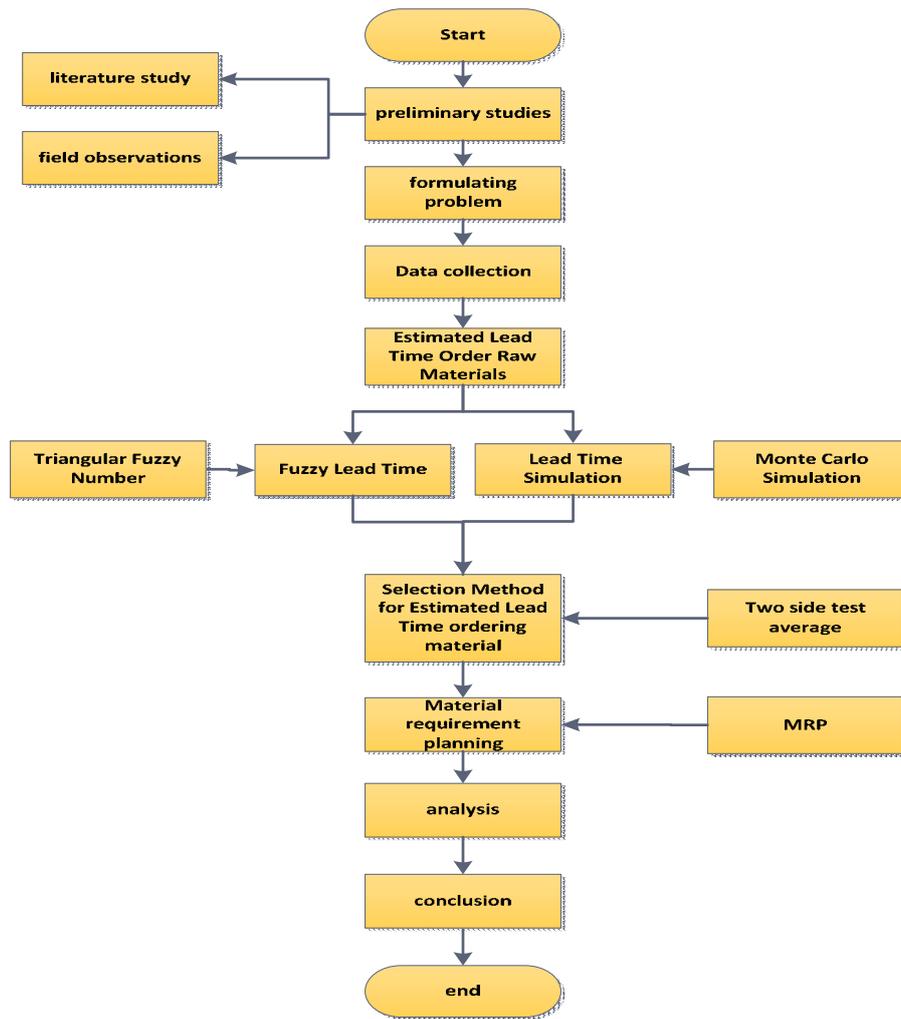


Figure 3 : Research Flowchart

Membership functions used in this research is triangle function (triangular fuzzy number). The steps in estimating a lead time of ordering raw materials consists of two processes that is fuzzyfication and defuzzyfication. [2]

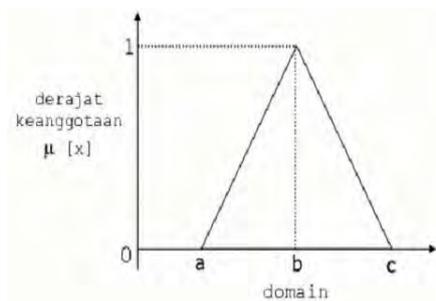


Figure 4 : Triangular function

To choose the best method between fuzzy techniques and Monte Carlo simulations in estimating lead time ordering raw materials used testing two hypotheses concerning two independent averages. From this statistical test is selected the average amount of lead time smallest.

The results of the plot pattern data used to determine the appropriate forecasting methods to forecast demand for the next 5 months. Piano sales forecasting UP B1 PE is calculated based on sales data last 24 periods. To forecast the demand piano UP

B1 PE comparison is done three forecasting methods. Forecasting methods used to forecast sales of pianos UP B1 PE in this research are a double moving average (3 monthly, 4 monthly, and 6 months), double exponential smoothing (using an alpha value of 0,1 to 0,9), and the naive method. To test accuracy of forecasting techniques are used MAPE (mean absolute percentage). The results MAPE smallest among forecasting method will be selected to forecast sales of pianos UP B1 PE.

#### 4. RESULT AND DISCUSSION

Fuzzification process can be seen in table 2. Domain fuzzy set is consists of three values represented by the triangular fuzzy number. Linguistic language used are:

- Fast (F). Fast interpreted orders component pedal rail iron up to fast with fuzzy variables 19, 19, 39.5 in units of days
- Medium (M). Medium interpreted orders component pedal rail iron up to Medium with fuzzy variables 19, 39.5, 49 in units of days
- Slow (S). Slow interpreted orders component pedal rail iron up to slow with fuzzy variables 39.5, 49, 49 in units of days

Table 1: Determination of the variable and the Universe Discussion Ordering Component Pedal Rail Iron

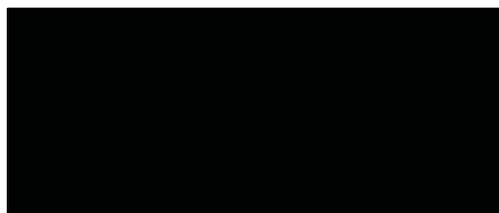


Table 2: Fuzzyfication Lead Time Oder Component Pedal Rail Iron

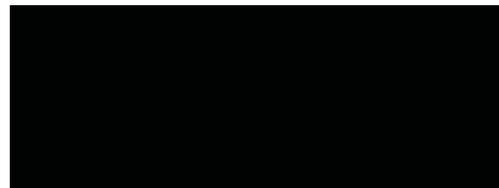
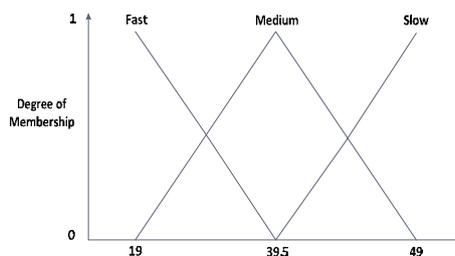



Figure 5: TFN Curve Representation Lead Time Order Components Pedal Rail Iron

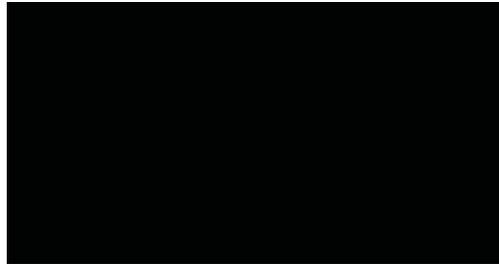
Based on table 3 both experts are equally say fast, so defuzzification lead time order Components Pedal Rail Iron as:

Table 3: Expert opinion, Average Geometry and Crisp Value Components Pedal Iron rail



The basis of the Monte Carlo simulation is the experimental probability distribution using random numbers. Column order is defined as a period of raw material orders. On column LT defined as lead time actual delivery orders period n with the actual number of actual delivery orders (SUM). Cumulative column is cumulative probability ordering. Column interval is the limit number representing the probability of each result. Determination of the interval based on cumulative probability. Here are the results of Monte Carlo simulations for the components Pedal Rail Iron:

Table 4: Probability Distributions and Cumulative Probability Distribution



Tabel 5: Recap Replication Monte Carlo Simulation

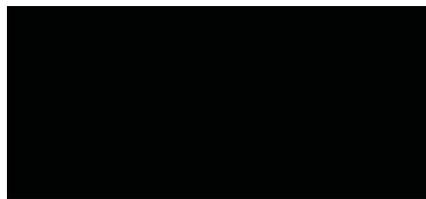
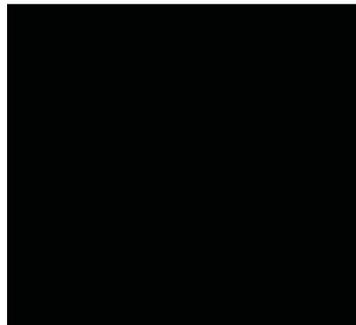


Table 6: Monte Carlo Simulation Component Pedal Rail Iron



For selection estimation method of lead time ordering raw material piano UP B1 PE used statistical techniques two side independent test average. The purpose of this test is to determine the smallest estimate of lead time. The company wants raw materials can come fast. Here is two side independent test average:

Hypothesis:

$$H_0 : \mu_1 = \mu_2$$

$$H_1 : \mu_1 > \mu_2$$

As  $Z > Z_{0,05}$ , then Z is in the region of rejection so the decision  $H_0$  is rejected. Based on these decisions can be interpreted that estimated average lead time ordering raw materials using fuzzy techniques is smaller than using Monte Carlo simulations

Plot of sales data shown in Figure. 6. Based on a plot of data patterns on Figure 6 data in the period September 2009, November 2009 and December 2009 had an abnormal data patterns. A third data is removed then created a new plot of data patterns, shown in Figure 7. Based on table 8 forecasting methods has the smallest MAPE is double moving average 3 (DMA 3), and it will be selected in this research.

Lead time is result of fuzzy techniques for ordering the components Pedal Iron Rail is 24 days. Amount required to make 1 unit of the piano is as much as 2 units. Based on the inventory records that have been described, requirement planning component Pedal Rail iron are as:

Table 9: Recap MRP



#### 4. CONCLUSION

1. Using a statistical technique two side independent test using significant level 0,05 z test statistic value of 5.83 and 1.645 for the z value table. Z value obtained test statistic is greater than the value of the z table, based on hypotheses which have made can be concluded that the optimal method for estimating the lead time of ordering raw materials piano type B1 UP PE is a fuzzy technique.
2. The method used for material requirement planning for pianos UP B1 PE is MRP technique. To plan material requirement planning pianos UP B1 PE companies must begin on 6 November 2010 for component Treble Bridge. Material requirement planning pianos UP B1 PE will be end on 23 June 2011 as many as 26 types of component

#### ACKNOWLEDGMENT

Authors would like to thank you to LP2M UAI that given a chance to publish author's article on this seminar by International Seminar Grant 2012.

#### REFERENCES

- [1] Moghaddam. R. Tavakoli. Dkk. "Application of Fuzzy Lead Time to a Material Requirement Planning System" (<http://www.wseas.us/e-library/conferences/2007vancouver/papers/558-154.pdf>) (accessed 12 March 2011).
- [2] Kusumadewi, Sri. 2002. Analisis Desain Sistem fuzzy menggunakan Tool Box Matlab. Graha Ilmu. Yogyakarta.
- [3] Marimin. 2004. Teknik dan Aplikasi Pengambilan Keputusan Kriteria Majemuk. Gramedia Widiasarana Indonesia. Jakarta.
- [4] Markidarkis, Spyros. dkk. 1993. Metode dan Aplikasi Peramalan. Erlangga : Jakarta

## Integrated Inventory Model under Lot-Streaming Delivery Policy using Vendor-Managed Inventory

Docki Saraswati<sup>a</sup>, Andi Cakravastia<sup>b</sup>, Bermawi P. Iskandar<sup>b</sup>, A. Hakim Halim<sup>b</sup>

<sup>a</sup>Production System Laboratory  
Department of Industrial Engineering  
Faculty of Industrial Technology  
Universitas Trisakti, Jakarta 11440  
Tel : +6221 5663232 ext 8407. Fax : +6221 5605841  
E-mail : docki@trisakti.ac.id

<sup>b</sup>Department of Industrial Engineering  
Faculty of Industrial Technology  
Institut Teknologi Bandung, Bandung 40132  
Tel : +6222 2504551. Fax : +6222 2504552  
E-mail : andi@mail.ti.itb.ac.id, bermawi@lspitb.org, ahakimhalim@lspitb.org

### ABSTRACT

This paper primarily investigates the single-manufacturer and single-buyer integration tool under deterministic environment. At the manufacturer, each product is produced with the constant rate, while at the buyer each product has a deterministic and constant demand. It is assumed that the manufacturer has sufficient capacity to meet the buyer's demand. Vendor-Managed Inventory (VMI) is an integration tool where manufacturer is authorized to manage the buyer's inventory stock-keeping units. This approach integrates the inventory cost between the manufacturer and the buyer through information sharing. Using EDI or internet, buyer is able to share the inventory information with manufacturer on a real-time basis. Manufacturer can then use this information to manage the inventory level at the buyer's facility. Using lot-streaming delivery policy the manufacturer delivers the product to the buyer during the production run and as soon as the quantity is equal to the batch size. This study shows that under a certain circumstances, information sharing for integrating inventory policy between manufacturer and buyer with VMI is more beneficial compare to the system without VMI. Therefore, an algorithm is developed to obtain the optimal strategy and numerical examples are presented to demonstrate the results of the integrated inventory model using VMI.

### Keywords:

*Single-manufacturer and single-buyer, information sharing, lot-streaming delivery policy, vendor-managed inventory.*

### 1. INTRODUCTION

The global economic crisis has caused a great burden in company's performance. This is an inevitable reality, for the companies producing complex products such as motor vehicle, heavy equipments, jig and fixtures, and electronics. To overcome the global crisis successfully, a competitive production which integrates between manufacturer and buyer has encourage both parties to optimize the system-wide performance. Moreover, the increasing relationship between manufacturer and buyer has challenged these companies to make synergies through the integration of various decision processes [1]. Minimizing the integrated inventory cost is one of the alternative solutions in increasing profit to both parties involves in the production systems network.

Vendor Managed Inventory (VMI) is an integration tool where manufacturer is authorized to manage the buyer's inventory. Reference [2] studied the benefits of VMI in an integrated inventory system for the short-term and long-term period. Specifically, VMI always provide greater benefits to buyers, whereas profits at the manufacturer may vary. For manufacturers, VMI with a long-term relationship will provide higher returns than the short-term. Meanwhile, study on comparison between the traditional approach and the VMI's approach in the integrated inventory system has been carried out by [3]. Conclusion of these two approaches is shown that for the dynamic demand is significantly more benefits provided by the integrated inventory system using VMI. The cost saving with the system using VMI is depended on the problem parameters. The ratio of the order cost of the supplier to the buyer as well as the ratio of the carrying cost of the supplier to the buyer will affect the value of saving cost [4]. According to [5] VMI enables to replenish decision making by the manufacturer. In this case the manufacturer makes delivery to the buyer based on buyer's inventory level. Hence the buyer inventory level observed continuously by the manufacturer. Therefore the buyer doesn't need to place an order. Reference [6] has proposed two delivery policies from the manufacturer to the buyer, i.e. 1) when deliveries are made after the production run, and 2) when deliveries are executed during the production run, as soon as the quantity is equal to the batch size, namely lot-streaming delivery policy.

This paper is divided into five sections. Section 2 addresses the assumptions and notations. Mathematical model of joint total cost with VMI is given in section 3. In section 4, a procedure is developed to determine the position of the continuation of the relationship between manufacturer and buyer using VMI. A numerical example is provided in section 5. Finally, some conclusions are given in section 6.

## 2. ASSUMPTIONS AND NOTATIONS

The model studied involves a single manufacturer that produces a single product at a production site and delivered it to a single buyer. Both the manufacturer and the buyer is a company engaged in the automotive industry. Demand from buyer is known and constant. One product buyer needs one unit of product manufacturer. According to the negotiation process, the manufacturer and the buyer has agreed to collaborate in the long-term contract as teamwork. The other assumptions are as follows; 1) no quantity discount is applied, 2) no backordered is allowed, 3) manufacturer and buyer are two companies that are not interdependent, and 4) manufacturer's production rate is constant and greater than the demand's rate. The following notations are used:

Parameter:

$D$	: demand rate for the buyer
$P$	: production rate for the manufacturer
$S$	: setup cost (\$/setup)
$A_p$	: cost of issuing an order (Rp./order)
$A_r$	: cost of receiving an order (Rp./order)
$A$	: buyer's total ordering cost (Rp./order), for $A = A_p + A_r$
$r$	: fraction of holding cost (%/period)
$C_b$	: unit purchase price at the manufacturer's (Rp./unit)
$C_w$	: unit holding cost in inventory at buyer's (Rp./unit/period)
$h_b$	: carrying cost of one unit in inventory at buyer's site (Rp./unit/period), for $h_b = rC_b + rC_w$
$C_v$	: unit holding cost in inventory at manufacturer's (Rp./unit/period)
$h_v$	: carrying cost of one unit in inventory at manufacturer's site (Rp./unit/period), for $h_v = rC_v$
$F_v$	: transportation cost (Rp./trip)

Decision variables:

$z_1^*$	: optimal ordering lot size without VMI (unit)
$z_2^*$	: optimal ordering lot size with VMI (unit)
$Q_v$	: production lot size at manufacturer (unit)
$n$	: number of deliveries per cycle

Objective function:

$TC_{b1}$	: buyer's total cost without VMI (Rp.)
$TC_{b2}$	: buyer's total cost with VMI (Rp.)
$TC_{v1}$	: manufacturer's total cost without VMI (Rp.)
$TC_{v2}$	: manufacturer's total cost with VMI (Rp.)

## 3. MATHEMATICAL MODELING

The relationship between manufacturer and buyer begins with the ordering of products at economic lot size,  $z_1$ , from the buyer to the manufacturer. Manufacturer makes deliveries on demand buyer. At the moment buyer received the product, the manufacturer gave the bill to the buyer for payment, and the product becomes the property of buyer. Finally, the products sold by the buyer to the end-user. For buyer, the total inventory cost per period is the sum of ordering cost  $((D/z_1)A)$  plus holding

cost  $((z_1/2)h_b)$ , where  $A = A_p + A_r$  and  $h_b = rC_b + rC_w$ . The buyer's total inventory cost equation can be written as follows:

$$TC_{b1}(z_1) = (D/z_1)(A_p + A_r) + (z_1/2)(rC_b + rC_w) \quad (1)$$

Equating the first derivative of (1) with regard to  $z_1$  to zero and solving the equation, the buyer's economic lot size is given by

$$z_1^* = \sqrt{(2(A_p + A_r)D)/(rC_b + rC_w)} \quad \text{or} \quad z_1^* = \sqrt{2AD/h_b} \quad (2)$$

Substituting (2) into (1), the optimal buyer's total inventory cost is

$$TC_{b1}(z_1^*) = \sqrt{2DAh_b} \quad (3)$$

This paper assumes that the manufacturer have known the quantity and the number of ordering from buyer, because of the information sharing. Thus it can be assumed that the manufacturer will begin production when the inventory level of buyer at the level of  $z_1$ . During the production period,  $T_p = Q_v/P$ , manufacturer produces at the rate of P. Therefore, the total inventory system increases at the rate of  $P - D$ . Manufacturer can still make the deliveries even if the production period has not been completed. Shipping is done if the lot size deliveries have been met, known as lot-streaming delivery policy. Although, the period of production has been completed, manufacturer still make the delivery to buyer until there are no more items in inventory of manufacturer. The manufacturer does not produce any product in the period of  $((Q_v/D) - (Q_v/P))$ . Inventory cycle time for the manufacturer is  $T = Q_v/D$ . The total accumulated inventory in manufacturer is  $(Q_v/2n)((2-n)D/P + n - 1)$ . The average inventory level for manufacturer is  $(Q_v/2n)((2-n)D/P + n - 1) + z_1/2$ , while the average inventory level for buyer is  $z_1/2$ . Finally, the average inventory level for system-wide is  $(Q_v/2n)((2-n)D/P + n - 1) + z_1$  [5]. The manufacturer's total cost is composed of setup cost, holding cost, shipment release cost and transportation cost. Therefore, the equation is given by

$$TC_{v1} = \frac{D}{Q_v}S + \frac{Q_v}{2n} \left( (2-n)\frac{D}{P} + n - 1 \right) h_v + \frac{z_1}{2} h_v + \frac{D}{z_1} F_v \quad (4)$$

Equation (4) is consisted of controllable and uncontrollable variables. The controllable variables are setup cost and holding cost, whereas the uncontrollable variable is determined by buyer, as a function of  $(z_1)$ . If equation (3) is substituted into equation (4), and  $Y = (D/Q_v)S + (Q_v/2n)((2-n)(D/P) + n - 1)h_v$ ,  $\gamma = F_v/A$ , and  $\phi = h_v/h_b$ , then equation (4) becomes

$$TC_{v1} = Y + (\gamma + \phi) \sqrt{\frac{DAh_b}{2}} \quad (5)$$

In this case manufacturer tend to change the uncontrolled variables become the control variables through collaboration with buyer by proposing vendor managed inventory (VMI) approach. According to VMI the buyer's ordering cost ( $A_p$ ) becomes the manufacturer's cost. Since the ordering cost is done by the manufacturer, the ordering cost becomes more efficient, with an efficient factor  $(1 - \alpha)$  for  $0 < \alpha < 1$  and it gives  $\alpha A_p$  as the manufacturer's cost. The manufacturer's total cost with VMI is given by

$$TC_{v2} = \frac{D}{Q_v}S + \frac{Q_v}{2n} \left( (2-n)\frac{D}{P} + n - 1 \right) h_v + \frac{D}{z_2} \alpha A_p + \frac{z_2}{2} h_v + \frac{D}{z_2} F_v \quad (6)$$

The first partial derivatives of equation (6) to  $z_2$ , yielding

$$z_2^* = \sqrt{(2D(F_v + \alpha A_p))/h_v} \quad (7)$$

Letting  $\lambda_1 = A_p/A$  and  $\lambda_2 = A_r/A$ , with  $\lambda_1 + \lambda_2 = 1$ , the lot size equation (7) can be written as follows

$$z_2^* = \sqrt{(\gamma + \alpha\lambda_1/\phi)}\sqrt{2AD/h_b} \quad (8)$$

By substituting equation (8) into equation (6), it will simplify the manufacturer's total cost by

$$TC_{v2} = Y + \sqrt{\phi(\gamma + \alpha\lambda_1)}TC_{b1} \quad \text{or} \quad TC_{v2} = Y + \sqrt{\phi(\gamma + \alpha\lambda_1)}\sqrt{2DAh_b} \quad (9)$$

Therefore, the manufacturer will implement VMI if  $TC_{v2} < TC_{v1}$  with saving cost  $\Delta TC_{v1-2} > 0$  for  $\Delta TC_{v1-2} = TC_{v1} - TC_{v2}$ .

**Proposition 1:**  $TC_{v2} < TC_{v1}$ , if  $(\gamma + \phi) > 2\sqrt{\phi(\gamma + \alpha\lambda_1)}$

**Proof:**  $TC_{v1} = Y + (\gamma + \phi)\sqrt{\frac{DAh_b}{2}}$  or  $TC_{v1} = Y + \sqrt{2DAh_b} \frac{(\gamma + \phi)}{2}$ , and

$$TC_{v2} = Y + \sqrt{2DAh_b} \sqrt{\phi(\gamma + \alpha\lambda_1)}. \quad TC_{v1} - TC_{v2} > 0 \text{ for } \sqrt{2DAh_b} > 0;$$

subsequently  $\sqrt{2DAh_b} \frac{(\gamma + \phi)}{2} > \sqrt{2DAh_b} \sqrt{\phi(\gamma + \alpha\lambda_1)} \rightarrow (\gamma + \phi) > 2\sqrt{\phi(\gamma + \alpha\lambda_1)}$ .

For buyer, the cost of issuing an order ( $A_p$ ) is removed to manufacturer's cost. Therefore, the buyer's total cost with VMI is given by

$$TC_{b2} = \sqrt{\frac{DAh_b}{2}} \left( \frac{(1 - \lambda_1)\phi + (\gamma + \alpha\lambda_1)}{\sqrt{(\gamma + \alpha\lambda_1)\phi}} \right) \quad (10)$$

Similarly, buyer will accept the proposal from manufacturer for implementing VMI, if  $TC_{b2} < TC_{b1}$  with saving cost  $\Delta TC_{b1-2} > 0$  for  $\Delta TC_{b1-2} = TC_{b1} - TC_{b2}$ .

**Proposition 2:**  $TC_{b2} < TC_{b1}$ , if  $(1 - \lambda_1)\phi + (\gamma + \alpha\lambda_1) < 2\sqrt{(\gamma + \alpha\lambda_1)\phi}$

**Proof:**  $\Delta TC_{b1-2} = TC_{b1} - TC_{b2} > 0$

$$\sqrt{2DAh_b} - \sqrt{\frac{DAh_b}{2}} \left( \frac{(1 - \lambda_1)\phi + (\gamma + \alpha\lambda_1)}{\sqrt{(\gamma + \alpha\lambda_1)\phi}} \right) > 0 \quad \text{or} \quad 2 - \left( \frac{(1 - \lambda_1)\phi + (\gamma + \alpha\lambda_1)}{\sqrt{(\gamma + \alpha\lambda_1)\phi}} \right) > 0$$

subsequently  $(1 - \lambda_1)\phi + (\gamma + \alpha\lambda_1) < 2\sqrt{(\gamma + \alpha\lambda_1)\phi}$ .

Therefore, the saving cost for system wide is given by the joint total cost between manufacturer's cost and buyer's cost, for  $TC_{v2} + TC_{b2} < TC_{v1} + TC_{b1}$  and  $\Delta TC_{s1-2} = (TC_{v1} + TC_{b1}) - (TC_{v2} + TC_{b2}) > 0$ .

**Proposition 3:**  $TC_{v2} + TC_{b2} < TC_{v1} + TC_{b1}$ , if

$$(\gamma + \alpha\lambda_1)(2\phi + 1) + (1 - \lambda_1)\phi < (\gamma + \phi + 2)\sqrt{(\gamma + \alpha\lambda_1)\phi}$$

**Proof:**  $\Delta TC_{s1-2} = (TC_{v1} + TC_{b1}) - (TC_{v2} + TC_{b2}) > 0$

$$TC_{v1} = Y + (\gamma + \phi)\sqrt{\frac{DAh_b}{2}} \quad \text{and} \quad TC_{v2} = Y + 2\sqrt{\frac{DAh_b}{2}}\sqrt{\phi(\gamma + \alpha\lambda_1)}$$

$$TC_{b1} = 2\sqrt{\frac{DAh_b}{2}} \text{ and } TC_{b2} = \sqrt{\frac{DAh_b}{2}} \left( \frac{(1-\lambda_1)\phi + (\gamma + \alpha\lambda_1)}{\sqrt{(\gamma + \alpha\lambda_1)\phi}} \right)$$

$$\Delta TC_{s1-2} = \sqrt{\frac{DAh_b}{2}} \left( (\gamma + \phi + 2) - \left( \left( \frac{2(\gamma + \alpha\lambda_1)\phi}{\sqrt{(\gamma + \alpha\lambda_1)\phi}} \right) + \left( \frac{(1-\lambda_1)\phi + (\gamma + \alpha\lambda_1)}{\sqrt{(\gamma + \alpha\lambda_1)\phi}} \right) \right) \right)$$

$$2(\gamma + \alpha\lambda_1)\phi + (1-\lambda_1)\phi + (\gamma + \alpha\lambda_1) < (\gamma + \phi + 2)\sqrt{(\gamma + \alpha\lambda_1)\phi}$$

$$(\gamma + \alpha\lambda_1)(2\phi + 1) + (1-\lambda_1)\phi < (\gamma + \phi + 2)\sqrt{(\gamma + \alpha\lambda_1)\phi}.$$

#### 4. SOLUTION PROCEDURE

The following procedure is developed to determine the position of the continuation of the relationship between manufacturer and buyer using VMI. Algorithm 1:

- Step 1 Calculate the value of  $\gamma = F_v/A$ ,  $\lambda_1 = A_p/A$ , and  $\phi = h_v/h_b$ .
- Step 2 Substituting the value of  $\gamma$ ,  $\lambda_1$ , and  $\phi$  into Proposition 3.
- Step 3 Examining Proposition 3, whether it meets the criteria?  
If YES, then go to step 4, otherwise go to step 9.
- Step 4 Substituting the value of  $\gamma$ ,  $\lambda_1$ , and  $\phi$  into Proposition 1
- Step 5 Examining Proposition 1, whether it meets the criteria?  
If YES, then go to step 6, otherwise go to step 5a.
- Step 5a Is the manufacturer intends to evaluate the manufacturer's total inventory cost?  
If YES, then go to step 5b, otherwise go to step 9.
- Step 5b Do improvements to the constraints that affect the manufacturer's total inventory cost, then go to step 4.
- Step 6 Substituting the value of  $\gamma$ ,  $\lambda_1$ , and  $\phi$  into Proposition 2.
- Step 7 Examining Proposition 2, whether it meets the criteria?  
If YES, then go to step 8, otherwise go to step 7a.
- Step 7a Is the manufacturer intends to evaluate the buyer's total inventory cost?  
If YES, then go to step 7b, otherwise go to step 9.
- Step 7b Do improvements to the constraints that affect the buyer's total inventory cost, then go to step 6.
- Step 8 Partnership between manufacturer and buyer using VMI is advised to continue.
- Step 9 Partnership between manufacturer and buyer using VMI is advised not to continue.

After learning that the partnership can be continue, the manufacturer determines the optimal delivery lot size, numbers of delivery, manufacturer's total inventory cost, buyer's total inventory cost, and overall system's total inventory cost with the following algorithm. Algorithm 2:

- Step 1 Calculate  $\gamma$ ,  $\phi$ , and  $\lambda_1$ .
- Step 2 Substituting  $\gamma$ ,  $\lambda_1$ , and  $\phi$  into equation (8), to get the optimal ordering lot-size with VMI ( $z_2^*$ ).
- Step 3 Set  $n = 1$ .
- Step 4 Substituting  $n$  and  $z_2^*$  into equation (9), to obtain the manufacturer's total cost ( $TC_{v2}$ ).
- Step 5 Is  $n = 1$ ? If YES, then go to step 5a, otherwise go to step 6.
- Step 5a Set  $n = n + 1$ , then repeat step 4 and step 5, to get the new value of  $TC_{v2}$ .
- Step 6 Is  $TC_{v2}(n) \leq TC_{v2}(n-1)$ ? If YES then go to step 5a, otherwise go to step 7.
- Step 7 Set  $TC_{v2}(n) = TC_{v2}(n-1)$ .
- Step 8 Substituting  $\gamma$ ,  $\lambda_1$ , and  $\phi$  into equation (10), to get the buyer's total cost ( $TC_{b2}$ ).
- Step 9 Calculate  $TC_{v2}(n) + TC_{b2}(n)$  as the total inventory cost for the overall system.

#### 5. NUMERICAL EXAMPLE

In order to illustrate the algorithms described earlier, it considers an inventory system with data as follows: for manufacturer:  $P = 15,000$  (unit/period),  $C_v = 20,000$  (Rp/unit),  $h_v = 2,000$  (Rp/unit/period),  $S = 360,000$  (Rp/setup),  $F_v = 30,000$  (Rp/trip), and  $\alpha = 0.2$ ; for buyer:  $D = 10,000$  (unit/period),  $C_b = 25,000$  (Rp/unit),  $h_b = 3,500$  (Rp/unit/period),  $A = 100,000$

(Rp/order),  $A_p = 10,000$  (Rp/order),  $D_v = 10,500$  (unit/period),  $C_w = 10,000$  (Rp/unit), and  $r = 0.1$ . In this example, the values are fixed for  $\phi = h_v/h_b = 0.571$ ,  $\lambda_1 = A_p/A = 0.1$ , and  $\gamma = F_v/A = 0.3$ . Referring to Eq. (2) and (3), the buyer's economic lot size is  $z_1^* = 756$  units and the buyer's total inventory cost is  $TC_{b1}(z_1^*) = 2,646,000$ . The minimum manufacturer's total inventory cost is obtained at four times delivery with  $TC_{v1}^*(z_1^*, n^* = 4) = 3,603,000$ , and for the system is  $TC_{s1} = TC_{v1}^*(z_1^*, n^* = 4) + TC_{b1}(z_1^*) = 6,249,000$ . It is showned that both parties has different optimal value for the total inventory cost. Therefore, manufacturer would like to offer a contract with buyer using vendor managed inventory (VMI). Before signing the contract, both parties agree to investigate whether the relationship beneficial. For algorithm 1, substituting  $\gamma, \phi$ , and  $\lambda_1$  into Proposition 3, 2, and 1 respectively. The calculation results show that all the criteria are met, hence the relationship between manufacturer and buyer can proceed to VMI. Further by VMI, the manufacturer determines the lot size and the number of deliveries that minimize the total cost of inventory. Using algorithm 2, substituting the value of  $\gamma, \phi$ , and  $\lambda_1$  are 0.3, 0.571, and 0.1 respectively into Eq. (8), to get  $z_2 \approx 566$  unit. Next, set  $n = 1$ , substituting  $z_2$  and  $n$  into Eq. (9), to get  $TC_{v2}(z_2 = 566, n = 1) = 7,869,000$ . Repeat step 4 to 6, until the value of  $TC_{v2}(n)$  is greater than  $TC_{v2}(n - 1)$ .

Finally, the result shows that  $TC_{v2}(z_2 = 566, n = 6) = 3,512,000$ ,  $TC_{b2}(z_2 = 566) = 2,581,000$ , and  $TC_{v2}(z_2 = 566, n = 6) + TC_{b2}(z_2 = 566) = 6,093,000$ . The saving cost for the manufacturer, buyer, and the overall system are shown as follows:

*Table 1: Saving cost for manufacturer, buyer, and overall system.*

	Without VMI	With VMI	Saving cost
Manufacturer	$TC_{v1} = 3,603,000$	$TC_{v2} = 3,512,000$	91,000
Buyer	$TC_{b1} = 2,646,000$	$TC_{b2} = 2,581,000$	65,000
System	$TC_{s1} = 6,249,000$	$TC_{s2} = 6,093,000$	156,000

Table 1 shows that the result for manufacturer and buyer under VMI will gain 2.5% saving cost. Nevertheless, the relationship between both parties has been influenced by the value of  $\gamma, \phi$ , and  $\lambda_1$ . The manufacturer will gain the benefit of the relationship, in the conditions; 1) if  $\gamma < 0.39$  and  $\gamma > 0.78$  (it obtains by using interpolation), 2) if  $\phi > 0.4793$ , for  $\gamma = 0.3$ . It means that the manufacturer's saving cost will increase significantly if the different between manufacturer's and buyer's holding cost becomes larger, and 3) if  $\lambda_1 < 0.2$ , for  $\gamma = 0.3$ .

## 6. CONCLUSION

This study develops the model of [5] by including transportation cost. At the beginning of the relationship between manufacturer and buyer, the lot size and numbers of delivery are determined by the buyer. Thus the manufacturer cannot influence the ordering lot size. Consequently, the manufacturer's total cost is not optimal, since the lot size determination is not based on manufacturing inventory policy. By offering VMI, manufacturer wants to minimize the total inventory cost of all parties, including manufacturer, buyer and the overall system. Numerical results show, by using VMI the relationship between manufacturer and buyer will provide cost savings for both parties, if it meets all the criteria required in propositions 1, 2, and 3.

## REFERENCES

- [1] M. Ben-Daya, M. Darwish, and K. Ertogral, "The joint economic lot sizing problem: Review and extensions," *European Journal of Operational Research*, vol. 185, issue 2, pp. 726-742, March 2008.
- [2] Y. Dong and K. Xu, "A supply chain model of Vendor-Managed Inventory," *Transportation Research Part E*, vol. 38, issue 2, pp. 75-95, April 2002.
- [3] S.M. Disney and D.R. Towill, "The effect of Vendor Managed Inventory (VMI) dynamics on the Bullwhip effect in Supply Chain," *International Journal of Production Economics*, vol. 85, issue 2, pp. 199-215, August 2003.
- [4] Y. Yao, P.T. Evers, and M.E. Dresner, "Supply chain integration in vendor-managed inventory," *Decision Support Systems*, vol. 43, issue 2, pp. 663-674, March 2007.
- [5] M. Gümüş, E.M. Jewkes, and J.H. Bookbinder, "Impact of Consignment Inventory and Vendor-Managed Inventory for a two party Supply Chain," *International Journal of Production Economics*, vol. 113, issue 2, pp. 502-517, June 2008.

- [6] D. Saraswati, A. Cakravastia, B.P. Iskandar, and A.H. Halim, Joint Economic Lot Size models with setup reduction for different delivery policies," *Proceeding of the 9<sup>th</sup> Asia Pacific Industrial Engineering and Management Systems Conference*, Bali, pp. 271-277, Dec. 2008.

## MODEL DEVELOPMENT OF PROJECT COMPLEXITY

**Oktiyanto Ade Saputro<sup>a</sup>, Budi Hartono<sup>b</sup>**

<sup>a</sup>Mechanical and Industrial Engineering Department, Universitas Gadjah Mada  
 Jl. Grafika No.2, Yogyakarta 55281  
 E-mail: oktiyantoades@gmail.com

<sup>b</sup>Mechanical and Industrial Engineering Department, Universitas Gadjah Mada  
 Jl. Grafika No.2, Yogyakarta 55281  
 boed@gadjahmada.ac.id,

### ABSTRACT

Uniqueness and uncertainty in a project is not easy to manage. Ability to manage the uncertainty is needed to minimize the risk. To manage the risk, the company have the project risk management to solve them. But today, the project risk's concept developed into more comprehensive concept, which called project complexity.

This study was more focused on determining the variables of project complexity. Variables obtained from the data taken in construction company and literature study. These variables are used to make the research instruments. Instruments conducted a qualitative pilot study, test reliability and test validity to evaluate the effectiveness of the instrument. To collect the data, the questioner was developed and distributed to 69 project managers in the construction industry. The processing data using exploratory factor analysis's methods to construct the dimension. Subsequently, the result provided was compared by the previous empirical study.

Based on the research process, it can be inferred that there are many improvements in developing the instrument. Validity and reliability produce 12 variables of complexity. While exploratory factor analysis showed that there are four dimensions of uncertainty in goals, uncertainty in methods, size complexity and interdependence. This is consistent with theoretical studies conducted by William.

### Keywords

*Project complexity, variabels, expert judgment, exploratory factor analysis.*

## 1. INTRODUCTION

The project is an important value of any construction company. Managing the project is a must. One of ability to manage the project is manage the risk of the project. The ability to handle and analyze project risks is usually done by the Project Risk Management. Mismanage the risk can lead to anticipate non-profitable projects, even the loss project.

The development and application of project management research shows that the concept of risk profiles have started to develop more widely. The concept of risk developed into a part of a more comprehensive concept, called the concept of project complexity. The concept of risk is the perspective of the value of uncertainty. When that happens the higher the uncertainty, the higher the risk of the project that must be faced, and vice versa. The uncertainty is one of project complexity dimension [1].

Complexity is an important part that can be used in managing a project. Complexity can reflect the characteristics and conditions that may occur in a project. In this case, the research on the complexity of the project has not been done by previous researchers. Testing the empirical models project complexity has been done.

Table 1: Project Complexity Theory

No	Researcher	Size	Uncertainty	Interaction	Diversity
1	Simon (1982) [2]	V		V	
2	Morris and Hough (1978) [3]		V		
3	Jones (1993) [4]		V	V	V
4	Turner and Cochran (1993) [5]		V		
5	Siestman (1994) [6]	V	V	V	
6	Baccarini (1996) [7]	V	V		
7	William (2002) [1]	V	v	V	

Based on Table 1. Project Complexity Theory, William theory is more up to date theory and comprehensive theory because William try to resume the past theory from the past researcher.

The dimension of complexity by William (Willams, 2002):

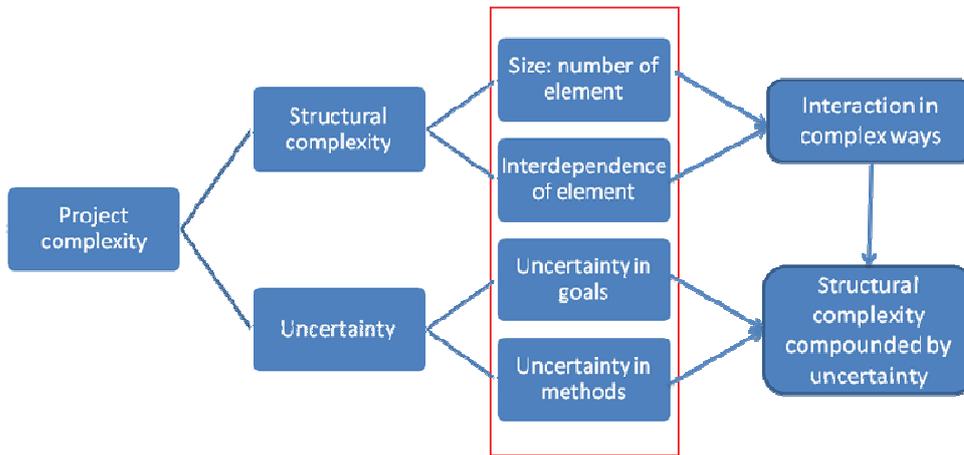


Figure 1: dimension of complexity by william

## 2. METHOD

This research is a part of studies to understand and to develop project complexity as a knowledge in project management. This research try to define the variabls of project complexity for more understanding project management study. In the first step, understanding in past study is an important stage. This research not only depends on past study but also try to generate the number of variabls using interview to national EPC company. Therefore, to represent the variabls of project complexity, this research used project manager in the construction company as respondents. In addition, this research was conducted by empirical approach known as cross-sectional survey with using primary data provided by questionnaire and survey.

The development of instrumental survey were assessed qualitatively, namely face validity and content validity by conducting pilot study. Face validity and content validity are obtained by using the pilot study to six practitioners about their respond on instrument proposed. After that, the instrument was ready to distributed.

Table 2 explains about the response rate, in which there were three methods for distributing questionnaire, namely email (52 questionnaires), survey mail (9 questionnaires) and direct survey (8 questionners). By using three methods are obtained the response rate as much as 50.7%. Hence, the sample size achieved is 35 respondents.

Table 2: Response Rate

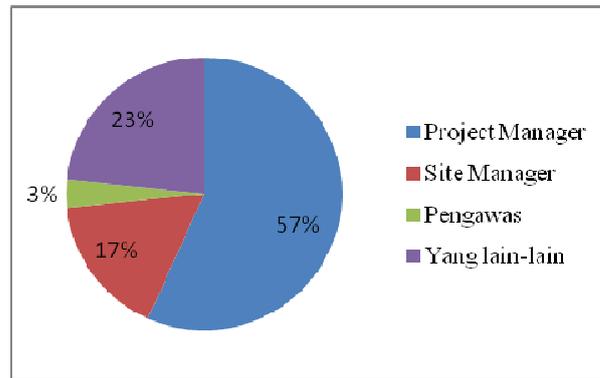
Questionnaire Distributed	Amount	Response Rate
Email	52	50,7%
Survey mail	9	
Direct Survey	8	
TOTAL	69	

## 3. RESULT AND DISCUSSION

Having distributed the quistionner and survey, the questioner was returned into researcher with response rate, for 50.7% (35 respondents) showed on Table 2. However by data cleansing, 5 of 35 data cannot be used because of the lack of experience of respondents. CAPM stated that the project practitioners can be guaranteed as the experience practitioners when they have experience more than three years.

### 3.1 Respondent

Rspndent's proffile can be described by all pie chart



Figures 1. Project respondent

Based on figures 1. Project respondent, most respondents are project managers. As we know that project anagers is a relevance respondent because their knowledge about managing the project.

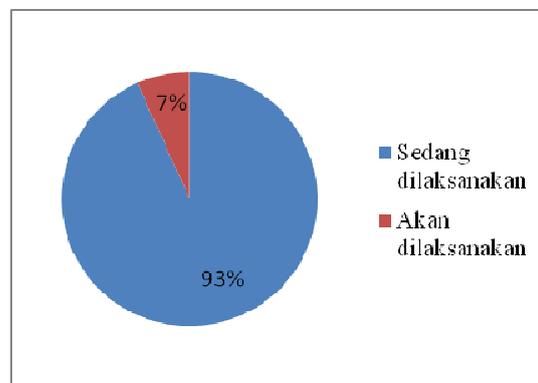


Figure 2. Project statue

Based on figures 2. Project Statue, most project are on going projects. This survey not accomodate past project because we argue that any possibility of over-confidence from project manager perception.

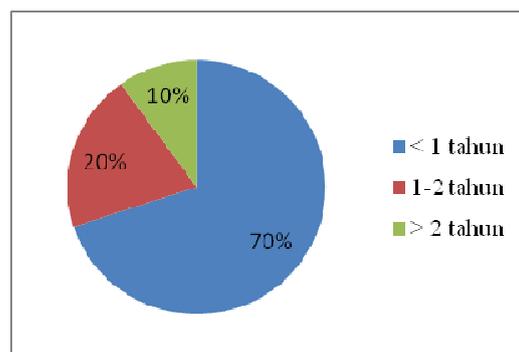


Figure 3. Project Duration

Based on figures 3. Project Duration, most project are going on less than a year projects.

Several stages were carried out to conduct the research. After descriptive analysis from the survey, the research were carried out to normality test, reliability test and validity test. 35 variables are tested, then the research get 12 right variables.

Table 3. Reliability testing

Dimension 1	Cronbach alpha	Dimension 2	Cronbach alpha	Dimension 3	Cronbach alpha	Dimension 4	Cronbach alpha
Goal Clarity	0.391	Degree of hazard	0.803	Number of man hours	0.752	Dependence Internal	0.847
Goal Tangibility		Tech. Difficulty		Project Size		Dependence External	
		Price Fluctuation				Diversity function	
		Reworks				Number of project	
		Payment system					
		Weather					
		Tech. Life					

Table 4. Validity Testing

Correlations													
		V6	V7	V8	V9	V11	V13	V17	V18	V26	V27	V28	V29
Spearman's rho	V6	1											
	V7	.392*	1										
	V8	-0.15	0.035	1									
	V9	0.096	-0.033	.576**	1								
	V11	-0.108	-0.171	.689**	.642**	1							
	V13	0.042	-0.21	0.334	.417*	0.225	1						
	V17	0.111	-0.051	0.095	0.355	0.36	0.027	1					
	V18	0.037	0.034	0.152	.429*	0.287	0.102	.587**	1				
	V26	-0.069	0.013	.453*	0.265	.383*	.371*	0.321	.462*	1			
	V27	0.093	-0.272	.441*	.444*	.425*	.507**	0.285	0.202	.647**	1		
	V28	0.116	-0.177	0.317	.451*	.394*	0.078	.637**	.531**	.541**	.551**	1	
	V29	-0.041	-0.235	0.21	0.194	0.16	.375*	0.336	0.18	.544**	.720**	.445*	1

Multivariate statistic will be conducted to make group of this variables. The variables are grouped as a dimension of project complexity. The exploratory factor analysis are used to make it. After analyze using exploratory factor analysis, this research can conclude the result as Table 6. The result.

Table 5: Exploratory Factor Analysis

Rotated Component Matrix				
	Component			
	1	2	3	4
V6	-0.14	-0.002	0.195	0.859
V7	0.016	0.167	-0.368	0.642
V8	0.855	0.121	0.133	-0.141
V9	0.78	0.245	0.183	0.125
V11	0.801	0.306	0.084	-0.223
V13	0.524	-0.223	0.581	0.143
V17	0.058	0.844	0.15	0.048
V18	0.223	0.79	-0.035	0.135
V26	0.325	0.519	0.519	-0.063
V27	0.332	0.223	0.82	-0.006
V28	0.244	0.723	0.392	-0.016
V29	-0.016	0.269	0.853	-0.075

Extraction Method: Principal Component Analysis.  
 Rotation Method: Varimax with Kaiser Normalization.  
 Rotation converged in 6 iterations.

Table 6: The Result

<i>Uncertainty in Goals</i>	
V6	Goal Clarity
V7	Goal Tangibility
<i>Uncertainty in Methods</i>	
V8	Degree of hazard
V9	Tech. Difficulty
V11	Reworks
V13	Weather
<i>Structure Complexity (Size)</i>	
V17	No. Of man hours
V18	Project Size (nilai project)
V28	Diversity function
<i>Structure Complexity (Interdependence)</i>	
V26	Dependence Internal
V27	Dependence External
V29	Diversity function

The result of this research can use to try define the contingency budget using project complexity. The dimension of project complexity, uncertainty in goals, can describe as the project risk which basically use to define contingency budget. Based on William, project risk is a component of uncertainty in goals where project risk usually use to predict contingency budget [1].

#### 4. CONCLUSION

There are 12 variables out of 35 variables that pass the test of validity and reliability related to the complexity of the project. Overall variable is derived from a combination of theoretical and the results of interviews with practitioners. Based on the results identified four dimensions of complexity. The study shows the suitability of the number of dimensions derived from empirical tests with William Complexity Theory.

#### REFERENCES

- [1] William TM, 2002, *Modelling Complex Projects*, John Wiley & Sons Ltd :New York
- [2] Simon HA, 1982, *Sciences of the Artificial*, 2nd edn, MIT Press: Cambridge, MA.
- [3] Morris and Hought, 1987, *The anatomy of major project: A study of the Reality of Project Management*, John Wiley: Chichester
- [4] Jones RE and Deckro RF, 1993, *The social psychology of project management conflict*, European Journal of Operational Research 64: 216-228
- [5] Turner JR and Cochrane RA, 1993, *Goals-and-Methods matrix: Coping with Projects with ill-defined goals and/or methods of achieving them*, International Journal of Project Management 11: 93-102
- [6] Sietsman K, 1994, *The project cube: a three-dimensional approach to project classification*. Proceeding of the INTERNET 12th World Congress on Project Management. Oslo, June 284-289
- [7] Baccarini D, 1996, *The concept of project complexity-a review*, International Journal of Project Management 14: 201-204

# Multipliers And Structural Path Analysis For Logistics Sectors In Social Accounting Matrix Framework Of Indonesia

Christine Natalia

*Industrial Engineering Department, Engineering Faculty,  
Atma Jaya Catholic University, Jakarta, Indonesia.  
Email : chrisnatalia@atmajaya.ac.id*

## ABSTRACT

The role of logistics sectors which considered more important in supporting the development of Indonesia economics and prosperity has become a starting point of this research. The research objective is to analyze the impact of changing income in logistics sectors on others sector, labor and household income. The analysis is using Social Accounting Matrix Model of Indonesia 2005 with disaggregation in logistics sectors. Based on multipliers analysis, the result show that income changing as an effect of economic stimulus or injection in logistic sectors has biggest impact on manufacturing industry sector. The result of more intensive research showing that income changing in logistic sectors can boost Indonesia's GDP. This increment achieved as a result of income rising in production factor, which is salary earning of production worker, transportation operation, manual and unskilled workforce. The impact to household mostly gain by low class household, both in rural and urban. This means income changing in logistics sectors will increase the income of most Indonesian low class society, which also means it could decrease poverty rate in Indonesia at the end. Path structural analysis showing that the biggest economic impact is flew directly from logistic sector to others sector. The most effective economic stimulus is the sectors that play a role as leading sector, which is Railway Transport Sector, Road Transport Sector, and Services Allied To Transport Sector.

## Keywords

*Logistics sectors, SAM, multipliers analysis, structural path analysis*

## 1. INTRODUCTION

In the world economic order, logistics or logistics management has an important role in supporting economic development and prosperity of a country. The World Bank has a special view of the logistics sector, which is to reduce costs and improve the quality of logistics and transport system that will improve access to international markets, increase trade, and through this, it will increase revenue and furthermore it means to reduce poverty significantly.

World Bank periodically conduct a survey on the performance of the logistics sector on many countries in the world, known as the Logistics Performance Index (LPI) in 2007, while Indonesia is ranked 43 (out of 150 countries surveyed), under Singapore, Malaysia and Thailand. Other research and survey called the Global Competitiveness Index (GCI) of the World Economic Forum in 2007-2008 put Indonesia on the order to 54 of the 131 countries surveyed, under Thailand (28), Malaysia (21), and Singapore (7). Both international survey showed that the logistics sector seen increasingly important role in supporting the development of the competitiveness of trade and industry of the country. Indonesia's national logistics system is now known to be "inefficient and ineffective" (Minister of Economic Coordinator Team, 2008). Some problems of distribution of commodities / products often become strategic issues at the national level, which showed weak support for a national logistics sector. The problems about the distribution of fertilizer, fuel, rice, sugar, and Election logistics are a few examples of logistics. Therefore, Ministry of Economy Coordination elaborate a blueprint of structuring and developing Indonesia's logistics sector so that the logistics sector could grow and become one of the greatest infrastructure for building national competitiveness.

The role of the logistics sector are considered increasingly important role in supporting economic development and prosperity of a country, this is the starting point of this research. Government effort shows by this Blueprint needs to proceed with precaution policies, such as through study or analysis using a specific methodology to anticipate the impact of the policy. The model commonly used in analyzing the impact of policy on the economy and social sector simultaneously is a model Social Accounting Matrix (SAM). Use of SAM models based on several aspects of the following (Sinaga and Alim, 2007): (1) SAM models can explain the link between the activities of production, distribution, consumption of goods and services, savings and investment, and foreign trade, (2) SAM can provide a framework that unites and serves the entire regional economic data, and (3) national economy can be calculated by SAM multiplier that is useful to measure the impact of the injection in the logistics sector on other sectors income, labour factor income and household income, which describes the structure of the economy. There are two main methods within a SAM framework, a Multiplier Decomposition and Structural Path Analysis (Pyatt and Round, 1995; Shantong, et al, 2004). The basic idea of the methods is to grouped the SAM accounts into into several sets in two major groups, namely endogenous and exogenous account and then to see what related effects happen as a result of the

external injection on certain endogenous account. Multiplier Decomposition shows the magnitude of global effect and reveals the quantity distribution of the global effect within and among endogenous accounts. Based on this values, Structural Path Analysis further illustrates the operation path and mechanism of external injection, i.e., along what path and to what extent does an external injection act on other accounts in an economy. Such analysis results will provide greater reference for policy makers and decision makers.

There is no research conducted on the impact of the policy in the logistics sector to the national economy as a whole. Most research related logistical problems focus on building models to minimize inventory costs, transportation models that minimize the total cost of transport to support the efficiency of logistics. Most research in the field of economics that uses SAM models focus on upstream industrial sectors, such as agriculture and agribusiness, as well as the downstream industry or manufacturing industry. Logistics hold supporting role as enablers in the flow of the supply chain, which is not involved directly to the trade and related industries, but providing supporting services, which is effectively and efficiently logistics services. Supporting role as participants make the logistics sector as if it does not have direct and significant on earnings, but through other sectors which hold main role as producer in the supply chain. This study fills a different space with previous research, where this research was to analyze the impact of government policies in the logistics sector to the national economy and other socioeconomic indicators by using Multiplier Decomposition and Structural Path Analysis method in a comprehensive manner of the SAM-logistics model of Indonesia in 2005.

## 2. LITERATURE REVIEWS

There are at least three major economic activity (Gilarso, 2004), namely: production, distribution, and consumption. Economic activity is conducted by the various parties, or the subject of economic actors. The beginning of the economic problems is the existence of human needs that can be met through the consumption of goods and services. Demand for commodities is desirable to be met through the production process. The process of production of goods and services can be done because of the participation factors of production are mostly owned by the household. So with the demand for goods and services production process occurs, which in turn creates income for owners of factors of production. From this it can be expected to occur in the distribution of income groups of households as owners of factors of production. The value-added (income) generated by the factors of production due to their participation in the production process (as corrected by depreciation, transfer payments, taxes, and subsidies), related to the household income distribution. This economic activity is comprehensively summarized in the Social Accounting Matrix (SAM) model.

SAM model is a traditional double accounting economic matrix in the form of a partition matrix that records all economic transactions between agents in the economy, especially between sectors in production blocks, sectors within institutional blocks (including households), and sectors within production factors (Pyatt and Round, 1995; Sadoulet and de Janvry, 1995; Hartono and Resosudarmo, 1998). It is a solid database system, since it summarises all transaction activities in an economy within a given time period, thus giving a general picture of the socio-economic structure in an economy and illustrating the income distribution situation. The multiplier models in the SAM may indicate changes in income that occur in particular when there is an endogenous variable injection or exogenous economic stimulus on the balance sheet (Defourney and Thorbecke, 1984). Social Accounting can be classified into two types (Shantong, et al, 2004), namely micro and macro SAM. The definition of a macro SAM framework is a macro picture of the economic and social aspects, in which the balance-sheet that is grouped into several sets in two major groups, namely endogenous and exogenous balance. General framework of the macro SAM is like the table 1.

Micro SAM is the development of a macro SAM with a more detailed classification in accordance with the subject who want to study and the availability of data. This study is a micro SAM with a more detailed classification in the logistics sector, according to the focus of this study. Multiplier decomposition analysis in SAM framework started with define of average expenditure propensities matrix, or long-term trend of expenditure, expressed as a proportion, that is similar to the matrix of direct input coefficients of IO model. (Prihawantoro and Resosudarmo, 1999; Shantong, et al, 2004). To get the numerical value of each element in the matrix, just divide the corresponding element of SAM by the total of the column which contains the element. Using  $A_n$  to denote the matrix of average expenditure propensities and then block  $A_n$  according to the pattern of 3x3 endogenous accounts matrix in the simplified SAM, we get

$$A_n = \begin{bmatrix} 0 & 0 & A_{13} \\ A_{21} & A_{22} & 0 \\ 0 & A_{32} & A_{33} \end{bmatrix}$$

Table 1. Framework of macro-SAM

Expenditure Income		Endogenous accounts			Exogenous accounts	Total
		1. Activities	2. Factors	3. Institutions		
Endogenous accounts	1. Activities	$T_{11}$		$T_{13}$	$X_1$	$Y_1$
	2. Factors	$T_{21}$			$X_2$	$Y_2$
	3. Institutions		$T_{32}$	$T_{33}$	$X_3$	$Y_3$
Exogenous accounts		$L_1$	$L_2$	$L_3$	$LX$	$Y_4$
Total		$Y_1$	$Y_2$	$Y_3$	$Y_4$	

Source : Shantong et al, 2004

In SAM framework, the total of column and the corresponding row must be equal, therefore the total income of endogenous accounts can be written as following:

$$Y_n = A_n \cdot Y_n + X \quad (1)$$

Transform the equation (1) and we can get the following equation which captures the relationship between the endogenous incomes  $Y_n$  and the exogenous injections  $X$ .

$$\begin{aligned} I \cdot Y_n &= A_n \cdot Y_n + X \\ I \cdot Y_n - A_n \cdot Y_n &= X \\ (I - A_n) \cdot Y_n &= X \\ (I - A_n)^{-1} \cdot (I - A_n) \cdot Y_n &= (I - A_n)^{-1} \cdot X \\ Y_n &= (I - A_n)^{-1} \cdot X \end{aligned} \quad (2)$$

If  $M_a = (I - A_n)^{-1}$ , then

$$Y_n = M_a \cdot X \quad (3)$$

The  $M_a$  is known as a multiplier matrix account, which shows the global impacts of changes in a particular economic sector on other sectors by a backward linkages approach as well, and  $(I - A)^{-1}$  is like as Leontief inverse matrix in the IO model (Susilowati, 2007). This multiplier matrix account in SAM reflects the global effects of the exogenous injection  $X_i$  on endogenous account  $Y_j$ . In order to examine the nature of linkage in the economy that leads to these outcomes, it is possible to decompose the SAM multipliers further into three multiplicative components (Pyatt and Round, 1995; Shantong, et al, 2004) :

$$M_a = I + (M_{a,1} - I) + (M_{a,2} - I) M_{a,1} + (M_{a,3} - I) M_{a,2} M_{a,1} \quad (4)$$

In the equation (4), matrix  $M_{a,3}$  is a block diagonal matrix which captures the circular transferred relationship of the income flows among endogenous accounts, thus it is referred to as *closed-loop* or circular multiplier matrix. Matrix  $M_{a,1}$  is also block diagonal, it reflects the effects of certain group of accounts on itself through direct transfers and is independent of the closed-loop nature of the system. It is referred to as the *transfers'* multiplier matrix. Matrix  $M_{a,2}$  is not diagonal and its diagonal blocks are all identity matrices. It captures all effects between partitions of the accounts. Therefore the matrix is called as the cross-effects matrix or *open-loop* multiplier matrix. Figure 1 visually exhibits the three effects of multiplier decomposition. Transfers' multiplier effects are reflected within the production activities accounts and the institutions accounts. Open-loop multiplier effects are reflected between any two different groups of endogenous accounts. Close-loop multiplier effects can start from any account and finally go back to the origin after a series of interactions.

Multiplier analysis only provide us with some quantitative reference and the mechanism of interactions remains a "black box", since the decision makers cannot find out that, along what paths do the influences among accounts transmit and which paths are better than the others in transmitting influences (Shantong et al, 2004). Based on multiplier decomposition, structural path analysis further reveals the transmission mechanism of the interactions among accounts, thus opens the "black box". The following will briefly describe the theory of structural path analysis by the aid of topology language. Take every endogenous account in SAM as pole and the link between any two poles is represented by arc  $(i, j)$ , then we can define the element  $a_{ji}$  in the average expenditure propensity matrix  $A_n$  as the intensity of arc  $(i, j)$  which reflects the magnitude of influence transmitted from pole  $i$  to pole  $j$ . A sequence of consecutive arcs  $(i, k), (k, l), \dots, (m, j)$  form a path and the number of arcs composing it is referred to as length of path. A path which does not pass more than one time through the same pole is called an elementary



path. A path whose pole of origin coincides with its pole of destination is referred to as circuit. In Figure 2,  $i \rightarrow x \rightarrow y \rightarrow j$  is an elementary path and  $x \rightarrow y \rightarrow z \rightarrow x$  is a circuit.

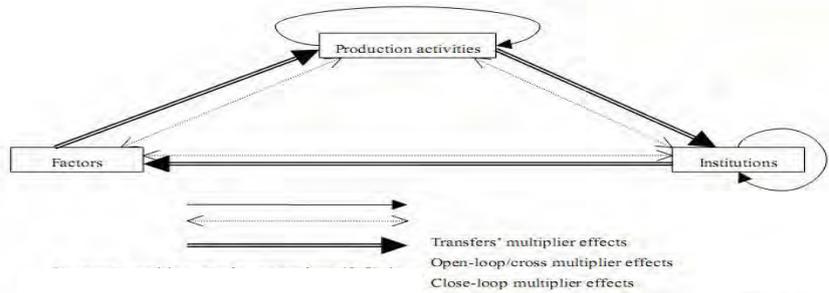


Figure 1. Three Different Multiplier Decomposition Effect in SAM framework

Source : Shantong et al, 2004

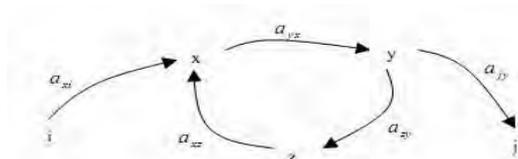


Figure 2. Circuit and elementary path

Source : Shantong et al, 2004

Suppose account  $i$  is disturbed by external injection and finally acts on account  $j$  by way of path  $s$ , then we can use  $(i \rightarrow j)_s$  to denote the influence of  $i$  on  $j$ . There are three kinds of influences between accounts: direct influence, total influence and global influence.

### 3. METHODOLOGY

In accordance with the background issues that have been described previously, the research generally aims to analyze the impact of the policy in the logistics sector using the model of Social Accounting Matrix (SAM) model of Indonesia. SAM model is used because these models can explain the integration relationship between economic and social aspects. However, the logistics sector has not been a specific sector within the framework of Indonesian' SAM. Therefore at the early stages, it must be modify SAM basic model of Indonesia to develop the sectors, that is included in the logistics sector, and the result is referred to as a SAM-Logistics model of Indonesia. This model became the first aim of this study. Subsequently, it was determined the logistics sector which acts as a leading sector using the backward and forward linkages index. Then determined the value of the multiplier of the sector and analyzed the effects of injection on this logistic sector to household incomes. Influence or impact is measured from the value of the multiplier on other sectors, the value of the multiplier factor of production as well as domestic institutions. Multiplier value indicates the amount of change in income that occurs when the balance of exogenous injections done. All of these changes can be obtained simultaneously using a multiplier (multiplier) balance in the SAM, where it is one of the reasons the use of SAM models. For multiplier analysis purposes, first do some preparatory steps which are grouping the balance-sheet according to macro SAM framework to look at the interactions that occur between the balance sheet through the block matrix operations. Preparatory steps include endogenous and exogenous aggregation of balance sheet.

SAM multiplier balance equation can be written in the matrix as in the equation (2) and equation (3) where  $M_a$  is the multiplier matrix account and  $(I - A_n)^{-1}$  is called the Leontief inverse matrix ( Susilowati, 2007). The model explains that the revenue of endogenous accounts (i.e accounts of production factors, the accounts of production sector and the institutions accounts ) expressed in the notation  $Y_n$ , will be changed by  $M_a$  units due to changes in exogenous accounts, expressed in notation  $X$  by one unit. The  $M_a$  amount is determined by the magnitude of multiplier coefficient matrix  $(I - A_n)^{-1}$ . The first step is to determine the matrix  $A_n$ . The matrix  $A_n$  is a matrix that shows the magnitude of the average expenditure propensity.  $A_n$  matrix is obtained by dividing each cell in the matrix of  $T$  with the number of columns.

Furthermore, the matrix multiplier is determined by the inverse matrix operation from the result of identity matrix reduced with the  $A_n$  matrix.  $M_a$  multiplier values indicate a global impact or impacts received a balance after the whole system. Multiplier backward linkages show show the spreader power, meaning that an increase in final demand for a particular sector, then the sector will drive an increase in output of all sectors with a multiple of the value of the multiplier. Meanwhile, forward linkages shows the degree of sensitivity of a given sector to final demand of all other sectors. The greater coefficient of backward linkage mean the longer of the rear linkage. Conversely, the smaller the multiplier coefficients imply its shorter association.

Sectors that have a degree of sensitivity index value or forward linkages effect ratio  $\beta_i > 1$  indicates that the sector has a role as an adjusting sector, a sector that is fast to react in the form of changes in the value of output of the sector as a result of any change in income from other sectors.

#### 4. RESULT AND DISCUSSION

Logistics sector consists of a wide range of sectors that serve to support logistics activities in accordance with the definition of Ballou (1992). In the framework of SAM, the sectors included in the logistic activities are part of the Production Activity account. As the sector is the focus of this study, it is necessary to develop a conceptual model within the framework of SAM with logistic sectors separate from other production activities in blocks of Production Activities. The separation was intended to determine the interaction between logistics sectors with the overall economic activity. Once the conceptual model of the logistics sector in the SAM framework has been developed, the next step is to develop the logistics sectors following the transaction values accordingly. Sectors within the framework of SAM Indonesia 2005 which amounted to 24 sectors are aggregations of 175 sectors in the Input Output Tables Indonesia 2005. This study defines the logistics sector based solely on the flow of material, then the sectors included in the logistics sector in the SAM framework sector: infrastructure (roads, bridges, ports), transportation (land, sea, air), and logistical support services. Infrastructure sector (roads, bridges, ports) is the sector with the code 146 in the Input-Output Tables and is a part of the construction sector in SAM framework, so we need to bring out this sector separately. The following table outlines what sectors should be developed to bring out logistics sectors.

Table 2. Logistics Sector disaggregation in Social Accounting Matrix (SAM) Framework

Sector Name in SAM (2005)	Sector Code in Input-Output Table	Sector Name in Input-Output Table
Construction	144	Residential and Non-Residential Buildings
	145	Agricultural infrastructure
	146	Roads, bridges and ports infrastructure
	147	Building and electricity, gas and water supply installations
	148	Other buildings
Land Transportation	152	Railway Transportation
	153	Road Transportation
Water and Air Transportation, Communication	154	Sea Transportation
	155	River and Lake Transportation
	156	Air Transportation
	158	Communication Services
Transportation Support Services, Warehousing	157	Transportation Support Services, Warehousing

There are seven logistics sector which are the sectors that are marked in the table above, and that made totally up to 32 sectors, both within the Production Sector account and Domestic and Import Commodity account. Hence the size of the SAM with the development of the logistics sector is 131 x 131. Additional data are used to fill the cells of other account transactions, which are data from (i) the National Socio-Economic Survey (SUSENAS) year 2007, (ii) the National Labor Force Survey (SAKERNAS) in 2007, (iii) Indonesia' Economic Indicators 2007, and (iv) Special Survey on Household Investment and Savings (SKTIR) in 2007. Once all of the relevant transaction cells filled, then balancing performed using cross-entropy method. Data resulting from the development of the logistics sector is processed directly by the BPS (Central Bureau Statistics of Indonesia) as a secondary data exclusively for the purposes of this study, because the primary data in SUSENAS, SAKERNAS and SKTIR not allowed to be used outside the BPS.

After the SAM-Logistics model of Indonesia was constructed, multiplier analysis used for further analysis of the linkages among sectors so that it can be determined which logistics sector play a role as a leading sector based on backwards and forwards linkage index. Index of dispersion or backward linkage effect and forward linkages effect can be seen in the table below:

Table 3. Backward Linkages and Forward Linkages for Logistics Sectors

Code	Sector Name	Backward Linkages		Forward Linkages	
		Value	Index	Value	Index
44	Roads, bridges and ports infrastructure	5.93	0.98	2.66	0.44
50	Railway Transportation	6.93	1.15	2.15	0.36

51	Road Transportation	6.85	1.13	5.17	0.86
52	Sea Transportation	5.95	0.98	2.77	0.46
53	River and Lake Transportation	5.36	0.89	2.39	0.40
54	Air Transportation	5.27	0.87	3.01	0.50
56	Transportation Support Services, Warehousing	6.32	1.05	3.37	0.56

Based on table 3 above, we can see that Railway Transportation Sector is the sector with the highest position as the leading sector, followed by Road Transportation Sector, Transportation Support Services Sector, and Warehousing, because they have Index of dispersion  $\alpha_j > 1$ . Also we can see that all logistic sector have forward linkages indeks  $\beta_i < 1$ , that means all logistics sector uneffective as following sector, means react slower for every changing in other sector income. Figure 3 and 4 show global effect of the injection that is done in Railway Transportation Sector and Road Transportation Sector to other sectors.

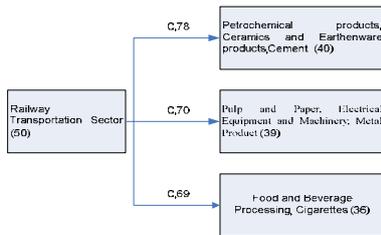


Figure 3: Global effect of Railway Transportation Sector

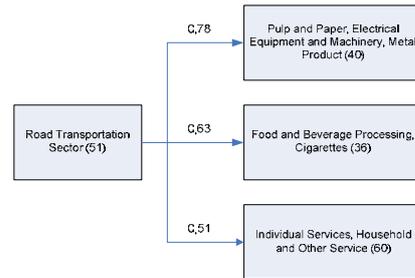


Figure 4: Global effect of Road Transportation Sector

The following tables describe the global impact of the injection that is done in the logistics sector to production factor and to institutional income:

Table 4  $M_a$  Value of logistics sector that give global impact on Production Factor

$M_a$  multiplier values can be decomposed into several components. Pyatt and Round (1995) decompose the SAM multipliers further into three multiplicative components, ie transfer multiplier, open loop multiplier and closed loop multiplier. Transfer multipliers show the impact occurred in a balance sheet in which the initial economic stimulus provided. For example, if you want to know the pressure on the land transport sector due to the injection of other sectors in the block production activity, then the multiplier transfer ( $M_{a1}$ ), the magnitude of the pressure can be determined. Logistics sector that is able to become a leading sector is the Railway Transportation Sector, followed by the Road Transportation Sector and Transportation Support Services Sector, and Warehousing. Based on multiplier decomposition, structural path analysis further reveals the transmission mechanism of the interactions among accounts. The table below is specifically showing the structural path analysis of the injection on Railway Transportation Sector that transfer directly their effect of the injection to Petrochemical products, Ceramics and Earthenware sector by 52,81%, and rest of the effect are transmitted to other sectors, production factor and institution income.

Table 5:  $M_a$  Value of logistics sector that give global impact Institution Factor

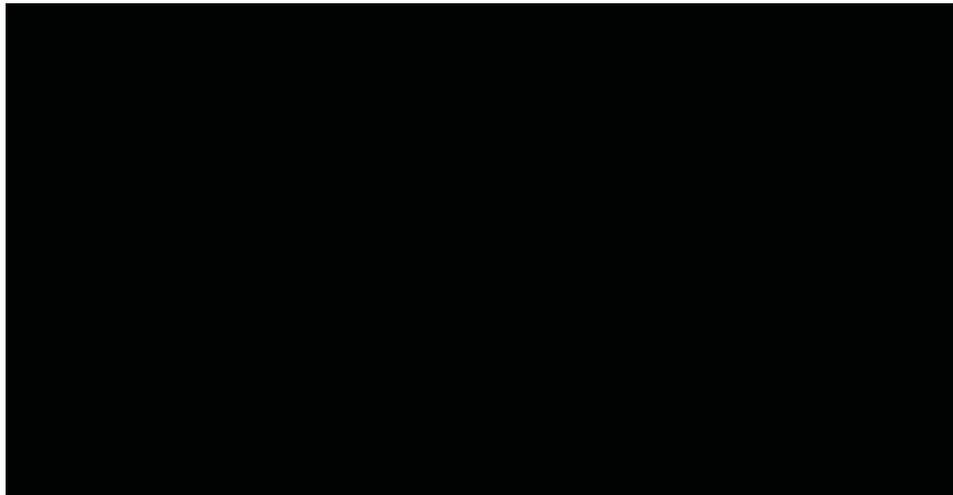


Table 6. Structural Path Analysis for Railway Transportation Sector to other's

No	Point of origin	Point of Destination	Global Effect Ma	Elementary Path	Direct Effect An	Path Multiplier Mp	Total Effect	Proportion (%)
	(1)	(2)	(3)	(4)	(5)	X (6)	= (7)	(8) = (7) / (3)
1	Railway Transportation (50)	Petrochemical products, Ceramics and Earthenware products,Cement (40)	0.7815	(50) --> (40)	0.0911	4.5324	0.4127	52.81%
2	Railway Transportation (50)	Pulp and Paper, Electrical Equipment and Machinery, Metal Product (39)	0.6952	(50) --> (39)	0.0491	5.5745	0.2740	39.41%
3	Railway Transportation (50)	Food and Beverage Processing, Cigarettes (36)	0.6891	(50) --> (36)	0.0056	5.3123	0.0299	4.34%
4	Railway Transportation (50)	Food Crops (29)	0.3317	(50) --> (29)	0.0000	4.7517	0.0000	0.00%
5	Railway Transportation (50)	Electricity, Gas and Clean Water (41)	0.2728	(50) --> (41)	0.0467	4.9985	0.2336	85.61%

## 5. CONCLUSION

Based on the analysis that has been described above, it can be concluded some of the following:

1. Logistics sectors within the framework of The 2005 Indonesian Logistics Social Accounting Matrix constructed in this research consists of seven sectors, namely: Roads, Bridges and Ports Infrastructure Sector (Code: 44); Railways Transportation Sector (50); Road Transportation (51); Sea Transportation Sector (52); Rivers and Lakes Transportation Sector (53), Air Transportation Sector (54), and Transportation Support Services Sector, and warehousing (50).
2. Logistics sector that is able to become a leading sector based on the analysis of backward linkages with  $\alpha_j > 1$  is the Railway Transportation Sector, followed by the Road Transportation Sector and Transportation Support Services Sector, and Warehousing. These sectors are able to attract other sectors to grow when performed injection on these sectors.
3. In general, injection on logistics sectors will give globally impact on specific sectors, namely Paper Industry, Printing, Transportation Goods and Metals Industry (39), Chemicals Industrial, Fertilizers, Clay, Cement (40), and Food, Beverages and Tobacco (36). These sectors are the manufacturing sector in 9 sectors classification of Input Output table. These results are consistent with the results of Firman's research (2007), which means that during five years (2000-2005), logistics sectors remains as the largest contributor to the manufacturing sector.
4. Certain labour factor income are affected by a change in logistics sectors, particularly on Formal Production, Transport Equipment Operators, Manual worker in Urban Area (6) ; Formal Clerical, Sales, Service Labour in Urban Area (10); and Informal Agricultural Labour in Rural Area. Labor factor accounted 51.30% of the Gross Domestic Product (GDP) of Indonesia in 2005 (CBS, 2007), and most of the value comes from the labour factor mentioned above . Thus, the injection of the logistics sector can boost the value of Indonesia's gross domestic product.
5. Injection on logistics sectors will give globally impact on specific household income, which are: Small Business Entrepreneur , Clerical , Sales, Transportation Worker , Individual Service Worker, Manual Worker in Urban Area (25) ; Medium to Large Business Entrepreneur , Non Agricultural Entrepreneur , Manager, Military, Professional, Technician, Teacher, Sales Executive in Urban Area (27) ; Small Business Entrepreneur , Clerical , Sales,

- Transportation Worker , Individual Service Worker, Manual Worker in Rural Area (22). In other words, the global impact of the injection in the logistics sector received by lower class households, both in rural and urban area.
6. Average expenditure propensity analysis of Railways Transportation Sector shows that the greatest expenditure of this sector is for operational cost, such as for fuel that derived from the oil refinery sector (USD 747.408 billion) and coal fuel derived from other items from nonmetal materials sectors (USD 20.943 billion). Expenditures for operation and maintenance of cleanliness and train stations from soaps and cleaning materials sector (USD 11.420 billion) in third place.
  7. Injections on Railways Transportation Sector will provide the greatest global impact on the sector itself to the value of the coefficient multiplier of 2.030. This value means that if the injection occurred in Railways Transportation Sector at IDR 1 then this sector income will be increased by IDR 2.030, which increased revenue by IDR 1 as a direct impact and IDR 1.030 as an indirect impact.
  8. Injection in Railways Transportation Sector will drive revenues increased mostly in the manufacturing, agriculture and Electricity, Gas and Clean Water sector.
  9. Injection in Railways Transportation Sector also has a smooth influence on labor in both rural and urban area, especially on Formal Production, Transport Equipment Operators, Manual worker. Labor factor accounted 51.30% of the Gross Domestic Product (GDP) of Indonesia in 2005 (CBS, 2007), and most of the value comes from Formal Clerical, Sales, Service Labour factors (36 , 44%) and Formal Production, Transport Equipment Operators, Manual worker. Labor factor (32.17%). Thus, the injection of Railways Transportation Sector has a great impact on Indonesia's gross domestic product.
  10. Global impact of injection on the Railways Transportation Sector received by lower class households, both in rural and urban.
  11. The effects of injection on the Railways Transportation Sector for the Petrochemical products, Ceramics and Earthenware Sector of 52.81% is transmitted directly between sectors.

## ACKNOWLEDGMENT

The authors would like to acknowledge the personnel of Badan Pusat Statistik ( Central Statistic Agency of Indonesia ) for helping to make this research a success

## REFERENCES

- [1] Ballou,R.H. *Business Logistic Management*, Prentice Hall, USA, 1999
- [2] Bowersox, Donald J., David D. Closs, and M. Bixby Cooper, *Supply Chain Logistics Management*, McGraw-Hill, New York, 2002,
- [3] Biro Pusat Statistik, *Input-Output Table 2005* , Volume 1, Badan Pusat Statistik, 2007, Jakarta
- [4] Biro Pusat Statistik, *Theory and Analysis Framework of Input-Output Table*, Badan Pusat Statistik, 2008, Jakarta
- [5] Biro Pusat Statistik, *Social Accounting Matrix of Indonesia 2005* , Badan Pusat Statistik, 2008, Jakarta
- [6] Biro Pusat Statistik, *Teknik Penyusunan Tabel Input-Output* , Badan Pusat Statistik, 2008, Jakarta
- [7] Defourney, J., and Thorbecke, E., "Structural Path Analysis and Multiplier Decomposition within a Social Accounting Matrix Framework" , *Economic Journal*, 1984, 94(373) , 111 – 136.
- [8] Gilarso, T. , *Introduction to Macroeconomics*, Kanisius Publisher, Yogyakarta, 2004, pp. 49 – 58,
- [9] Hartono, D. and B.P. Resosudarmo, "Existence of the multiplier matrix and the Pyatt and Round Decomposition Matrix for a Social Accounting Matrix", *Ekonomi dan Keuangan Indonesia*, 46(4), pp. 473-496., 1998
- [10] Prihawantoro,S., dan Resosudarmo, B.P , "Direct and Indirect Influence of Log Industry in Indonesia", *Journal of Economics and Bussiness*, Vol.4, No.4, 1999, pp. 62 – 81
- [11] Pyatt, G. dan Round, J.I, " Social Accounting Matrix : A Basis for Planning" , *World Bank Symposium*, Washington, D.C., 1995
- [12] Round, J.I , Social Accounting Matrix and SAM Based Multiplier Analysis, <http://www.PovertyWorldBank.org/files/chapter 14.pdf> , 2003
- [13] Sadoulet, E., and A. de Janvry, *Quantitative Development Policy Analysis*, The Johns Hopkins, University Press, 1995
- [14] Shantong,Li, Ying,Gao, Jianwu, He, SAM-Based Multiplier Analysis for China's Economy, Paper prepared for the XII *INFORUM World Conference*, in Marina di Ascea-Velia, Italy , 2004
- [15] Sinaga, Bonar.M., Alim, Moch. Rum , : *Economic Sector Linkage Income Distribution Analysis in Java : Social Accounting Matrix Approach* , 2007, unpublished
- [16] Sinaga, Bonar.M., Susilowati, Sri Hery, *The Impact of Economic Policy in Agroindustry Sector on Sectoral, Laour and Household Income Distribution in Indonesia : Social Accounting Matrix Analysis* , 2007, unpublished
- [17] Susila, Wayan.R., Setiawan, IDM Dharma , The role of Estate Crop-Based Industries on Economics Growth and Equity: A Social Accounting Matrix, *Agro- Economics Journal*, Volume 25, No.2, 125-147, 2007
- [18] Susilowati, Sri Hery (2007) : *The Role of Agro-Industry Sector in the National Economy and Agriculture Household Income*, Center of Social Economic and Agricultural Policy, 2007
- [19] Republic Indonesia Minister of Economic Coordinator Team, *Blueprint of Logistic Sector Development of Indonesia* , 2008

# Improving Product Quality Of Dining Table Through Painting Process By Using Taguchi Method

Eko Muh Widodo, Oesman Raliby, Candra Widiarso

Industrial Engineering Departement Faculty of Engineering, Muhammadiyah University of Magelang  
Email: emwidodo@yahoo.co.id

## ABSTRACT

In the process of painting a product, it commonly occur defect results including corrugated painting, perforated, less smooth, speckled and uneven surface of painting. This can occur due to the setting parameters in the process of painting is not appropriate. This research is done to reduce the high rate of defects in the process of painting products of table by setting parameters using the Taguchi method. Processing data using the Taguchi method are distinguished by two ways: (1) to see the impact of uncontrollable factors on the percentage of defective products and (2) to see the controllable factors to the variability of the number of defective products. Controllable factors in this study are: composition of paint, painting distance, pressure and temperature. The survey results revealed that a significant factor level against average and variability of percentage number of defective products are composition of the paint level 2 (0.75: 1), the distance painting level 2 (20-25 cm), pressure level 1 (50 psi fluid tip round 1.88 mm), temperature level 2 (60 ° C), sanding sealer level 2 (15-20 cm) and a clear top coat level 1 (20-25 cm).

## Keywords

*Product Defects, Level Factor, Taguchi*

## 1. BACKGROUND

The increasing demands of consumers and the development of science, technology and information lead to changes in consumer tastes toward a product. Thus, consumer demand for the product will be more variety to fulfill the market segmentation that affects the tightness of the competitiveness of the company. One way to ensure that the product is able to compete and survive in the market is to control the quality of products. Furniture Company is a business that requires good quality control in term of aspects of components or finished products produced. One important variable in the furniture company is the quality of painting process. One attempt to improve the quality of the product needs to be a good design parameter that defective products can be reduced. In this case the concept of quality control that is used is the Taguchi method.

Taguchi Concepts is a method to analyze a variety of variables and parameters in bulk and interactions among different variables to achieve a high quality which time and cost is relatively low. The application of the method is expected to solve the problems of the company that is able to find the right parameters in reducing defects so that the products produced are in accordance with the specification set.

## 2. PROBLEMS

Based on the background of these problems, the research is done to improve the quality of painting furniture product so that it is to reduce the level of defects by (1) determining a significant factor level against the contribution of defect rate (2) determining the sensitive parameters to lower defective products and (3) comparing the level of defects between the policies of the company with the proposal based on setting parameter.

## 3. METHOD

The quality of the product is a combination of characteristics products and services both in terms of engineering, manufacturing, marketing and maintenance so as to meet customer needs. To produce products that have a strong performance, Taguchi introduced the design method in three stages (Isa S. Toha, et ell, 1996) (1) designing system that is an attempt to bring the concepts, ideas and methods to improve the quality of products (2) designing parameters, that is selecting the best design of controllable factors and minimizing the environmental impact (3) designing tolerance, that is the stage of range to find a balance between making a loss (manufacturer) and buyer (consumer) products.

The Taguchi method is an effective method to reduce variation in products and processes through optimization process of designing the robust product using orthogonal array in the design of experimental procedures. Taguchi method also uses financial considerations through quadratic loss function to determine tolerance.

## 4. THE RESULT OF RESEARCH

In this study, there are two factors that can be identified as controlled factors and interference factors. Controllable factors are factors which its value can be set or factor which its value is to be regulated or controlled, while the interference factor is a factor which its value can not be regulated or controlled. In control experiments for each factor are two levels as follows:

Table : Controlled Factors

Factors Control	Composition 1	Composition 2
Paint Composition	0,5 : 1	0,75 : 1
Distance Painting	15-20 cm	20-25 cm
Wind Pressure	50 Psi Fluid tip Round 1,8 mm	60 Psi Fluid tip Round 2 mm
Temperature	± 50 minute with a temperature of 50 <sup>0</sup> C	± 50 minute with a temperature of 60 <sup>0</sup> C
Sanding Sealer	20-25 cm	15-20 cm
Top Coat Clear	20-25 cm	15-20 cm

Source : PT Kayu Lima Utama Temanggung

As for the uncontrollable factor is as follows:

Table 2: Factors Not Controlled

Factor Not Controlled	Level	
	1	2
Working time	Morning	Noon
Physical and biological workers	Dedication	Extras
Environment	Comfort	Crowded

Source : PT Kayu Lima Utama Temanggung

From the experimental results, controllable variables considered to be influence to the process of painting is the composition of paint used to compare the viscosity of paint (A), the distance of the painting process (B), the wind pressure when painting process (C), the temperature used during the drying paint (D), sanding sealer when painting process (E) and a clear top coat when painting process (F). The test results are as follows:

Table 3: The results of calculation of the average number of squares

Source of variation	Df	Sum of Squares (SS)	Mean of Squares (MS)
A	1	20	20
B	1	16.78	16.78
C	1	16.78	16.78
D	1	37.03	37.03
E	1	56.18	56.18
F	1	18.37	18.37
AB	1	17.95	17.95
BC	1	15.32	15.32
CD	1	16.78	16.78
DE	1	20	20
EF	1	18.37	18.37
E	18	100.17	5.56
SS <sub>t</sub>	29	344	11.86

Source: Processed Data

Incorporating factor starting from the number of the least squares of insignificant factor combined with the number of errors. The incorporation of an insignificant factor to these errors will result anova table structure as follows:

Table 4: First Pooling Effect Factor ANOVA

Factor	Df	SS	MM	SS'	P %	F. Count	F(0.05;150)
A	1	20	20	14.44	5.81	3.59	2.70
B	1	16.78	16.78	11.22	4.87	3.01	2.70
C	1	16.78	16.78	11.22	4.87	3.01	2.70
D	1	37.03	37.03	31.47	10.76	6.66	2.70
E	1	56.18	56.18	50.62	16.45	10.10	2.70
F	1	18.37	18.37	12.81	5.34	3.30	2.70
AB	1	17.95	17.95	12.39	5.21	3.22	2.70
BC	1	15.32	15.32	9.76	4.58	2.75	2.70
CD	1	16.78	16.78	11.22	4.87	3.01	2.70
DE	1	20	20	14.44	5.81	3.59	2.70
EF	1	18.37	18.37	12.81	5.34	3.30	2.70
E	18	100.17	5.56				
SS <sub>t</sub>	29	344	11.86				

Source: Processed Data

Based on the average of each factor and the calculated level can be explained most optimum level for defective product as follows:

Table 5. Average Response Effect Each Factor

Factor	Level 1	Level 2	Diference	Rank
A	3.22	2.72	0.5	5
B	3.05	2.88	0.17	1
C	2.88	3.05	0.17	1
D	3.22	2.88	0.34	3
E	3.22	3.05	0.17	1
F	2.83	3.11	0.28	2
AB	2.27	3.16	0.89	6
BC	2.83	3.00	0.17	1
CD	2.88	3.05	0.17	1
DE	3.22	2.72	0.45	4
EF	3.11	2.83	0.28	2

Source: Processed Data

After doing confirmation experiments to prove that the results are in accordance with previous experimental results. The experiments were conducted for 4 times, the first experiment uses set proposal as follows:

Table 6: Proposed Composition

Level control	Factors
Paint composition	A2
Painting distance	B2
Wind pressure	C1
Temperature	D2
Sanding sealer	E2
Top coat clear	F1

Source: Processed Data

The results of experiments using proposal composition as follows:

Table 7: Proposed Composition Experiment Results

Control factor	Code	N Experiment	Defective paint	
			Unit	% Unit
Paint Composition	A2	19	2	10.52%
Painting distance	B2	19	2	10.52 %
Wind pressure	C1	19	1	5.26 %
temperature	D2	19	1	5.26%
Sanding Sealer	E2	19	2	10.52%
Top coat clear	F1	19	2	10.52%
Total			10	56.60%
Average			1.67	8,76%
Sd			0.5163	

Source: Processed Data

The experiment using factor level of company policy is as follows:

Table 8. Composition of Company Policy

Control factor	Level
Paint Composition	A1
Painting distance	B1
Wind pressure	C2
Temperature	D1
Sanding sealer	E1
Top coat clear	F2

Source: Processed Data

The experimental results using the composition of the company's policy as follows:

Table 9. Experiment results of Company Policy

Control factor	Code	N Experiment	Defective Product	
			Unit	% Unit
Paint Composition	A1	19	4	21.05%
Painting Distance	B1	19	4	21.05%
Wind Pressure	C2	19	3	15.78%
Temperature	D1	19	5	26.31%
Sanding sealer	E1	19	3	15.78%
Top coat clear	F2	19	3	15.78%
Total			22	115.75%
Average			3.67	19.29%
Sd			0.8164	

Source: Processed Data

Based on the validation test is known that early experimental results that do not differ from the results of experimental confirmation. Loss costs as shown in the graph loss function for defective product, the proposed parameter with an average value of 1.67 and Ly 122,979.85 shown on the chart shown below:

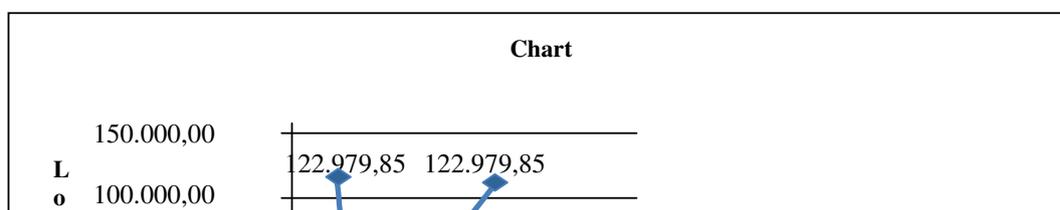


Figure 1: Loss Function of Composition Proposal Chart

While the loss function charts for defective products of company policy parameters with the average value of 3:00 and Ly 416,264, - is shown in the figure below:

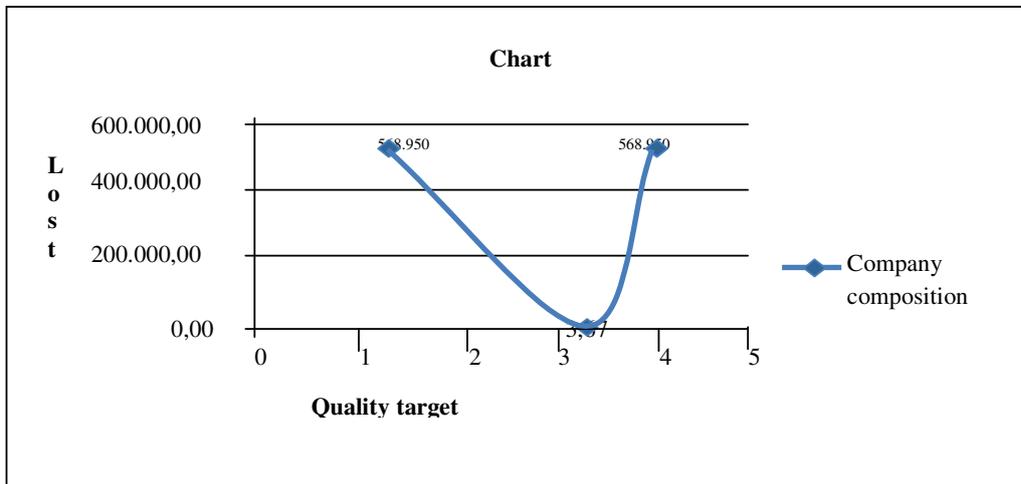


Figure 2: Lost function of company policies chart

## 5. CONCLUSION

Based on the results of research and discussion, the following conclusions can be drawn:

- 1) Level factor that has significant contribution to the percentage of a defective product, are factor level of paint composition at B2 level, factor level of painting distance at B2 level, factor level of air pressure at C1 level, air temperature at D2 level, sanding Sealer at E2 level and clear coat top at F1 level.
- 2) Sensitive parameters that affect the quality of the painting are the composition of paint, painting distance, air pressure, temperature, sanding sealer and top coat clear.
- 3) Setting the parameters proposed by the research can reduce defects percentage from 19.29% to 8.76%.

## REFERENCES

- [1] Austin.TG., and Jasifi E., *Industri Proses Kimia* Jilid 1, Edisi V., Penerbit Erlangga, Jakarta, 1996.
- [2] Djarwanti dan Pangestu S., *Statistik Industri*, Edisi IV BPFE, Yogyakarta
- [3] Feigerboun, A.V., *Kendali Mutu Terpadu*, Erlangga, Jakarta, 1992.
- [4] Gaspersz, Vincent., *Total Quality Management*, Gramedia, Jakarta, 2002.
- [5] Gaspersz, Vincent, *Statistical Process Control*, Gramedia, Jakarta, 1998.
- [6] Peace, G.S, *Taguchi Method*, Addison Wesley Publishing Company, USA, 1993.
- [7] Ross, PJ., *Taguchi Technique for Quality Engineering*. 2nd Edition., McGrawhill, 1996.
- [8] Sadi, *Diktat Kuliah Rekayasa Kualitas*, Teknik Industri Universitas Pembangunan Nasional "Veteran", Yogyakarta, 2008.
- [9] Sudjana, *Design dan Analisis Eksperimen*, Edisi IV Tarsito, Bandung, 1995.
- [10] Wahyudi D., Gan San dan Yohan Pramono., *Optimasi Proses Injeksi Dengan Metode Taguchi*, Fakultas Teknik Universitas Petra, Surabaya, 2004.

## Data Mining Techniques for Redesign Traditional Market

Harwati<sup>a</sup>, I.D Widodo<sup>b</sup>, Azka Yasser<sup>c</sup>

<sup>a,b,c</sup>Data Mining Laboratory Industrial Engineering  
Faculty of Engineering  
Universitas Islam Indonesia, Yogyakarta 55501  
Tel : (0274) 895287 ext 118. Fax : (0274) 895007  
E-mail : harwati@uii.ac.id

### ABSTRACT

Traditional market, in this time, start to lose their customer because they fail to compete with the modern market in several aspects. Common problem faced by traditional market is no arrangement for the traders that causes the traditional market is always impressed disorganized as traders are free to sell the product at anyplace. This unorganized also causes consumers are difficult to buy their needs effectively and efficiently. This paper presents two step to redesign traditional market where the first step classify traders based on the type of their product sold and the second step place a group of traders based on proximity characteristics between traders. There are two data mining techniques used in this approach, clustering for the first step and association rules for the second step. A case study in one traditional market is used to describe this approach.

### Keywords

*Traditional Market, Clustering, Association Rules*

### 1. INTRODUCTION

The traditional market basically is the place where the sale and purchase between grassroots communities met. The existence of this traditional market in addition is not only to connect rural and urban economies but also a source of quest and fulfillment of daily needs for some people [4]. The bargaining activities as prices formation process becomes its own characteristics that make traditional markets on the one hand not only economic value but also social value.

One thing that kept bothering existence of traditional markets is the existence of the modern market as supermarkets, retail, self service, franchise and so on. Although basically each type of market has its own mass base but the modern market that built close to the traditional market tends to disserve because it saturates consumers who have a common goal to purchased the same products [3]. The responsive enthusiasm of the community is also lead modern retail businesses continue to increase their business by increasing the number of outlets in various parts of the region

The traditional market is a place for buyers sellers met that are located close to a residential community with a certain environment and certain cultural conditions as well. According [5] traditional market conditions commonly observed are as follows:

1. Simple building shape, room to sell is not extensive, have sufficient lighting and no air conditioners.
2. Hygiene market is usually less secure, many scattered garbage that cause odor. If it rains, the market looks muddy and dirty.
3. Limited parking facilities.

Major problems being faced by the traditional market is increasingly left by visitors are turning to the modern market. This is likely due to the impression of a dirty, chaotic, and uncomfortable, smell has always been associated with the market environment. Lack of knowledge and skills of the HR business market is also a factor. This problem can actually be solved by restructuring the facility to restore the image of the market that is clean, safe, comfortable, and regular [7]. Reference [6] stated some basic differences between the traditional with the modern market (the Table 1).

Table 1: Differences Characteristics between Traditional Market and Modern Market

No	Aspect	Traditional Market	Modern Market
1	Historic	Long evolution	New phenomenon
2	Physical	Mostly are deficient	Good and lux
3	Ownership	Community, Local Government	Generally private companies
4	Capital	Poor capital, subvention, local community	Strong capital by private companies
5	Consumers	Generally, the lower middle class	Generally, middle class and above
6	Service Method	Be served, bargaining	Service him/her self, fixed price
7	Land Status	State-owned land	Land owned by a private company
8	Financing	Oftenly getting subvention	No subvention
9	Construction	Generally, the physical development by local governments / village / community	Generally, provided by private companies
10	Sellers who entered	Variouly, mass, informal sector to middle and strong seller	Owners of capital are also merchants (single) or several medium and large formal sellers
11	Opportunity to join the market	Mass	Limited (sellers that have strong financing)
12	Network	Regional market	Cooperation chain system

The traditional market has a typical transaction. The process of buying and selling occurs interactively. Price is not a definite, but it is the result of an agreement through negotiation between sellers and buyers [1] That cultural values has become the marketability of a traditional market. But the shortage of structuring facilities still needs to be fixed because basically consumers are not only looking at price alone but also choose a more convenient and representative place.

The rapid growth and development of modern markets become serious competitors to traditional markets. Each year, 2 percent decline of traditional market is recorded. The problem faced by the traditional market includes policy and management market. [3] stated that the issues are related to the physical market, operational management and government policy. Physical problems include building markets, infrastructure and spatial market. Operational management is associated with the management of the market and traders. Government policies is related to restructuring and retail markets, fostering market management, finance, supply-demand, commodity prices and policy consistency

One feature of the market itself in general is the number of traders that are not accommodated by the capacity of the market stalls so many traders are scattered outside the market, the market is not maintained cleanliness and location settings irregular traders. It makes the consumer difficulty in shopping. Sometimes buyers have toured the market for similar goods just because a remote merchant location. In general, the image generated from the unorganized market design is the impression of dirty, messy and inefficient. This should be a matter for local government studies as traditional market managers how to increase the chances of developing markets essentially have to revamp the traditional market design based on meeting the needs of consumers so that consumers feel comfort to visit and shop at traditional markets.

References [5] have arranged a research plan to redesign the layout of a traditional market where using data mining techniques approach. This study will attempt to realize this vision for redesigning traditional markets using data mining techniques such as cluster analysis (Clustering Analysis) and (MBA Market-Based Analysis). Cluster analysis is used to determine the distribution maps so that consumers and merchants profiling and placement used in the design can be run more effectively. MBA is used to design the layout strategy based on traditional market shoppers spending close relationship groove at a time. This technique became known for his ability to analyze the contents of a shopping cart in a supermarket as a basis for setting the rack setting (display) products. In this study, the analysis technique will be tested applied to traditional buyers in the market to produce a new design that is expected to reinforce the existence and competitiveness of traditional markets in the face of the growth of the modern market. For ease of analysis, the case study will be conducted in one of the traditional markets in Sleman as an illustration of the constructed model approach.

### 1.1 Research Objective

The purpose of this study is to redesign the traditional market that focuses on the relationship with the seller and buyer using data mining techniques..

## 2. DISCUSSION

The first step in redesigning the layout of traditional markets is to knowing the clusters of traders in the market based on the products sold. These types of traders in traditional markets based on the products sold.

Table 2: Market trader types

No	Types of traders	No	Types of traders
1	Onion, garlic, pepper, salt	24	Rice
2	Spinach, carrots, kale, celery, green beans, etc.	25	Grated Coconut Services
3	Soap, T-shirts, shirts, trousers, skirts, etc.	26	Squeeze Oil
4	Klepon, martabak, agar-agar, risoles, sponge, etc.	27	slippers
5	rice, vegetables, fried fish, fried chicken, etc	28	underpants
6	T-shirts, shirts, trousers, skirts, etc.	29	Shoes
7	food and drink wrappers from plastic	30	Tailor
8	Soap, cigarettes, detergents, flour, beverage packaging, etc.	31	Broom
9	Meat, shredded, bones, meatballs	32	Toy
10	Walok	33	Banana
11	Coconut, Salak, Onion	34	T-shirts, shirts, trousers, skirts, etc.
12	Seasonings Padang cuisine	35	home and kitchen furnishings
13	jewelry	36	Cabinets
14	Fish	37	Pillow
15	Chicken	38	Wood home furnishing
16	Watermelon, mango, bark, etc.	39	Cooking materials
17	Accessories	40	girl bag
18	Snack, Bakpia, chocolate, chips, etc.	41	Bucket, bucket, basin etc.
19	Accessories, bag	42	Casual Bag
20	Glassware	43	Flower
21	Soap, toothpaste, toothbrushes, etc.	44	Spices
22	Yarns, Accessories, Scissors	45	Satai
23	vegetables, fried tofu, fried tempeh, catfish, fried chicken		

K-Means clustering method is used to classify the types of merchants above. There are three instrument variables are used as the basis for grouping, namely:

1. The nature of the goods (dry or wet goods)
2. Type of goods (food, clothing, or shelter goods)
3. Categories of Goods (raw or finished goods)

The calculations using SPSS16 shows that there are 5 clusters existing traders in traditional markets such as shown in Figure 1 and Figure 2.

	Cluster				
	1	2	3	4	5
Kind_of_product	1	1	1	1	0
Type_of_product	1	2	3	1	1
Category_of_product	1	0	0	0	1

Figure 1: Final Cluster Centers

Cluster 1	9.000
2	10.000
3	15.000

	4	7.000
	5	4.000
Valid		45.000
Missing		.000

Figure 2: Number of Seller in each Cluster

The five clusters formed and the members of seller included in are performed in Table 3 .

After getting the grouping of market stalls, the study followed by observing the tendency of consumer shopping behavior. It is based on the frequency of purchases and the relationship of the five groups that have been defined previously. Researchers asked each respondent in one time period what are the shopping items they buy. Then the researchers put the data in accordance with the market stalls that have been clustered. If there is no buyer who only make purchases only on one group of market stalls, then the buyer will not be included in the market basket analysis.

Table 3: K means clustering result

Name of Cluster	Member of Sellers			
<b>Kitchen's needs</b>	1	Onion, garlic, pepper, salt	6	Grated Coconut Services
	2	Spinach, carrots, kale, celery, green beans, etc.	7	Cooking materials
	3	Coconut, Salak, Onion	8	Spices
	4	Seasonings Padang cuisine	9	shredded coconut
	5	Rice		
<b>Mini Ritel</b>	1	Soap,T-shirts, shirts, trousers, skirts, etc.	9	Toy
	2	food and drink wrappers from plastic	10	home and kitchen furnishings
	3	Soap, cigarettes, detergents, flour, beverage packaging, etc.	11	Cabinets
	4	Glassware	12	Pillow
	5	Soap, toothpaste, toothbrushes, etc.	13	Wood home furnishing
	6	Yarns, Accessories, Scissors	14	Bucket, bailer, basin etc.
	7	Tailor	15	Flower
	8	Broom		
<b>Fast Food</b>	1	Klepon, martabak, agar-agar, risoles, sponge, etc.	5	Watermelon, mango, bark, etc.
	2	rice, vegetables, fried fish, fried chicken, etc	6	Snack, Bakpia, chocolate, chips, etc.
	3	Walok	7	Banana
	4	vegetables, tofu, fried tempeh, catfish, fried chicken		
<b>Side Dish</b>	1	Meat, shredded, bones, meatballs	3	Chicken
	2	Fish	4	Satai
<b>Fashion</b>	1	T-shirts, shirtshouse dress	6	underpants
	2	jewelry	7	Shoes
	3	Accessories	8	T-shirts, shirts, trousers, skirts, etc.
	4	Accessories, bag	9	girl bag
	5	slippers	10	Casual Bag

This is due to the current study focused on the relation of market stalls that require spending information over an existing market stalls. After the data is collected the next step is to perform calculations using the Market Basket Analysis consists of the support, confidence and lift ratio with the following results (Table 4):

Table 4: The Result of Market Basket Analysis (Ten of The Largest Mark)

Conf. (%)	Antecedent (a)	Consequent (c)	Support(a U c)	Support (%)	Lift Ratio	Total Mark (Conf*S support)
-----------	----------------	----------------	----------------	-------------	------------	-----------------------------

Conf. (%)	Antecedent (a)	Consequent (c)	Support(a U c)	Support (%)	Lift Ratio	Total Mark (Conf*S support)
76,92	Kitchen's Need=>	Fast Food	140	0,466667	1,044205	35,896
63,35	Fast Food=>	Kitchen's Need	140	0,466667	1,044205	29,56333
69,88	Mini Ritel=>	Fast Food	116	0,386667	0,948591	27,02027
79,21	Side Dish=>	Fast Food	80	0,266667	1,075221	21,12267
78,22	Side Dish=>	Kitchen's Need	79	0,263333	1,289305	20,59793
52,49	Fast Food=>	Mini Ritel	116	0,386667	0,948591	20,29613
56,63	Mini Ritel=>	Kitchen's Need	94	0,313333	0,933404	17,74407
74,47	Kitchen's Need, Mini Ritel=>	Fast Food	70	0,233333	1,010879	17,37633
79,75	Kitchen's Need, Side Dish=>	Fast Food	63	0,21	1,082536	16,7475
78,75	Side Dish, Fast Food=>	Kitchen's Need	63	0,21	1,298077	16,5375

By knowing the relationship between the five groups of stalls in the traditional market, the new stall layout plan prepared in order to increase profits and the level of visits to the market by providing services in accordance with the trend of buyer behavior where it has been represented by the results of the analysis of Market Basket Analysis . As in this case study, it is assumed that the two market stalls that had the highest relationship, will be brought closer in the layout of the new market stalls. It is based on the idea that it will facilitate buyers to shop. In addition, it can also be assumed to improve profit due to the buyer as if reminded not to forget to buy the goods that had been being associated in the minds of buyers. The final result of planning the layout is performed in Figure 3.

Size layout described above is based on a percentage of the number of traders in the market Sleman. Layout is also a representation of the form of the land market. Market stall trader from the fashion should be placed the back because the value of the top ten association rule calculation, it does not have a relationship with another market stall so it is assumed he was in a fairly indirect encountered by most buyers. It may also be based on the likelihood that the most visited market to meet the needs of the community kitchen.

## 7. CONCLUSION

Based on the discussion above, it could be taken a conclusion that:

1. Based on three grouping variables, namely, nature of the goods, type of goods, and category of Goods, saler members are classified in five groups. They are kitchen's needs, Fast Food, Mini Ritel, Side Dish, and Fashion.
2. Market relayout has been performed based on market basket analysis. Proposed layout is expected to be able to satisfy buyers by easier finding products and shorter distance.

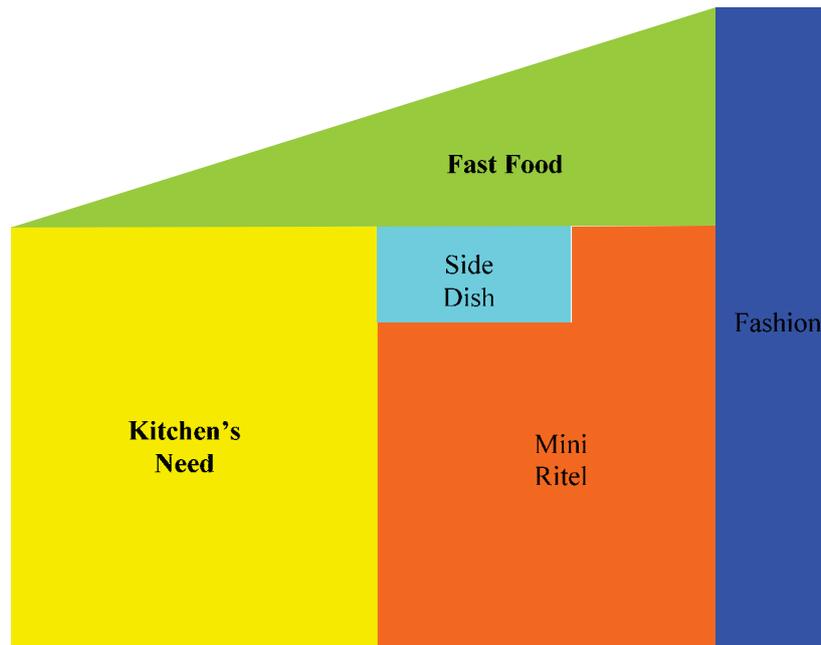


Figure 3 Proposed Market Stalls Based on Analysis

## ACKNOWLEDGMENT

This research was supported, in part, by Directorate of Research and Community Service Universitas Islam Indonesia.

## REFERENCES

- [1] Aryanti, Tutindan Ira Ernandayanti.2003. *Perempuan Pedagang di Pasar Ciwalengke, Majalaya*.Working Paper No. 13.Bandung :Akatiga
- [2] Muslimin, L., Indriati, F., dan Widayanti, T., 2007, Kajian Model Pengembangan Pasar Tradisional, *Buletin Ilmiah Penelitian dan Pengembangan Perdagangan*,Vol 1, No 2, hlm 2-46.
- [3] Harwati, Azka Yr, Hidayatullah S, 2011, Re-design Pasar Tradisional dengan pendekatan SEM, Clustering Analysis,dan MBA sebagai penguaitan Nilai daya Saing, *Prosiding Seminar Nasional Riset dan Teknologi Terapan*. Universitas Atmajaya Jakarta
- [4] Sinaga Pariaman, 2008, Menuju Pasar yang Berorientasi pada Perilaku Konsumen, Seminar pengembangan pasar tradisional oleh Koperasi dan UKM, Bogor
- [5] Sofianty, Nila, Sigit Widiantoro, dan F. Pramudita. 2007. *Wahana Ilmu Pengetahuan Sosial*. Jakarta :Yudhistira
- [6] Tambunan, M., Edi Priyono dkk.. *Dampak Krisis Ekonomi dan Liberalisasi Perdagangan terhadap Strategi dan Arah Pengembangan Pedagang Eceran Skala Kecil-Menengah di Indonesia*. Jakarta : Center for Economic and Social Studies (CESS), 1998
- [7] Takaendengan, Teddy.. Tesis Evaluasi dan Penyusunan Strategi Peningkatan Sistem Sanitasi Pasar-Terminal PAAL Ii Manado.Surabaya : ITS , 2007

## **Integrating Steepest Ascent for Taguchi Experiment: A Simulation Study**

**M. Arbi Hadiyat<sup>a</sup>, Rahman Dwi Wahyudi<sup>b</sup>**

<sup>a,b</sup> Faculty of Engineering, University of Surabaya, Surabaya 60293

<sup>a</sup>E-mail : arbi@staff.ubaya.ac.id

<sup>b</sup>E-mail : rahman.dwi.wahyudi@staff.ubaya.ac.id

### **ABSTRACT**

The Steepest Ascent (SA) method had been proven for its ability in moving experiment factor levels to optimal area in Response Surface Methodology (RSM). This method leads the design of experiment to track direction of factor levels movement, so that the global optimum would be reached. However, sometimes response variable being optimized by using RSM can't fulfill the classic statistical assumption following the surface regression model. Taguchi's orthogonal array as alternatives for RSM gives more loosely statistical assumption in performing the analysis. This method doesn't yet support for moving the factor level to optimum direction. Following the procedures of RSM in finding the optimal level combination by SA method, the Taguchi experiment also can lead to the global optimum response.

Integrating SA method in Taguchi experiment then was applied to a simulated response surface. The performance of this procedure then was evaluated according to its direction to reach the optimum. The simulation data was generated for two factors, representing the real case. The proposed procedure was then applied. The result from simulation study shows that the integrated SA method for Taguchi experiment successfully find the factor level combination that yields optimum response even not as close as possible as the RSM done.

### **Keywords**

*Steepest ascent, Response Surface Methodology, Taguchi, Regression model, Optimum response*

**This paper is published in International Journal of Technology (IJTech)**

## Quality Management Assessment of Food and Beverages Companies in Indonesia

Yuliana, ST<sup>a</sup>, Ir. Linasani Hadi, MSEM<sup>b</sup>, and Helena Juliana Kristina, MT<sup>c</sup>

<sup>a</sup>Faculty of Industrial Technology, Pelita Harapan University, Tangerang 15811  
E-mail : yuliana.fti@uph.edu

<sup>b</sup>Faculty of Industrial Technology, Pelita Harapan University, Tangerang 15811  
E-mail : linasani.hadi@uph.edu

<sup>c</sup>Faculty of Industrial Technology, Pelita Harapan University, Tangerang 15811  
E-mail : helena.kristina@uph.edu

### ABSTRACT

*Food and beverage industry is the largest industrial sub-sector in Indonesia. This research reports the assessment of quality management practices at Indonesian food and beverages companies. Assessment criteria were developed based on Malcolm Baldrige National Quality Award (MBNQA) 2011-2012 criteria. The survey was conducted to 27 food and beverage companies from small, medium to large industries. The results show the implementation of quality management practices at Indonesian food and beverages companies are at intermediate level. The results of factors measurement (scale from 1 to 9) consist of leadership (6.250), strategic planning (6.568), customer focus (3.880), measurement, analysis, and knowledge management (4.863), workforce focus (5.306), operations focus (5.200), and result (5.929). The results also indicate the influence of business scale and certification to quality management implementation in the companies. Six from seven existing factors show significant differences when grouped by business scale as well as certification. The factors that have significant differences are leadership, customer focus, measurement, analysis, and knowledge management, workforce focus, operations focus, and results.*

### Keywords

*Quality Management, MBNQA, Food and Beverages Industry, Indonesia*

### 1. INTRODUCTION

Food and beverage industry is the largest industrial sub-sector in Indonesia. Association of Indonesian Food and Beverage Companies (GAPMMI) [1] stated that, until the year 2009, there were 1.159.983 companies in this sub-sector, where 6.316 are large and medium industries, 66.178 small industries and the rest, 1.087.489 are home industries. The export from Indonesian food and beverages industry also increased during 2005 to 2009 with an average growth to 16% per year. During the period from January to May 2011, there is an increase in exports by 17.02% over the same period of the previous year. This growth in export market indicates the acceptable of Indonesian products in global market.

Since 2010, there has been an agreement in trading between ASEAN countries and China called China ASEAN Free Trade Area (CAFTA). One of the challenges facing the company, according to the Indonesian Directorate General of International Trade Cooperation Department of Commerce [2] is the way companies improve the efficiency and effectiveness of production. In addition, the company's ability in the mastery of information and communication technology is also kind of challenges. The government also faces the challenge of creating a good environmental business climate as well as regulations that are transparent, efficient and friendly to business world. Quality management is an answer to those challenges. American Society for Quality (ASQ) defines Total Quality Management (TQM) as a management approach to achieve long-term success by giving customer satisfaction through continuous improvement in quality, in terms of products, services, human resources, processes, and also the environment.

Over the last two decades, many researches have been done in quality management. Saraph, Benson, and Schroeder [3] initiated a study to identify critical success factors of quality management implementation. The study produced eight factors, namely management leadership, regulation of quality, training, product or service design, relationship with suppliers, process management, data and reports on quality, and employee relations. Tamimi and Gershon [4] developed an instrument to measure the implementation of quality management based on Deming's 14 points. Powell [5] developed 12 factors based on

the criteria of Deming, Juran, Crosby, and Malcolm Baldrige National Quality Award (MBNQA) 1992. The specific research in quality management implementation based on the criteria of MBNQA was conducted by Lau, Zhao, and Xiao [6]. They compared the application of quality management in companies focused on inspection, quality control (QC), and total quality management (TQM) in China. The result showed companies that focus on TQM have superior performance than companies that focus on inspection or QC. Prybutok, Zhang, and Peak [7] conducted a study to test the application criteria of MBNQA 2002 in the sectors of government organizations. The research concluded that MBNQA criteria model 2002 can be used to review and measure organizational performance.

Some researchers also tried to identify factors that may affect the application of quality management. Wali [8] examined factors such as firm size, ownership, cooperation, export, quality experience, leadership style, formal communication, informal communication, and competition. The research showed that only some factors such as ownership, quality experience, and leadership styles that affect the application of quality management. Yusof [9] conducted a study concerning the application of quality management in manufacturing small and medium-scale (small and medium enterprise) in Malaysia. Yusof also compare the critical success factors of quality management implementation between small and medium enterprises and large enterprises. The results show there are significant differences on several factors such as management leadership, resource management, measurement and feedback, and continuous improvement. Research on factors affecting the implementation of quality management was also done by Hendricks and Singhal [10] and Tesfayohannes [11]. Their results showed the influence of firm size on the application of quality management. However, this can not be proved by Saraph, Benson, and Schroeder [3] and Powell [5].

Some researchers also looked at the relationship or influence of ISO on quality management implementation. Gotzamani and Tsiotras [12] conducted empirical studies to look at ISO 9000 contribution to the company towards total quality management. They conducted a survey to measure the implementation of quality management in companies that already have ISO 9000 certification in Greece. The results indicated a good contribution of ISO 9000 for quality management implementation. It is supported by an increase in performance measurements on several factors, although not all of these factors indicate a significant difference before and after certification

The purpose of this research is to measure the implementation of quality management practices in Indonesian food and beverages companies based on MBNQA 2011-2012 guideline assessment. It will also identify the influence of business scale and certification to the results of the assessment.

## 2. LITERATURE REVIEW

Starting in 1987, U.S. Government through the National Institute of Standards and Technology (NIST) annually gives awards to companies and organizations in several fields such as manufacturing, service, education, health, small businesses, and nonprofit who successfully demonstrated quality and excellent performance improvements. This award is known as the Malcolm Baldrige National Quality Award (MBNQA). In 2005, Indonesia established Indonesian Quality Award Foundation (IQAF) who has a similar role with NIST. Annually, IQAF held Indonesian Quality Award which was adopted from the MBNQA.



Figure 1: Baldrige Criteria for Performance Excellence Framework  
 Source: NIST [13]

MBNQA criteria which also known as the **Baldrige Criteria for Performance Excellence** are embodied in seven categories such as shown in figure 1. The **leadership** category examines how senior management leads the organization and

how the organization leads within the community. The way organization fulfills its legal, ethical, and societal responsibilities are also measured in this category. The **strategic planning** category examines how organization develops its strategic objectives and action plan, implement their strategies and actions, and develop performance indicator to measures the progress. The **customer focus** category examines how organization engages its customer for long-term market success. It includes how organization listens to the voice of its customer, builds customer relationship and uses customer information to create improvement and innovation. The **measurement, analysis and knowledge management** category examines how organization collects and uses data to improve its performance. The **workforce focus** category examines organization's ability to assess workforce capability and capacity needs and build a conducive work environment. It also examines how organization empowers and involves its workforce. The **operation focus** category examines how organization designs, manages, and improves its work systems and work processes to deliver customer value and achieve organizational success and sustainability. The **result** category examines organization's performance and improvement in five key areas – product and process outcomes, customer-focused outcomes, workforce-focused outcomes, leadership and governance outcomes, and financial and market outcomes.

### 3. METHODOLOGY

The research method diagram can be seen in figure 2. The research was started with literature review to identify research problem and state the purpose of the research. As was stated before, the purpose of this research is to measure the implementation of quality management practices in Indonesian food and beverages companies based on MBNQA 2011-2012 guideline assessment identify the influence of business scale and certification to the results of the assessment.

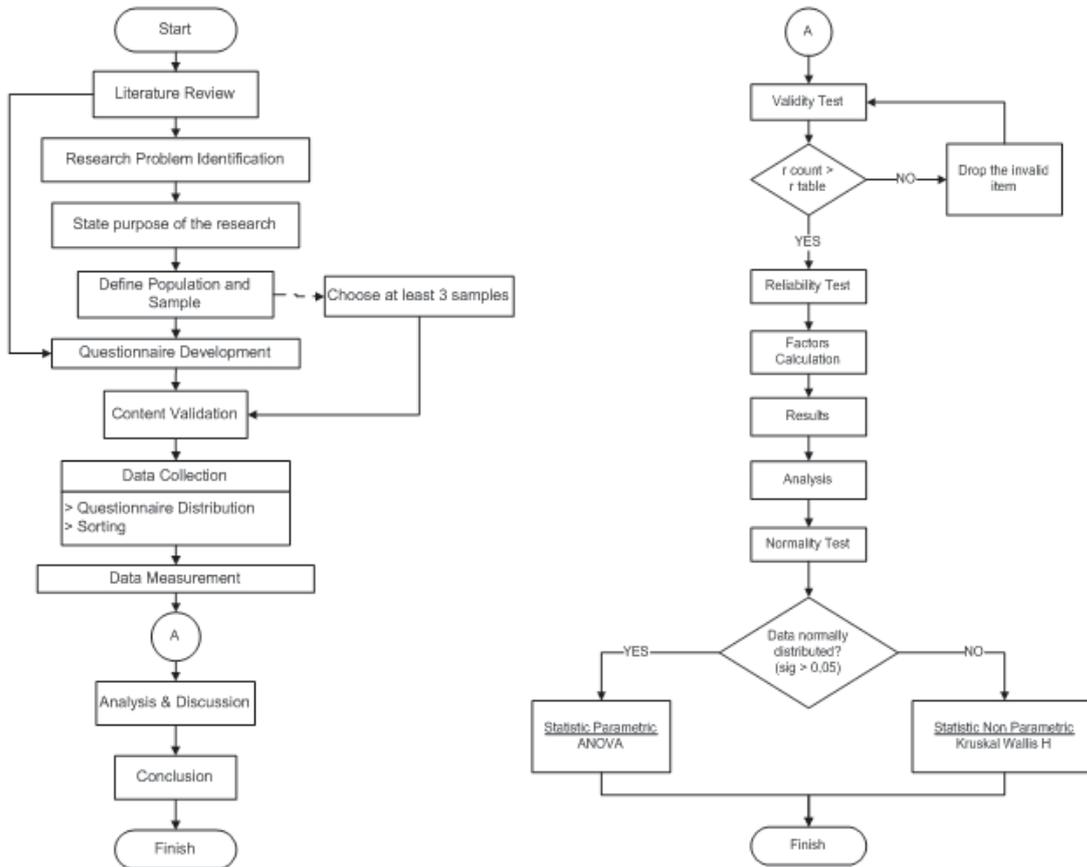


Figure 2: Method Diagram

#### 3.1 Participants

The participants of this research are companies from food and beverages industry in Indonesia. The number of population is 72.494 companies [1]. Based on Krejcie and Morgan [14], the number of minimum samples needed is 382 companies.

Respondents are senior leaders in the companies who are considered to have enough knowledge about the situation in several functional areas of the company.

### 3.2 Measurement

The measurement was based on questionnaires that were answered by the corporate leaders. The content of the questionnaire firstly be validated by minimum three experts who came among the corporate leaders. The questionnaire consists of two major parts. The first part includes profile of respondents and company attributes. The respondent's profile includes job position and the years of work at the company. Meanwhile, the company attributes consist of business area, form of business, number of labors, scope of market, and programs and certifications that have been achieved by company. The second part consists of indicators based on seven factors that were developed based on MBNQA criteria 2011-2012. These factors are leadership (F1), strategic planning (F2), customer focus (F3), measurement, analysis, and knowledge management (F4), workforce focus (F5), operations focus (F6), and results (F7). The response to each indicator was rated on a scale of 1 to 9 with five different type of answer, from very poor to very good. The influence of business scale and certification to quality measurement result later were examined using analysis of variance.

### 3.3 Procedures

The questionnaires were distributed to companies via email. The answered questionnaires then were sorted. Two parts of questionnaires should be answered completely. Hence, the questionnaires were tabulated. The factors then were tested for their validity and reliability. Factors that have been validated and considered to be reliable then be calculated. The results later be analyzed and compared to the previous findings.

## 4. DATA COLLECTION AND MEASUREMENT

The survey was planned to be conducted online by sending a letter and a web-based link address to corporate emails. 382 companies are needed as samples, but only 100 email addresses that successfully obtained. 100 emails were sent and 18 gave response. After a further review, only 12 corporate data can be used. It was then decided to get more data by going directly the respondents. It was done by visiting the exhibition of food and beverage industry and creating an appointment with the corporate leaders. Finally, 15 additional data obtained from direct visits. Thus, the overall data obtained to be processed further for this study is 27, where 14 are small and medium enterprises (SME) and 13 are large enterprise. The percentage number of respondent can be seen in figure 3.

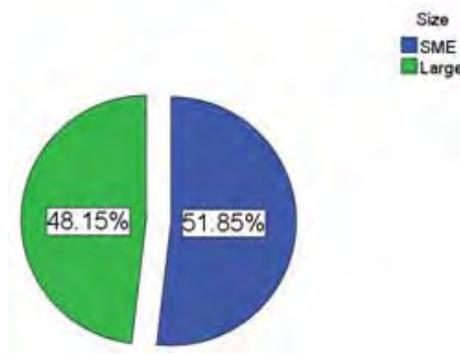


Figure 3: Percentage of Respondent Based on Business Scale

Table 1 shows descriptive results of respondents' profile. Respondents consist of owner, director, manager, and supervisor. Most of them (48,1%) have worked at the company for less than five years. 25,9% have been worked for five to ten years. Only a few (3,8%) who have worked for more than 20 years.

Table 1: Profile of Respondent

		SME (%)	Large (%)	Total (%)
<b>Respondent Position</b>	Owner	29,6	-	29,6
	Director	-	3,8	3,8
	Manager	14,8	25,9	40,7
	Supervisor	7,4	18,5	25,9
<b>Years of work</b>	< 5 years	29,6	18,5	48,1
	5-10 years	7,4	18,5	25,9
	10-15 years	-	-	-
	15-20 years	11,1	11,1	22,2
	> 20 years	3,8	-	3,8

Table 2 shows companies' attributes. Company attributes consist of company age, business form, scope of market and certification. 40,7% companies are less than 5 years. It indicates a growth trend in this industry. The business form consists of five types which were regulated by Indonesian government. Scope of market also consists of types, in local city, inter-city, inter-province, inter-island, and export. It is enabled for a company to have several scope of market. Meanwhile the certification attribute classify companies which have none certification, only national certification, or national and international certification. The result shows 48,2% companies have national and international certification, 37% only have national certification, and only 14,8% who have none of certification. The influence of certification and also business scale to the quality management result will be discussed in the next section.

Table 2: Company Attributes

		SME (%)	Large (%)	Total (%)
<b>Company Age</b>	< 5 years	29,6	11,1	40,7
	5-10 years	7,4	-	7,4
	10-15 years	-	3,8	3,8
	15-20 years	11,1	7,4	18,5
	> 20 years	3,7	25,9	29,6
<b>Business Form</b>	PT (PMA)	-	3,7	3,7
	PT (PMDN)	22,2	44,4	66,7
	CV	3,7	-	3,7
	Proprietorship	18,5	-	18,5
	None	7,4	-	7,4
<b>Scope of market</b>	In Local City	44,4	37,0	81,4
	Inter-City	29,7	37,0	66,7
	Inter-Province	37,0	37,0	74,0
	Inter-Island	37,0	40,8	77,8
	Export	3,7	37,0	40,7
<b>Certification</b>	None	14,8	-	14,8
	National	33,3	3,7	37,0
	National+	3,8	44,4	48,2
	International			

The second part of the questionnaire, the assessment indicators, then were measured by counting the mean of indicators for each factors. Table 3 shows the measurement results. It later be grouped based on their business scale and the certification to identify the influence of business scale and certification to the implementation of quality management in companies. The measurement were done using independent t-test for business scale's group (only two group) and ANOVA for certification's group. Before that, the data should be test for its normality and homogeneity. Based on business scale's group, factor 3 and 7 were found to be not normal. So, they were tested using Mann-Whitney U test, while factor 1, 2, 4, 5, and 6 be tested using independent t-test. Factor 1, 2, 4, 5, and 6 are homogen. Based on certification group, factor 5 and 7 were founded to be not normal. They later were tested using Kruskal-Wallis H test, while factor 1, 2, 3, 4, and 6 be tested using ANOVA. Factor 1, 2, 3, 4, and 6 are homogen.

Table 3: Measurement Results

Factor	Details	Mean
F1	Leadership	6,250
F2	Strategic Planning	6,568
F3	Customer Focus	3,880
F4	Measurement, Analysis, and Knowledge Management	4,863
F5	Workforce Focus	5,306
F6	Operations Focus	5,200
F7	Results	5,929

## 5. ANALYSIS AND DISCUSSION

Data measurement of quality management practices in table 3 shows that the quality management practices in Indonesia are at intermediate or medium level. The lowest score is factor 3, customer focus (3,880). The highest score is factor 2, strategic planning (6,568). Based on the scale used, from 1 to 9, the highest factor's score is still at intermediate level and need to be increased.

The study of Lau, Zhao, and Xiao [6] in companies in China indicated a better achievement in which the average value for each factor ranged from 7 to 8. Table 4 shows the comparison of the measurements of quality management in food and beverage companies in Indonesia with companies (manufacturing and services) in China.

*Table 4: Comparison of quality management measurement between companies in Indonesia and China*

Factor	Results of Quality Management Assessment	
	Indonesia	China
F1	6,250	8,020
F2	6,568	7,440
F3	3,880	7,947
F4	4,863	7,633
F5	5,306	7,563
F6	5,200	7,177
F7	5,929	7,213

The measurement results of quality management implementation in companies in China show superiority on each existing factors. Lau used MBNQA criteria 2002 as guideline assessment. The respondents came from manufacturing and service sector. While in this study, the criteria were based on MBNQA 2011-2012. The respondents were also limited to companies engaged in manufacturing sub-sectors of food and beverage industry. However, the result of Lau, Zhao, and Xiao is expected to give some idea as a comparison of quality management practices among companies of Indonesia and China.

### 5.1 Identification of business scale influence to quality management practices

Business scale is grouped into two categories, small and medium enterprises (SME) and large. The influence will be seen whether there are significant differences between factors on these two categories. Table 5 shows the summary of independent t-test and Mann Whitney U test on the factors.

Table 5 shows that there are significant differences in factor 1, 3, 4, 5, 6, and 7. There is no significant difference in factor 2, strategic planning. The calculation of the average value also clearly indicates the absence of significant differences in this factor. Some indicators in the assessment of this factor is short-term, medium, and long-term planning, forecasting, back-up plan, SWOT (Strengths-Weaknesses-Opportunities-Threats) analysis, considerations in strategic planning (economic conditions, market conditions, customer desires, and competition), making the work plan in accordance with the capacity and capability, and establishing indicators to measure the progress achieved during the implementation strategy of the company. The application of these assessment indicators on SME and large scale enterprises in Indonesia did not differ significantly. SME companies demonstrate the ability of strategic planning that is good enough and does not differ much when compared with large companies. Based on the existing seven factors, one factor did not differ significantly. Thus, it can be stated that the business scale has an influence in the implementation of quality management in the company. These results are supported by the findings of Hendricks and Singhal [10], as well as Tesfayohannes [11]. However, there are also some studies showing there is no effect between the scale of the business with the implementation of quality management, contributed by Saraph, Benson, and Schroeder [3], Powell [5], and Wali [8].

*Table 5: Measurement of Quality Management Practices based on Business Scale*

Factor	Par/nPar	Business Scale		Sig
		SME	Large	
F1	Par	5,735	6,804	Yes
F2	Par	6,213	6,950	No
F3	nPar	2,438	5,433	Yes
F4	Par	3,600	6,223	Yes
F5	Par	4,552	6,119	Yes
F6	Par	4,342	6,124	Yes
F7	nPar	5,402	6,497	Yes

## 5.2 Identification of certification influence to quality management practices

Certifications are grouped into three categories, namely companies that have none of certification, companies that only have national certification, and companies that already have national and international certification. National certifications consist of certification from Indonesian food and drugs regulatory agency, named BPOM and Indonesian National Standard, called SNI. International certifications can be International Standard organization (ISO), Hazard Analytical and Critical Control Points (HACCP), Good Manufacturing Practices (GMP), and other international standards. Table 6 shows summary of ANOVA and Kruskal Wallis H test which are used to identify the influence of certification to quality management practices.

Table 6 shows that there are significant differences in factor 1, 3, 4, 5, 6, and 7 as same as the results showed at table 5. Table 6 also showed companies with national and international certification have the highest score among the other two categories. The scores of companies that only have national certification are found to be lower on some factors than companies that have no certification. The post hoc test also showed that there is no significant difference between factors on companies that have no certification with companies that only have national certification.

Table 6: Measurement of Quality Management Practices based on Companies' Certification

Faktor	Par/ nPar	Certification			Sig
		None	National	National and International	
F1	Par	6,145	5,258	7,045	Yes
F2	Par	6,783	5,925	6,996	No
F3	Par	2,125	2,662	5,356	Yes
F4	Par	3,530	3,903	6,012	Yes
F5	nPar	4,841	4,309	6,217	Yes
F6	Par	4,580	4,004	6,311	Yes
F7	nPar	5,747	5,209	6,539	Yes

The national certification from BPOM can be differed into three labels, SP, MD, and ML. SP is given to small businesses with limited capital and supervision provided by the District Health Office / municipality. MD given to companies with greater capital and are expected to follow the food safety requirements set by the government. While the ML labels are given for processed food products and beverages that are imported products. The existence of various classifications of certification from BPOM results in the lack of standardization if we only look at the label of national certification or certification authorities from BPOM. So, it has to be clearer which type of national certification that the companies have.

The superiority shown by companies with national and international certification in any assessment of factors indicates that the quality management practices at these companies are better than the two other categories. One type of international certification that generally owned by company is ISO. ISO is a certification given to companies that have managed to meet a given set of requirements, depending on the type of ISO certification of registration undertaken by the company. ISO is required by companies to be more competitive in the global market. Gotzamani and Tsiotras [12] also indicated a significant difference in the performance of companies that already have ISO certification with those who have not yet.

## 6. CONCLUSION

This study aims to measure the quality management implementation among food and beverages companies in Indonesia. The survey was conducted of 27 companies engaged in food and beverage industry subsector. The study lasted four months, from August 2011 to November 2011. The following are results that can be inferred from the data analysis and discussion that has been done.

1. The measurement of quality management implementation is based on seven factors with the common assessment scale 1 (very poor) to 9 (very good). The results of measurements of these factors consist of leadership (6.250), strategic planning (6.568), customer focus (3.880), measurement, analysis, and knowledge management (4.863), workforce focus (5.306), operations focus (5.200), and result (5.929).
2. The application of quality management in food and beverage industry in Indonesia is at intermediate level. It is shown by an average factor value of 5.428.
3. Factor with the highest score is strategic planning (6,568). Factor with the lowest score that needs special attention from the company is customer focus (3.880).
4. Results identify the influence of business scale to quality management implementation. There are significant differences on the leadership factor (sig. 0.028), customer focus (sig. 0.000), measurement, analysis, and management information (sig. 0.000), workforce focus (sig. 0.002), operations focus (sig. 0.004), and the results (sig. 0.009).

5. Results also identify the influence of the company's certification to quality management implementation. There are significant differences in leadership (sig. 0.001), customer focus (sig. 0.000), measurement, analysis, and management information (sig. 0.000), workforce focus (sig. 0.005), operations focus (sig. 0.001), and the results (sig. 0.015).

## REFERENCES

- [1] GAPMMI. "Impor Makanan Minuman Melonjak 17%". June, 19 2011. Available from <http://www.gapmmi.or.id/?pilih=lihat&id=119>; Internet accessed on October, 2 2011.
- [2] Ditjen KPI Departemen Perdagangan. "ASEAN-China Free Trade Area". Februari 2010. Available from <http://ditjenkpi.depdag.go.id/Umum/Regional/Win/ASEAN%20-%20China%20FTA.pdf>; Internet accessed on October, 2 2011.
- [3] Saraph, J.V., Benson, P.G. & Schroeder, R.G. "An instrument for measuring the critical factors of quality management". *Decision Sciences* (1989), 20(4), pp. 810 –829.
- [4] Tamimi N. & Gherson M. "A tool for assessing industry TQM practice versus Deming philosophy". *Production and Inventory Management Journal* (1995), Vol. 36, pp. 27 –32.
- [5] Powell, T. C. "TQM as competitive advantage: A review and empirical study". *Strategic Management Journal* (1995), Vol. 16, pp. 15-37.
- [6] Lau, R.S.M., Zhao, Xiande, and Xiao, Ming. "Assessing quality management in China with MBNQA criteria". *International Journal of Quality and Reliability Management* (2003). Vol. 21 No. 7.
- [7] Pyburok, Victor, Zhang Xiaoni, and Peak, Daniel. "Assessing the effectiveness of the Malcolm Baldrige National Quality Award model with municipal government". *Socio-Economic Planning Sciences* (2010).
- [8] Wali, Senda. "Factors affecting TQM implementation: an empirical study in Tunisian firms". *The Global Conference on Business and Economics* (2007).
- [9] Yusof, Sha'ri Mohd. Total Quality Management (TQM) Advancement and Critical Success Factors for Implementation in Manufacturing Small and Medium Sized enterprise (SMEs). 2003.
- [10] Hendricks, K. & Singhal V. "Firm Characteristics, total quality management, and financial performance," *Journal of Operations Management* (2001), Vol. 19, pp.269-285.
- [11] Tesfayohannes, M. "The Implications of Total Quality Management in South African Small Industries," *Stockholm: International Council for Small Business and Entrepreneurship* (2011), Vol. 10.
- [12] Gotzamani, Katerina D. dan Tsiotras, George D. "An empirical study of the ISO 9000 standards' contribution towards total quality management," *International Journal of Operations and Production Management* (2001), Vol.21, No.10, pp.1326-1342.
- [13] NIST. "Malcolm Baldrige National Quality Award: Criteria for Performance Excellence 2011-2012". Available from <http://www.nist.gov/baldrige>; Internet accessed on August, 15 2011.
- [14] Krejcie, Robert V. dan Morgan, Daryle W. "Determining Sample Size for Research Activities". *Educational and Psychological Measurement* (1970).
- [15] BSN. "SNI Daya Saing Penguat Bangsa". 2010. Available from [http://www.bsn.go.id/files/1704711/genapsnibuku/BAB\\_9.pdf](http://www.bsn.go.id/files/1704711/genapsnibuku/BAB_9.pdf); Internet accessed on August, 20 2011.

# Factors Affecting The Selection of Toll Payment System: A Nested Logit Approach

Isti Surjandari <sup>a</sup>, Ruth Palupi Widya Handari <sup>b</sup>, Vanessa Janette <sup>c</sup>

<sup>a, b, c</sup> Industrial Engineering Department, Faculty of Engineering, University of Indonesia  
Kampus UI, Depok 16424, Indonesia  
E-mail: isti@ie.ui.ac.id ; ruth.palupi\_ti08@yahoo.com ; vanessa\_ti08@yahoo.com

## ABSTRACT

Electronic Toll Collection (ETC) has been implemented in Indonesia as a response of congestion caused by toll payment system inefficiency. The implementation of ETC and the utilization in Jabodetabek is still very low because there are wide variations in user characteristics and other factors influencing toll users' preferences in choosing toll payment alternatives. The main contribution of this research is to analyze user characteristic and determine factors affecting the selection of toll payment system using nested logit method. Nested logit predicts probability of each alternatives and coefficient of independent variables that affecting dependent variables. The result of this study shows that transaction time, initial investment, age, gender, frequency of using toll, and the use of e-toll card are significantly affect consumers' choice. The most preferred alternative is e-toll card (37,2%), e-toll pass (34,3%), and cash payment g(28,5%).

## Keywords

*Nested Logit, Electronic Toll Collection, Discrete Choice Analysis, E-toll Card, E-toll Pass*

## 1. INTRODUCTION

Toll road was built as an alternative to reduce the congestion that often occurs in metropolitan cities like Jakarta. However, congestion often occurs in the toll road itself, which is often the case of a very long queue at the toll gate. This is due to the toll payment system that is not efficient; especially by using the manual payment system that only accept cash. Manual payment system takes time because every car should stop between 4-6 minutes to make payment on the toll booths. One way to cope with long queues at the toll gates is to use an Electronic Toll Collection system (ETC).

In an effort to increasing its services, PT. Jasa Marga as the operator of toll roads, has started to implement the use of ETC in the form of e-toll-card in 2009. However, the ETC facility is only available in some toll roads only. Later, in 2012, PT. Jasa Marga introduces another alternative payment through ETC that is by using e-toll-pass. E-toll-pass can only be used at toll booths that have Automatic Toll Gate (GTO) system. E-toll-pass is an electronic toll payment system using communication devices installed on the vehicle (onboard-unit / OBU) which is automatically detected by the devices installed on the toll booth / GTO, so the vehicles passing through the toll booth does not need to stop for transaction. Just like the e-toll-card, e-toll-pass can only be used on some toll roads only.

Apart from the benefits in reducing congestion at the toll gates, the adoption of ETC usage in Indonesia is still low, where in the last three years the level of ETC used is only 20% of the total transactions. The low level of use of e-toll card could be because people are afraid of the risks in adopting new technology that they do not know well [1; 2; 3]. Along with efforts to increase the use of ETC, it is necessary to investigate factors that may affect users in choosing ETC to pay for the toll, so it can help PT. Jasa Marga in formulating marketing strategies of ETC. This study aimed to determine factors that affect the user in selecting toll payment system using Nested Logit method.

## 2. METHODOLOGY

Nested logit is one of the Discrete Choice methods that can be used to model problems in the selection of discrete alternatives. Nested Logit basically using logistic regression method to model discrete choices in the form of a hierarchical structure (nested), which describes the relationship between discrete alternatives as the dependent variable ( $Y_i$ ) and factors that influence the choice of discrete alternatives as the independent variables ( $X_{ij}$ ). The goal is to predict the probability of each alternative (the dependent variable) and to estimate the regression coefficients of each independent variable that may affect the dependent variable. Logistic regression is a type of regression that is appropriate for use when the dependent variable is categorical and has value between 0-1, while the independent variable is a variable that has a metric scale.

General notation of the Logit function can be described below [4]:

$$P(z) = \frac{1}{1 + e^{-z}} \quad (1)$$

Where  $P(z)$  is the probability of the dependent variable, and  $Z$  is the utility function of the independent variables. Utility function is a function that comes from all the independent variables used in the model. General notation of a utility function ( $z$ ) is described below:

$$Z = \beta_0 + \beta_1x_1 + \beta_2x_2 + \dots + \beta_ix_i \quad (2)$$

where  $\beta_0$  is a constant parameter, and  $\beta_1, \beta_2, \beta_i$  is the regression coefficient of the variable  $x_1, x_2, x_i$ . Logistic regression models can be classified based on the structure and number of dependent variables in the model. The simplest type of logistic regression is a binomial logit, where the dependent variable is only two. While in the multinomial logistic regression, the number of dependent variable number can be more than two. This study uses a Nested Logit as the number of dependent variable more than two, and the model has the form of a hierarchy.

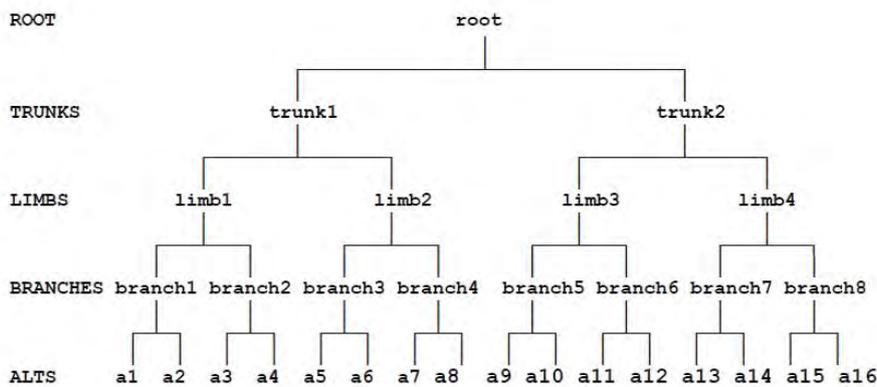


Figure 1: Hierarchical structure of nested logit model

This study uses primary data collected through questionnaires. To simplify the number of trials (the number of questions in the questionnaire), a "fractional factorial design" was used [5]. Hierarchical structure of the model used in this study can be seen in Figure 2 below.

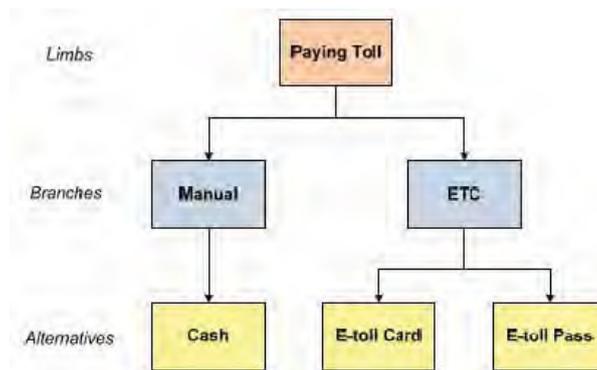


Figure 2: Hierarchical structure of the model in the selection of the toll payment system

Independent variables used in this study are: age, gender, education, marital status, occupation, income, frequency of using toll in a week, toll road which most often used, whether to use the e-toll card, transaction time and length of queue at the toll gate, total saving using ETC, bank provider of the e-toll card, initial investment to be able to use the e-toll card.

Dependent variable is considered to have a strong relationship with the customer behavior that can be formulated in the following utility function [6].

$$U = f(V_1, V_2, V_3, \dots, V_n) \quad (3)$$

where  $U$  is the total value of customer satisfaction, and  $f(V_1, \dots, V_n)$  is the functional relationship of the independent variables that affect the value of total customer satisfaction.

To get the values of the constant and coefficients of the regression function, this study uses the Maximum Likelihood Estimation method (MLE), that is, by maximizing its likelihood function [7]. Mathematically the likelihood function can be expressed as follows:

$$f(x_i) = p(x_i)^{y_i} [1 - p(x_i)]^{1-y_i} \quad (4)$$

Since each observation is assumed to be independent, then the likelihood function is the product of the individual likelihood function, namely:

$$L(\beta) = \prod_{i=1}^n f(x_i) \quad (5)$$

To maximize the likelihood function, it is necessary to find the maximum value of the function by using a differential technique, i.e. by changing the likelihood function into logarithmic form, as follows:

$$\ln L(\beta) = \ln \left( \prod_{i=1}^n f(x_i) \right) = \sum_{i=1}^n \ln f(x_i) \quad (6)$$

Once the utility function is obtained, then the expected number of consumers who choose an alternative toll can be estimated using the Nested Logit method. The probability of each alternative  $j$ , on branch  $b$ , limb  $l$ , and trunk  $r$  ( $j | b, l, r$ ) can be formulated as follows:

$$P(j|b,l,r) = \frac{\exp(\beta' \alpha_j | b,l,r)}{\sum \exp(\beta' \alpha | l,r)} \quad (7)$$

The probability of selecting a particular branch on limb  $l$  and trunk  $r$  can be written as follows:

$$P(b|l,r) = \frac{\exp(\alpha' \gamma | l,r) + \beta | l,r | b | l,r}{\sum \exp(\alpha' \gamma | l,r)} \quad (8)$$

While the probability of choosing limb  $l$ , on trunk  $r$  can be formulated as follows:

$$P(l|r) = \frac{\exp(\beta' \alpha | l,r) + \beta | l,r | l | r}{\sum \exp(\beta' \alpha | l,r)} \quad (9)$$

The probability of selecting trunk  $r$  is formulated as follows:

$$P(r) = \frac{\exp(\beta' \alpha | r) + \beta | r | r}{\sum \exp(\beta' \alpha | r) + \beta | r | r} \quad (10)$$

Hence, the probability of an individual in choosing an alternative can be formulated as follows:

$$P(j,b,l,r) = P(j|b,l,r) \times P(b|l,r) \times P(l|r) \times P(r) \quad (11)$$

### 3. RESULTS AND DISCUSSION

Data were collected from 210 samples, each consisting of 1890 observations (210 x 9 observations). Results of Nested Logit estimation can be seen in Figure 3. From the estimation results, it can be seen that costumers tend to prefer Electronic Toll Collection (ETC) with a probability of 71.53%, where the use of e-toll card is 37.25%, while the e-toll-pass 34.28%. This means that the majority of toll road users still prefer to use e-toll card instead of the e-toll-pass. But the probability is not very significantly different. When viewed from the respondents with a low frequency of using toll (1-2 times a week), it can be seen that the probability of the e-toll-pass is still quite large.

To determine the effect of the independent variables, it is necessary to compare the Wald test with its p-value of each variable. In Wald test, the null hypothesis is  $\beta_i = 0$  (no significant effect), while the alternative hypothesis is  $\beta_i \neq 0$  (there is a significant effect). If the independent variable significantly affect the selection of alternatives (the dependent variable), then the effect can be seen in the utility function (i.e., whether the regression coefficient is positive or negative). If positive, it will add to the utility, otherwise will reduce the utility.

Table 1 shows the result of the Wald test with its p-value. The t critical value for Wald test with  $\alpha = 0.05$  and  $df = 20$ , is 1.96. From Table 1 it can be seen that factors that significantly affect the individual in choosing the toll payment system are: age, gender, frequency of using toll in a week, whether to use the e-toll-card, transaction time and length of queue at the toll gate, and initial investment to be able to use ETC.

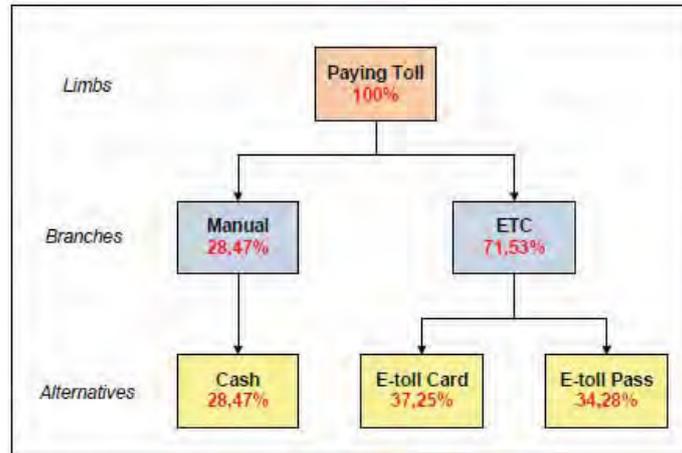


Figure 3: Probability of choosing the Toll Payment System

Table 1: Significance test

Variable		Wald Test		P-value test		Conclusions
		b/St. error	t-critical	P-value	$\alpha$	
Cash	Transaction Time	-2.35486	$\pm 1,96$	0.01853	0,05	reject Ho
E-Card	Transaction Time	-2.16179	$\pm 1,96$	0.030634	0,05	reject Ho
	Saving	0.972375	$\pm 1,96$	0.330864	0,05	accept Ho
	Bank Provider	-1.49746	$\pm 1,96$	0.134274	0,05	accept Ho
	Initial Investment	-2.13543	$\pm 1,96$	0.032726	0,05	reject Ho
E-Pass	Saving	1.91244	$\pm 1,96$	0.05582	0,05	accept Ho
	Bank Provider	-1.7894	$\pm 1,96$	0.073551	0,05	accept Ho
	Initial Investment	2.49134	$\pm 1,96$	0.012726	0,05	reject Ho
Age		-2.11456	$\pm 1,96$	0.034468	0,05	reject Ho
Gender		-2.15549	$\pm 1,96$	0.031124	0,05	reject Ho
Education		-0.97676	$\pm 1,96$	0.328686	0,05	accept Ho
Marital Status		-0.65342	$\pm 1,96$	0.513487	0,05	accept Ho
Occupation		1.94095	$\pm 1,96$	0.052264	0,05	accept Ho
Income		1.83422	$\pm 1,96$	0.066621	0,05	accept Ho
Frequency of using toll		2.17386	$\pm 1,96$	0.029716	0,05	reject Ho
Toll road which most often used		-1.67552	$\pm 1,96$	0.093832	0,05	accept Ho
Whether to use ETC		2.17196	$\pm 1,96$	0.029859	0,05	reject Ho

Based on the gender variable, it can be seen that the proportion of men who choose ETC system is larger than of women. Men who chose ETC is 78%, where women who choose ETC (e-toll card or e-toll pass) is 63.9% and 36.1% of them choose to pay in cash. This shows that men tend to prefer the ETC, while women tend to prefer the manual payment system (in cash). This may be due to the mindset of men who are able to accept and try new technology than women [8].

Table 2 shows the constant and coefficients of the utility functions of each alternative. While the probability of an individual in choosing the toll payment system (i.e. paying by cash, using the e-toll card, or using the e-toll pass) can be seen in formula 12, 13, and 14.

Table 2: Utility Function of each alternative

Choice Alternatives	Alternatives	Utility Function
Alternatives	Cash	- 0,1737 transaction duration - 0,0096 age - 0,0693 gender - 0,0091 education level - 0,0218 marital status + 0,0295 occupation + 0,0007 income + 0,0286 toll frequency - 0,0104 toll segment + 0,1801 use card
	E-Card	- 0,2134 - 0,0717 transaction duration + 0,0033 saving - 0,0249 bank - 0,0019 investment - 0,0096 age - 0,0693 gender - 0,0091 education level - 0,0218 marital status + 0,0295 occupation + 0,0007 income + 0,0286 toll frequency - 0,0104 toll segment + 0,1801 use card
	E-Pass	- 1,1815 + 0,0082 saving - 0,0466 bank + 0,0009 investment - 0,0096 age - 0,0693 gender - 0,0091 education level - 0,0218 marital status + 0,0295 occupation + 0,0007 income + 0,0286 toll frequency - 0,0104 toll segment + 0,1801 use card

P(CashManual, Pay Toll) =

$$e^{\frac{e^{\left(-0,1737 \text{ transaction duration} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}\right)}}{e^{\left(-0,1737 \text{ transaction duration} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}\right)} + e^{\left(-0,2134 - 0,0717 \text{ transaction duration} + 0,0033 \text{ saving} - 0,0249 \text{ bank} - 0,0019 \text{ investment} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}\right)} + e^{\left(-1,1815 + 0,0082 \text{ saving} - 0,0466 \text{ bank} + 0,0009 \text{ investment} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}\right)}}} \quad (12)$$

P(E-CardETC, Pay Toll) =

$$e^{\frac{e^{\left(-0,2134 - 0,0717 \text{ transaction duration} + 0,0033 \text{ saving} - 0,0249 \text{ bank} - 0,0019 \text{ investment} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}\right)}}{e^{\left(-0,2134 - 0,0717 \text{ transaction duration} + 0,0033 \text{ saving} - 0,0249 \text{ bank} - 0,0019 \text{ investment} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}\right)} + e^{\left(-0,1737 \text{ transaction duration} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}\right)} + e^{\left(-1,1815 + 0,0082 \text{ saving} - 0,0466 \text{ bank} + 0,0009 \text{ investment} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}\right)}}} \quad (13)$$

P(E-Pass|ETC, Pay Toll) =

$$\frac{e^{\beta} (-1,1815 + 0,0082 \text{ saving} - 0,0466 \text{ bank} + 0,0009 \text{ investment} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}}{e^{\beta} \ln(e^{\beta} (-0,2184 - 0,0717 \text{ transaction duration} + 0,0083 \text{ saving} - 0,0249 \text{ bank} - 0,0019 \text{ investment} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}) + e^{\beta} (-1,1815 + 0,0082 \text{ saving} - 0,0466 \text{ bank} + 0,0009 \text{ investment} - 0,0096 \text{ age} - 0,0693 \text{ gender} - 0,0091 \text{ education level} - 0,0218 \text{ marital status} + 0,0295 \text{ occupation} + 0,0007 \text{ income} + 0,0286 \text{ toll frequency} - 0,0104 \text{ toll segment} + 0,1801 \text{ use card}))}$$

(14)

#### 4. CONCLUSIONS

Adoption of Electronic Toll Collection (ETC) by toll road users in the Greater Jakarta (Jabodetabek) area is still low. Using Nested Logit method, this study aims to look at the effect of user characteristics in selecting toll payment system, which consists of 3 discrete choices, i.e. payment by cash, using the e-toll card, and using e-toll-pass.

The results of this study show that the characteristics of toll users are significantly influence the selection of toll payment system. Based on the Wald test, it was found that: age, gender, frequency of using toll in a week, whether to use ETC, transaction time and length of queue at the toll gate, initial investment to be able to use ETC were statistically affect the individual in choosing the toll payment system. The results of this study also showed that the toll payment system most widely used by respondents is the e-toll card (37.2%), followed by e-toll-pass (34.3%), and payment in cash (28.5%), where the proportion of men who use the ETC is more than that of women. Probability of toll users to use the ETC is 71.55%, which shows that the ETC is very potential to be developed in the Greater Jakarta (Jabodetabek) area.

#### REFERENCES

- [1] L. Ebolli, "Willingness-to-pay of public transport users for improvement in service quality," *European Transport*, no. 38, pp.107- 118, 2008.
- [2] D.A. Hensher, and J.M. Rose, "Toll product preferences and implications for alternative payment options and going cashless," *Transportation*, vol. 36, no. 2, pp. 131-145, 2009.
- [3] J. Holguín-Veras, and M. Preziosi, "Behavioral investigation on the factors that determine adoption of an electronic toll collection system: passenger car users," *Transportation Research Part C*, vol. 19, no. 3, pp. 498-509, 2011.
- [4] D.G. Kleinbaum, and M. Klein, "Logistic Regression, A Self-Learning Text," London: Springer Science Business Media, 2010.
- [5] D.A. Hensher, J.M. Rose, and W.H. Greene, "Applied Choice Analysis: A Primer," Cambridge: Cambridge University Press, 2005.
- [6] M. Ben-Akiva, and S.R. Lerman, "Discrete Choice Analysis: Theory and Application to Travel Demand," Cambridge, MA: MIT Press, 1985.
- [7] Gujarati, D. N. (2010). *Dasar-Dasar Ekonometrika*. Jakarta: Salemba Empat.
- [8] I. Wahyuningrum, "Strategi Pemasaran untuk Konsumen Wanita," *Jurnal Manajemen Informatika*, vol.1, no. 1, pp. 66-72, 2009.

# A Comparative Study of Housing Quality in Nigerian Public Housing Developments

Ishiyaku, Bala<sup>a</sup>, Kasim, Rozilah<sup>b</sup>, Harir, Isa Adamu<sup>c</sup>,

<sup>a,b,c</sup> Faculty of Technology, Management and Business, University Tun Hussein Onn Malaysia  
Parit Rajah, Batu Pahat, Johor Darul Ta'zim  
E-mail : balaishiyaku@yahoo.com

## ABSTRACT

*The study assessed the quality of public Housing in Nigeria, using accommodation capacities, structural qualities and material types indicators with a view to highlight the performance of State Housing Corporations in the provision of quality housing units for sustainable development. The major objectives are to identify the accommodation capacities, structural qualities and material types used in Housing Corporations' developments and analyse the relationship between houses developed by State Ministries of Housing and State Housing Corporations. Literature on relevant topics such as housing policy and housing development efforts in Nigeria were reviewed. Systematic random sampling technique was adopted to sample three states in Nigeria. The study reveals that the quality of houses developed by the State Housing Corporations is less than that of the State Ministries of Housing. Therefore Corporations should improve the materials used in their developments especially by venturing into local materials in their individual states to guarantee sustainable development.*

## Keywords

*Housing quality, public housing, housing development, housing corporations, ministries of housing*

## 1. INTRODUCTION

Housing is one of the most basic necessities of life, and the most important durable and long-time basic need of human life [16]. The relative importance of housing has through the years been generally recognised in the international development agenda. Virtually most of the studies, policies, programmes and strategies for international development agenda ranging from those of the International Year of Shelter for the Homeless (IYSH) between 1987 and 1988, to the Istanbul Declaration, the Habitat Agenda (1996), the Global Strategy for Shelter by the year 2000 (GS – 2000) and the declaration on cities and other human settlements in the New Millennium (2001) had all acknowledged and affirmed the critical importance of housing [3].

Reference [4] quoted a UN estimates (cited in Durand – Lasserre), which indicated that Africa has the world's highest urban growth, with an annual average of 4%. 37% of the total population of Africa live in an urban area and by 2030 the urban population is expected to account for more than 50% of the total population. Over the next two decades, it was estimated that nearly 90% of the population growth in Africa will take place in urban areas [2]. In 2008, the Nigerian housing deficit (to meet such growth) was estimated to be 14 million units, requiring about ₦35 trillion (\$270 billion) to fund. In fact, the World Bank estimated that Nigeria requires the production of about 720,000 housing units annually for 20 years in order to solve the housing needs of the country [25]. The agencies involved in housing delivery in Nigeria comprise of the Federal Mortgage Bank of Nigeria, Private Real Estate Developers, the Primary Mortgage Institutions, Commercial/merchant banks, insurance companies, pension administrators and State Housing Corporations.

## 2. BACKGROUND TO STUDY

Housing Corporations, as state owned corporate bodies operate under the general direction and supervision of Boards of Directors that are appointed by the state governments. The authority to appoint the Boards is almost exclusively vested with the state governors. This means that the Housing Corporations have separate legal personalities and can therefore enter into legally binding agreements and contracts with third parties, and they can sue and be sued in a court of law. The states own and control them by virtue of holding their share capital and appointment of their Board members and key officers [9]. While many agree that these corporations still have a role to play in the housing delivery system, there is a lack of consensus on how to go about making them more effective players in the production of quality units for the housing market. Some have suggested privatisation in one form or the other [10, 11, 9], while others have foresighted that more competition from private developers will force the Corporations to live up to expectation by producing most cost effective, cheapest and high quality houses in their respective states [18]. As there was no empirical evidence to justify their performance on housing quality especially for comparison with other public Housing Institutions, this study bridged the gap by providing in-depth comparative empirical study using performance indicators like accommodation capacity of the houses, structural quality and material types used.

Therefore, this study provided the yardstick that can be used to measure the sustainability or otherwise of the present policies of the State Housing Corporation. The contemporary issue is how far have these Housing Corporations gone in providing quality housing to the citizens? This refers to the quality of the houses as against that of other public housing institutions like State Ministries of Housing. When these issues were localised to the North Eastern region of Nigeria, then this research becomes relevant, soul searching and provide far reaching solution to Housing Corporation problems and the housing dilemma in general, especially with the growing urban needs for housing. The study sets to answer the questions; what is the accommodation capacity of the houses? How is the structural quality of the houses? What types of materials were used in public housing developments in the study area?

The aim of the study is to compare the performance of State Housing Corporations with State Ministries of Housing through housing quality with a view to highlight the performance of State Housing Corporations in the provision of quality housing units for sustainable development. To achieve the aim, the following objectives were forwarded;

- i) To identify the accommodation capacity of the houses developed by State Housing Corporations and State Ministries of Housing in North Eastern Nigeria.
- ii) To analyse the structural quality of the properties developed by State Housing Corporations and State Ministries of Housing in the study area.
- iii) To find out the type of materials used in the developments by State Housing Corporations and State Ministries of Housing in the study area.
- iv) To assess the differences in accommodation capacities, structural qualities and material types of the houses developed by State Housing Corporations and State Ministries of Housing in the study area.

### 3. LITERATURE REVIEW

As far back as 1996, [18] have observed that a little more than 50 years before, fewer than 7% of Nigerians lived in urban centre (that is, settlements with populations of 20, 000 or more). This proportion rose to 10% in 1952 and 19.2% in 1963. It was estimated that it was more than 45% in 1996. In fact, Nigerian cities are among the fastest growing in the world. Nigeria now has more than 7 cities with populations at 1 million; 18 cities, at more than 500,000; 36, at more than 200,000; and 78, at more than 100,000. As well, there were 5,050 towns with more than 20,000 people [18]. Furthermore, in 2002 [21] estimated that there are more than 85 cities in Nigeria with at least 200,000 people. Governments at Federal, State and local levels are therefore concerned with ensuring adequate provision of acceptable minimum standard houses to all households in demand [22] by implementing policies that address the problems of housing development, such as encouraging local materials development[20]. Building materials are believed to constitute 55% to 65% of the total cost of construction input. For instance, the table 1 from [14,15] below shows that iron sheets is the most commonly used roofing material in north eastern Nigeria while local materials such as mud bricks and wood bamboo were the least. These materials are the most available in Nigeria and if used effectively can make quality houses.

*Table 1: Percentage distributions of households in north eastern Nigeria by type of roofing materials*

State	Mud/Mud Bricks	Thatch/ Grass	Wood Bamboo	Iron Sheets	Cement Concrete	Roofing Tiles	Others	Total
Adamawa	10.8	34.5	0.6	53.2	0.7	0	0.2	100
Bauchi	9.9	47.2	1.4	33.3	0	0	8.1	100
Borno	7.8	19.5	1.6	56.2	1.5	0.2	13.1	100
Gombe	17.7	31.7	0.2	45.7	0	1.6	3.1	100
Taraba	14.4	29.4	0.6	43.0	0	0.6	12.0	100
Yobe	31.0	17.2	0.9	45.9	0.1	0	4.9	100

Another critical problem in quality housing production in Nigeria is sustainability of existing housing programmes. [8] asserted that the concept of sustainable development first emerged in the context of ecological and environmental concerns relating to the impact of human activity especially in developed industrial countries on the natural world. Sustainability is about meeting the needs of both the present and the future through clear thinking and sound planning. There is serious concern in Nigeria on sustainability of housing policies, finance, programmes and even housing institutions. It is a tradition in Nigeria and some African countries that whenever there is a change of government, most of the housing policies, finance system, programmes, and even institutions will be reshuffled, not because they are not performing but to suit the junta's interest, while Policy is a yardstick and cannot be thrown away with whenever and wherever the meaningful result is desired. This position might have been the reason for the introduction of the numerous housing-related policies witnessed in Nigeria. This includes the establishment of the Federal Mortgage Bank of Nigeria (1977); enactment of the Land Use Act (1978); founding of primary mortgage institutions (1989); floating of the Federal Housing Authority (1990); launching of a National Housing Policy (1991); introduction of the National Housing Fund (1992); initiation of the 'Housing for all by the year 2000' campaign; endorsement of and prosecution of the Vision 2010 crusade; formation of the various National Development and Rolling Plans; coming on board of an autonomous Ministry of Housing and Urban Development (2003); ratification of the NEPAD Initiative

and the Millennium Development Goals (MDGs); articulation of the National Policy on Housing and Urban Development (2004); extensive re-structuring of the banking sector (2006) and a host of such other efforts [1,19]. [24] complained that “with all beautiful programmes put forward to solve the housing problems in Nigeria, the problems of execution at the managerial level have been the stumbling block of these programmes”. The numerosity in housing policies in Nigeria may be blamed for the inconsistencies and overlap in their provisions. This factor further brings confusion to the investing public as they end up not knowing which policy or legislation takes precedence over the other to guide their housing developments.

The importance of Housing Corporations in housing development in Nigeria and worldwide cannot be overemphasized in view of the critical need for housing. [6] pointed that one of the major efforts by the government aimed at increasing housing delivery is the establishment of Federal Housing Authority and the counterpart State Housing Corporations. [5] observed that internationally, housing investments constitute 2 – 8% of Gross National Product (GNP), 20 -50% of household expenditure that indicates a significant correlation between the housing sector and the level of a country’s level of economic growth and development. Housing corporations have over the years assumed a strategic role in the housing delivery process. This can be attributed to the ever-widening housing delivery gap and the need to bridge the gaps. Although the appellation varies in different countries, the functions of the Housing Corporations are usually the same and are essentially geared towards housing delivery. In Nigeria, there are State Housing Corporations of which their names are inclined to the respective state and there is Federal Housing Authority (FHA), in Kenya, they called it National Housing Corporation (NHC), in Tunisia, Societe Nationale Immobiliere de Tunisie (SNIT), Botswana, The Botswana Housing Corporation (BHC), in Namibia, National Housing Enterprise (NHE), Tanzania, National Housing Corporation (NHC), and in Senegal, Office des Habitations a LogerModere (OHLM) to mention but a few [5].

#### 4. RESEARCH METHODOLOGY

The study was carried out through the interview and administration of questionnaire containing various questions on the components of the houses; such as number of bedrooms, living rooms, toilets, kitchens, availability of a garage, fence and materials used in ceiling, roof and floor. The data required for the purpose of this study were grouped and presented in the analysis according to the objectives and scope of the study [13] as demonstrated in table 2 below;

Table 2: Data requirement

Accommodation Capacity	Structural Qualities	Material Qualities
Number of Bedroom	Kitchen Quality	Windows/Doors Materials
Number of Kitchen/Store	Toilets Quality	Ceiling Materials
Number of Toilets/Baths	Doors/Windows Quality	Roofing Materials
Number of Living Rooms	Ceiling Quality	Wall Materials
Open Space	Floor Quality	Floor Materials
Fence	Roofing Quality	
Garage		

A total number of 500 questionnaires were administered and 311 were collected. The parameters used in measuring the quality variables of the houses on the questionnaire were presented in table 3 and table 4 below. Individual options were scaled based on their importance to the general public. Hence, an institution with higher points at each group and or after summation of the groups is determined to have better quality than the other.

Table 3: Measurement scale on accommodation

Questions	Scale			
	4	3	2	1
No. of rooms	Otherwise	5-6	3-4	1-2
No. of kitchen/store		Above 2	1-2	None
No. of toilets/baths		Above 2	1-2	None
No. of living room(s)		Above 2	1-2	None
Open space			Available	Not available
Fence			Available	Not available
Extra space			Available	Not available
Garage			Available	Not available

Table 3 above presents the parameters used in measuring accommodation spaces in the properties, with four (4) options given.

Table 4: Measurement scale on structural quality

Questions	Scale		
	3	2	1
Kitchen	Good	Fair	Bad
Toilets	Good	Fair	Bad
Doors/Windows	Good	Fair	Bad
Ceiling	Good	Fair	Bad

Floor	Good	Fair	Bad
Roofing	Good	Fair	Bad

There are three options given on structural quality of the house components in table 4 above. This was because the material and the accommodations were measured separately.

Table 5: Measurement scale on material type

QUESTIONS	SCALE				
	5	4	3	2	1
Window/door	Glass	Glazed Aluminium	Metal	Wood	Otherwise
Ceiling	Suspended	Asbestos sheet	Wooden	Plain Board	Otherwise
Roofing			Long span aluminium	Asbestos	Corrugated Iron sheet
Wall			Bricks	Sandcrete blocks	Mud
Floor	Tiles	Ceramics	Cement secrete	PVC	Otherwise

There are five (5) options given on materials as shown in table 5 above.

## 5. DATA PRESENTATION AND ANALYSIS

The data collected to answer the Research Questions were statistically presented in mean tables and descriptively analysed. The term Housing Corporations and Ministries of Housing were abbreviated 'Corps' and 'Mins' respectively. Analysis of the data collected for hypotheses was carried out with t-test statistical tool and descriptively analysed.

### 5.1 Accommodation Capacity of Houses

Table 6: The mean for accommodation capacity of houses developed by corporations and ministries

	Bedroom No.		Kitchen/Store No.		Toilets/Baths No.		Living Rooms No.		Open Space		Fence		Extra Space		Garage	
	Corps	Mins	Corps	Mins	Corps	Mins	Corps	Mins	Corps	Mins	Corps	Mins	Corps	Mins	Corps	Mins
Mean	1.44	1.70	2.04	2.05	2.04	2.37	2.05	2.19	1.90	1.77	1.54	1.50	1.71	1.78	1.19	1.49
Std. Error of Mean	0.045	0.044	0.016	0.024	0.017	0.039	0.023	0.037	0.025	0.032	0.042	0.038	0.039	0.032	0.045	0.046
Mode	1	2	1	2	1	2	1	2	2	2	2	1	2	2	1	1
Std. Deviation	0.527	0.575	0.186	0.312	0.204	0.508	0.277	0.485	0.301	0.425	0.500	0.501	0.457	0.413	0.531	0.598
Variance	0.277	0.331	0.035	0.097	0.042	0.258	0.077	0.235	0.091	0.180	0.250	0.251	0.209	0.171	0.282	0.357

The accommodation capacity of most houses developed by State Housing Corporations in North Eastern State are 1 – 2 bedrooms with 1 – 2 number of kitchens, toilets and living rooms. There are open spaces, fences and extra spaces for future development in the houses. There are more houses without garages than those that have it. However, when compared with the houses developed by State Ministries of Housing, It can be seen that the major areas of diversion are in the number of bedrooms, the houses developed by State Ministries of Housing are mostly 3-4 bedrooms capacity in contrast to 1-2 bedrooms with more kitchens/stores, toilets/baths, living rooms and availability of fencing.

Table 7: The t – test of significance on mean responds from corporations and ministries on accommodation capacity

		Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
NO. OF ROOMS	Equal variances assumed	0.415	0.520	-4.010	309	0.000	-0.253	0.063
	Equal variances not assumed			-4.045	305.097	0.000	-0.253	0.063
NO. OF KITCHENS	Equal variances assumed	7.843	0.005	-0.565	309	0.573	-0.017	0.030
	Equal variances not assumed			-0.592	284.401	0.554	-0.017	0.029
NO. OF TOILETS	Equal variances assumed	407.478	0.000	-7.102	308	0.000	-0.325	0.046
	Equal variances not assumed			-7.654	232.937	0.000	-0.325	0.042
NO. OF LIVING ROOMS	Equal variances assumed	58.668	0.000	-2.971	309	0.003	-0.137	0.046
	Equal variances not assumed			-3.127	278.262	0.002	-0.137	0.044
OPEN SPACE	Equal variances assumed	45.217	0.000	3.141	309	0.002	0.134	0.043
	Equal variances not assumed			3.246	303.114	0.001	0.134	0.041
FENCE	Equal variances assumed	1.052	0.306	0.743	308	0.458	0.042	0.057
	Equal variances not assumed			0.743	295.483	0.458	0.042	0.057
SPACE FOR DEVELOPMENT	Equal variances assumed	9.370	0.002	-1.549	309	0.122	-0.076	0.049
	Equal variances not assumed			-1.534	283.512	0.126	-0.076	0.050
GARAGE	Equal variances assumed	30.336	0.000	-4.624	309	0.000	-0.300	0.065
	Equal variances not assumed			-4.679	306.921	0.000	-0.300	0.064

Table 7 above shows that there is a significant difference in Number of Rooms, Toilets and Garage at 0.001 levels, while Number of Living Rooms and Availability of Open space are significant at 0.05 level. There is no significant difference in Number of Kitchen, Fence and Space for Future Development. In addition, t is significant within the institutions at 0.001 in Number of Toilets, Living Rooms, Open space and Availability of Garage. It is also significant in Space for Future Development. In contrast, t is not significant within the institutions in Number of Rooms and Fence.

## 5.2 Structural Qualities of Houses Produced by State Housing Corporations

Table 8: Structural qualities of houses developed by state ministries of housing

	Kitchen Quality		Toilets Quality		Doors/Windows Quality		Ceiling Quality		Floor Quality		Roofing Quality	
	Corps	Mins	Corps	Mins	Corps	Mins	Corps	Mins	Corps	Mins	Corps	Mins
Mean	2.50	2.65	2.41	2.58	2.50	2.47	2.42	2.35	2.44	2.62	2.47	2.71
Std. Error of Mean	0.044	0.043	0.045	0.043	0.043	0.044	0.047	0.044	0.047	0.041	0.045	0.039
Mode	3	3	2	3	3	2	3	2	3	3	3	3
Std. Deviation	0.578	0.509	0.583	0.509	0.558	0.515	0.613	0.521	0.615	0.487	0.588	0.458
Variance	0.334	0.259	0.339	0.259	0.311	0.266	0.376	0.271	0.379	0.238	0.346	0.209

Table 8 above presents that the kitchen, doors and windows, ceiling, floor and roofing components in Housing Corporation developments were of good quality with 3points each, and toilets were of fair quality with 2points. In contrast, the kitchen, toilet facilities, floor and roofing materials were also of good quality in Ministries developments, while that of doors and ceilings were of fair quality.

Table 9: The t – test significance of mean responds from state housing corporation and state ministries of housing on structural quality

		Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
KITCHEN QUALITY	Equal variances assumed	10.811	0.001	2.404	308	0.017	0.150	0.063
	Equal variances not assumed			2.435	306.000	0.015	0.150	0.062
TOILET QUALITY	Equal variances assumed	5.642	0.018	2.673	306	0.008	0.169	0.063

		Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
DOOR QUALITY	Equal variances not assumed			2.708	304.836	0.007	0.169	0.062
	Equal variances assumed	2.193	0.140	-0.360	306	0.719	-0.022	0.062
CEILING QUALITY	Equal variances not assumed			-0.363	301.830	0.717	-0.022	0.061
	Equal variances assumed	10.542	0.001	-1.139	306	0.255	-0.075	0.066
FLOOR QUALITY	Equal variances not assumed			-1.157	305.675	0.248	-0.075	0.065
	Equal variances assumed	17.935	0.000	2.814	306	0.005	0.181	0.064
ROOF QUALITY	Equal variances not assumed			2.877	305.594	0.004	0.181	0.063
	Equal variances assumed	33.732	0.000	3.892	306	0.000	0.238	0.061
	Equal variances not assumed			3.986	305.118	0.000	0.238	0.060

Table 9 reveals that there is a significant difference between the institutions in Kitchen Quality, Quality of Toilet, Floor Quality and Roof Quality. There is also a significant difference within the institutions in the Ceiling, Floor and Roofing Qualities, while there is no significance in Quality of doors both between and within the institutions.

### 5.3 The material quality of houses produced by State Housing Corporations

Table 10: Material qualities of houses developed by state Housing Corporation

	Windows/Doors Materials		Ceiling Materials		Roofing Materials		Wall Materials		Floor Materials	
	Corps	Mins	Corps	Mins	Corps	Mins	Corps	Mins	Corps	Mins
Mean	4.11	3.68	2.91	3.77	2.39	2.79	2.07	2.09	3.38	3.89
Std. Error of Mean	0.065	0.080	0.111	0.073	0.077	0.043	0.036	0.031	0.071	0.081
Mode	4	4	2	4	3	3	2	2	3	3
Std. Deviation	0.769	1.043	1.308	0.952	0.911	0.566	0.427	0.404	0.844	1.065
Variance	0.591	1.088	1.711	0.907	0.830	0.320	0.182	0.163	0.712	1.135

The response in table 10 shows that glass doors/windows, plain board ceiling, long span aluminium, sandcrete block wall and cement in floors were widely used. The only difference with properties developed by State Housing ministries is in ceiling materials where the suspended ceiling materials were used instead of plain boards. The table 11 below presents the statistical relationship between material qualities of housing units developed.

Table 11: The t – test of significant on mean responds from corporations and ministries on material type

		Test for Equality of Variances		t-test for Equality of Means				
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
DOOR TYPE	Equal variances assumed	22.962	0.000	4.058	309	0.000	0.430	0.106
	Equal variances not assumed			4.180	305.798	0.000	0.430	0.103
CEILING TYPE	Equal variances assumed	43.656	0.000	-6.737	309	0.000	-0.865	0.128
	Equal variances not assumed			-6.533	247.654	0.000	-0.865	0.132
ROOFING TYPE	Equal variances assumed	102.973	0.000	-4.694	309	0.000	-0.397	0.084
	Equal variances not assumed			-4.490	222.489	0.000	-0.397	0.088
WALL TYPE	Equal variances assumed	1.614	0.205	-0.345	309	0.730	-0.016	0.047
	Equal variances not assumed			-0.343	290.031	0.732	-0.016	0.047
FLOOR TYPE	Equal variances assumed	55.354	0.000	-4.607	309	0.000	-0.510	0.111
	Equal variances not assumed			-4.714	308.680	0.000	-0.510	0.108

It is clear from the table 11 that there is a significant difference in between the institutions in types of Door, Ceiling, Roofing and Floor materials used. It can be seen that only in Wall Type there is no significant difference. However, the table also reveals that there is a significant difference within the institutions in Types of Doors, Ceiling, Roofing and Floor Types used and there is also no significant difference in the Wall as between them mentioned above.

## 6. DISCUSSION OF FINDINGS

The reveals that State Housing Corporations were mostly involved in the production of 1-2 bedrooms, State Ministries of Housing was mostly involved in the production of 3-4 bedroom houses, the types of material and quality in State Housing Corporation houses were inferior to that of the State Ministries of Housing. The study identified two major quality deficient areas which are quality of toilets (table 8) and type of ceiling (table 10). These are the only areas, apart from the number of rooms, that the State Housing Corporation units were ranked lower than State Ministries of Housing and at the same time showing a significant level of difference between the institutions. The State Housing Corporations also have an edge over State

Ministries of Housing in provision of a fence (table 6), doors/windows and ceiling quality (table 8) but there is no significant difference between them. Therefore, the quality of houses developed by the State Housing Corporations is lower than that of State Ministry of Housing.

The findings of this study confirmed the criticism levelled against State Housing Corporations by [5]. He argued among other things that quality of houses developed by Housing Corporations is generally low which affect programmes and delivery capabilities. The findings of this study were further confirmed by personal interviews with staff of both institutions and physical observation of the houses. Hence, as good housing quality is important to the economic development of the households and quality of life [17] and also reduces cost of maintenance, hence encourages saving and effective economic planning. Housing Corporations should improve on the utilisation of standard building material types in their respective states. This can be achieved through research on locally available building material resources. Housing Corporations should as a matter of importance devise a means of utilising their microfinance banks and security development institutions in funding such researches toward improving quality housing developments. Reference [12] opined that “the answer to the question whether Housing Corporations should be privatised or commercialised can best be given by individual (states) considering their circumstances as revealed by this study. This study agreed that while some states are really trying, some need improvement as far as quality of houses is concern. Hence, they are not the required solution for efficient housing delivery in the region.

## 7. CONCLUSION

The continued government participation in housing delivery has generated a wide range of argument and concerns amongst analysts and researchers. Housing Corporations are very vital institutions for implementation of public housing programmes but they are poorly managed. The efforts of the State Housing Corporations in North Eastern Nigeria need applause here, as in most of the 18 number of the indicators used, their performance are relatively good. This shows that with little effort, Housing Corporations can be symbols of efficiency which can lead other public housing development institutions toward the provision of quality houses for sustainable public housing development.

## REFERENCES

- [1] A.G. Onibokun, & A.J. Kumuyi, “Governance and Waste Management in Africa,” Kenya Centro Internacional de Investigaciones para el Desarrollo, 1996.
- [2] B. T. Aluko, and A. Amidu “Issues on Urban Growth: Customary Title and Informal Settlements, Urban Low – Income Settlements, Land Deregulation and Sustainable Development in Nigeria,” Paper Presented at 5<sup>th</sup> Fig Regional Conference. Accra, Ghana, March, 2006.
- [3] D. C. I. Okpala, “Housing for All in Africa: The Institutional, Legal and Financial Frameworks for Efficient Housing Delivery,” in *Proceedings of Shelter-Afrique Annual Symposia*, M. W. Kimani, & O. Okonkwo, Eds. Nairobi, Kenya, Shelter-Afrique Publications, 1991-2004, pp. 163-174
- [4] D. K. Irurah, “Urbanisation and Housing Challenges,” Paper Presented at Cities in Africa Conference; Parallel Sessions on Urban Land Management, School of Architecture and Planning, University of the Witwatersrand, Dec. 2003.
- [5] F. Badejo, “Theoretical Premises: Housing Corporations in a Privatising Africa,” in *Proceedings of Shelter-Afrique Annual Symposia*, M. W. Kimani, & O. Okonkwo, Eds. Nairobi, Kenya, Shelter-Afrique Publications, 1991-2004, pp. 103-111
- [6] G. T. N. Tabansi, “Housing Delivery and Urban Renewal in Practice,” Paper presented at Jos-Bukuru Metropolis- Problems and Prospects on Housing Delivery/Urban Renewal, Jos, Nigeria. Oct. 2007.
- [7] I.E. Chukwujekwu, “The Roles of Housing Corporations in Housing Delivery; A Case Study of Kogi Investment and Properties Ltd,” *Housing Today*, 2005, Vol. 1, no. 9, pp. 6-8.
- [8] J. Chadchan, “Strategies for Sustainable Urban Housing Development - A Case of Pune City,” Roorkee, India, R.R. Shankar Indian Institute of Technology, 2007.
- [9] J. M. Malombe, “Future Prospects And Sustainability Of Housing Corporations In A Privatising Africa: The Case Of The National Housing Corporation In Kenya,” in *Proceedings of Shelter-Afrique Annual Symposia*, M. W. Kimani, & O. Okonkwo, Eds. Nairobi, Kenya, Shelter-Afrique Publications, 1991-2004, pp. 112-120
- [10] M. D. Rimber, “Housing Corporations in a Privatising Africa; the Kenya Experience,” in *Proceedings of Shelter-Afrique Annual Symposia*, M. W. Kimani, & O. Okonkwo, Eds. Nairobi, Kenya, Shelter-Afrique Publications, 1991-2004, pp. 125-129
- [11] M. Kasekende, “Future Prospects and Sustainability of Housing Corporations in A Privatising Africa: The Case of the National Housing and Construction Corporation (NHCC) Kampala, Uganda,” in *Proceedings of Shelter-Afrique Annual Symposia*, M. W. Kimani, & O. Okonkwo, Eds. Nairobi, Kenya, Shelter-Afrique Publications, 1991-2004, pp. 121-124
- [12] M. Molapo, “Making An Impact On Housing Delivery Experiences Of Lesotho Housing And Land Development Corporation,” in *Proceedings of Shelter-Afrique Annual Symposia*, M. W. Kimani, & O. Okonkwo, Eds. Nairobi, Kenya, Shelter-Afrique Publications, 1991-2004, pp. 130-139
- [13] N. Asika, *Research Methodology in Behavioural Sciences*. Lagos, Longman Nigeria PLC, 2005.
- [14] NBS/CBN (2006). Socio-Economic survey on Nigeria. Abuja. National Bureau of Statistics.
- [15] NBS/EU (2006). Core Welfare Indicators Questionnaire (CWIQ) survey. Abuja. National Bureau of Statistics.
- [16] N. Imam, “Nigeria’s 16 Million Housing Deficit still Rising,” Daily Trust, Dec. 2008, Retrieved from <http://www.dailytrust.com.ng>.

- [17] O. Lelkes and E. Zolyomi, "Housing Quality Deficiencies and The Link to Income in the EU," policy brief, European Centre for Social Welfare Policy and Research, Vienna, March 2010.
- [18] O. Okonkwo, "*Promotion and Financing of Real Estate Development in Nigeria, Bottlenecks, Recent Developments and Strategies,*" Paper Presented at Shelter Afric 5<sup>th</sup> International Conference and Exhibition on Housing, Abuja, Nigeria. March, 2006.
- [19] O.W. Ikechukwu, "*Policy Inconsistency in the Housing Sector: A Case for Reform,*" Paper Presented at Shelter Afric 5<sup>th</sup> International Conference and Exhibition on Housing. Abuja, Nigeria. March 2006.
- [20] P. V. Asperen, "Can Lessons Be Learnt From Improving Tenure Security in Informal Settlements," Delft, Netherlands. Jaap Zevenbergen Otb Research Institute, 2007.
- [21] R. Butler "Cities and urban areas in Nigeria with population over 100, 000," 2003, date accessed 16/02/2010. Retrieved from [www.mongabay.com](http://www.mongabay.com).
- [22] S. Lansley, "*Housing and Public Policy,*" London, Croom Helm Ltd, 1979.
- [23] T. K. Danso, "Provision of Housing in the Gambia. in *Proceedings of Shelter-Afrique Annual Symposia*, M. W. Kimani, & O. Okonkwo, Eds. Nairobi, Kenya, Shelter-Afrique Publications, 1991-2004, pp. 82-91
- [24] W. A. O. Akewusola, "*Solving Housing Problems in a Developing Economy- Case Study of Nigeria Housing Policies,*" Paper Presented at Shelter Afric 5<sup>th</sup> International Conference and Exhibition on Housing. Abuja, Nigeria. March, 2006.
- [25] Y. Kolawole, "Nigeria: Experts' Views on Housing Development," Vanguard. April 2008, Retrieved from <http://www.vanguardng.com>

## Simple Dual-Mode Wearable Antenna for Body-Centric Wireless Communications

**Koichi Ito**

*Graduate School of Engineering  
Chiba University, Chiba, 263-8522 Japan  
Tel : (043)290-3326. Fax : (043)290-3327  
E-mail : ito.koichi@faculty.chiba-u.jp*

### ABSTRACT

In recent years, a topic of body-centric wireless communications (BCWCs) has received an increasing amount of attention due to their potential applications in several areas, such as personal healthcare, identification system, entertainment and medical applications. Above all, many researchers have considered personal healthcare as the biggest potential application with all kinds of wearable wireless devices which can be used in on-body and off-body communications. For on-body communications, the communication range is limited on the human body. Both wearable transmitter and receiver are mounted on the surface of the human body, and biophysical signals obtained from body sensors can be transmitted along the human body. Off-body communications usually mean the communication between a device on the surface of the human body and a near external device. At least one antenna is located on the human body and biophysical signals can be transmitted from the antenna on the human body to the external device. For on-body communications, relatively low frequency bands (tens of MHz) are of great interest to a number of researchers, while for the off-body communications, 2.45 GHz ISM (industrial, scientific and medical) band is a good candidate, because higher data rate can be carried out and license is not needed. In this review paper, we introduce a simple dual-mode wearable antenna for BCWCs. In on-body mode, the received voltage at 10 MHz and in off-body mode, the reflection coefficient and radiation patterns at 2.45 GHz will be investigated. We consider a practical situation where the proposed antenna can be used for a medical care system. Some wearable and implantable sensors are mounted on or implanted into the human body. The proposed dual-mode antenna is mounted on the human arm. Medical information such as body temperature, blood pressure and heartbeat is transmitted from the sensors at 10 MHz to the receiver which is of dual-mode function for on-body communication. After receiving the information, the collected medical data can be transmitted from the antenna to an external device at 2.45 GHz. For a further study, we will develop more practical and useful wearable antennas for BCWCs.

### Keywords

*Wearable antenna, dual-mode, body-centric communications, on-body, off-body*

## Single-dopant Atom Devices for Future of Nanoelectronics

Michiharu Tabe, Daniel Moraru, Earfan Hamid and Takeshi Mizuno

Research Institute of Electronics  
Shizuoka University, 3-5-1 Johoku, Naka-ku, Hamamatsu, Japan  
Tel : +81- 53-478- 1307 Fax : +81- 53-478- 1335  
E-mail : romtabe@rie.shizuoka.ac.jp

### ABSTRACT

Since invention of *transistor* in 1948, dopant atoms have played key roles in semiconductor technology, and we have utilized averaged effect of a statistically large number of dopant atoms on electronic properties. However, with continuous miniaturization of transistors in silicon integrated circuits, the number of dopant atoms is dramatically reduced, reaching even below ten in the nanometer-sized channel. Thus, we are facing at huge fluctuation in  $I$ - $V$  characteristics of transistors due to *individuality of dopant atoms*. Nowadays, many researchers in Si technology are working to suppress the dopant-induced fluctuation.

However, our direction is different, and we are challenging to create a new type of devices, that is, *atom transistors*. The atom transistors are promising in terms of the highest density of transistors and the lowest consumption energy in integrated circuits. We believe that the single-dopant-atom technology opens up future of nanoelectronics.

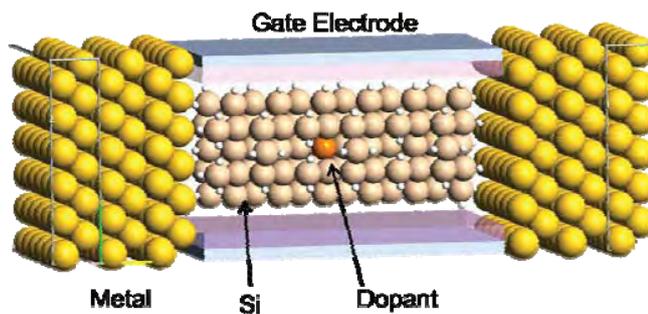


Fig.1 Schematic view of a single-dopant-atom transistor.

### Keywords:

Atom device, single-dopant, silicon, nanodevices, nanoelectronics

# Nanophotonics for Live Cell Observation with High Resolution

Wataru Inami

Division of Global Research Leaders,  
 Shizuoka University  
 Johoku, Hamamatsu 432-8561, Japan  
 Inami@eng.shizuoka.ac.jp

Yausunori Nawa and Yoshimasa Kawata

Department of Mechanical Engineering,  
 Shizuoka University  
 Johoku, Hamamatsu 432-8561, Japan  
 kawata@eng.shizuoka.ac.jp

**Abstract**—We have developed electron beam excitation assisted optical microscope, and demonstrated its resolution higher than 50 nm for live cell observation. In the microscope, a light source in a few nanometers size is excited by focused electron beam in a luminescent film. The microscope makes it possible to observe dynamic behavior of living biological specimens in various surroundings, such as air or liquids. Scan speed of the nanometric light source is faster than that in conventional near-field scanning optical microscopes. The microscope enables to observe optical constants such as absorption, refractive index, polarization, and their dynamic behavior on a nanometric scale. We also have developed a direct electron-beam excitation assisted optical microscope with a resolution of a few tens of nanometers and it can be applied for observation of dynamic movements of nanoparticles in liquid. In the microscope, fluorescent materials are directly excited with a focused electron beam. The direct excitation with an electron beam yields high spatial resolution since the electron beam can be focused to a few tens of nanometers in the specimens. We demonstrated an observation result of living CHO cells. The microscope opens new microscopy applications in nano-technology and nano-science.

**Keywords**—Optical microscopy, electron scanning microscopy, near-field optical microscopy, nano-imaging, bio-imaging, cathodoluminescence

## I. INTRODUCTION

Nanoimaging of specimens in liquid conditions are highly required in various applications such as analysis of colloidal solutions, observation of microcrystal growth and self-assembly process, etc. Especially, imaging of biological specimens with high resolution is crucial for a deeper understanding of cell functions. Fluorescence microscopy has been widely used to analyze the dynamic behavior of cellular components in living cells, because stained molecules of interest in the specimens can be imaged with high contrast [1, 2]. In addition, the use of light for cell imaging enables relatively non-invasive observations under physiological conditions. However, many structures in cells are small to be resolved with a standard optical microscope as a consequence of the finite resolution due to the diffraction limit of light.

Recently, several concepts for super-resolution techniques have been developed and proposed for observations of nanostructures in cells [3–6]. Fluorescence microscopy is required to become an even more useful tool for biological analysis with nanometer-scale resolution.

Near-field optical scanning microscopes [7-9] (NSOMs) are possible to overcome the resolution limitation, because they confine illumination area on the specimen by small aperture of metal-coated fiber probe [10-13], or apertureless tip probe [14,15], optically-trapped gold particle [16], solid immersion lens [17], non-optically probing technique [18]. Images are acquired by scanning the small aperture near specimen surface while keeping a constant distance from the specimen surface. A common method of keeping probe-specimen distance is detection of shear forces between the end of the near-field probe and the specimen surface [19,20].

In the NSOMs low throughput [11] of the small aperture limits the scanning speed, because accumulation of signal is required in order to obtain a higher signal-to-noise ratio. Throughput of the fiber probe is given by  $< (d/\lambda)^4$  where  $d$  is the diameter of the aperture and  $\lambda$  is wavelength. Signal-to-noise ratio decreases in proportion to the fourth power of the diameter of the aperture, and worsens rapidly with increasing the resolution. Therefore, the scanning speed of the fiber probe is restricted by difficulty of keeping the probe-specimen distance and low signal-to-noise ratio. The low frame rate of the NSOMs limits the applications to observe dynamic process of living biological specimens or other fast phenomena.

Here, we present electron beam excitation assisted optical (EXA) microscope in which electron beam focused on a luminescent thin film excites nanometric light source near the specimen. The light emission is well known as cathodoluminescence [21,22]. It is possible to excite a light source of a nanometric size, because electron beam can be focused to a few nanometers. EXA microscope combines scanning electron microscopy that has nanometric resolution and optical microscopy that is advantageous to dynamic observation of living biological specimens.

## II. 2. DEVELOPMENTS OF EXA OPTICAL MICROSCOPY

Figure 1(a) shows schematic diagram of the proposed EXA microscope. An electron beam is focused on a luminescent film. A specimen is put on the luminescent film directly. The inset in Fig. 1(a) shows magnified image of the luminescent film and the specimen. Nanometric light source is excited in the luminescent film by the focused electron beam. The light source illuminates the specimen, and the scattered or transmitted radiation is detected with a photomultiplier tube (PMT). The light source is scanned by scanning of the focused

electron beam in order to construct on image. Figure 1(b) shows the structure of sample holder used in EXA microscope. A square aperture of  $100 \times 100 \mu\text{m}^2$  size was fabricated on silicon substrate and sealed by SiN film with a thickness of 50 nm.

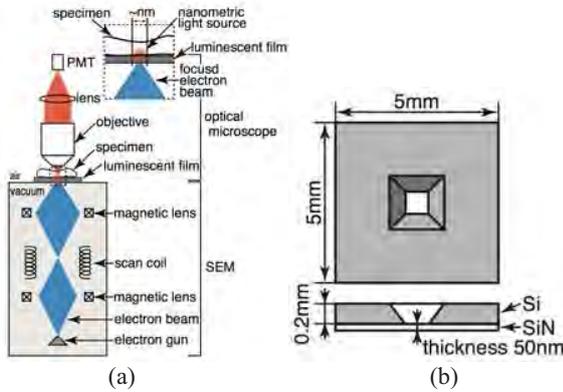


Fig. 1. (a) Schematic diagram of EXA microscope. The scanning electron microscope (SEM) is used for excitation and scanning of nanometric light source and the optical microscope is used to detect the light. (b) Layout of silicon nitride membrane.

In EXA microscope, focusing of the electron beam confines the size of optical spot instead of small apertures used in conventional NSOMs. A few tens nanometer size optical spot is produced easily, by electron beam focused in a few nanometers area. The microscope has a potential to observe dynamic activities of living biological specimens with video frame or faster frame rate, because electron beam can be scanned with modulation of magnetic or electric field without any mechanical moving parts. Higher signal-to-noise ratio is possible, by using highly efficient luminescent film for electron beam irradiation.

Another unique advantage of EXA microscope is the possibility to observe specimens in various environments, such as air, gases, liquids, as well as vacuum. The luminescent film separates air or liquids surrounding specimens from vacuum where electron beam is focused. Since electron beam energy is converted to light at the luminescent film, and scattered and transmitted radiation from the specimen is detected as signal, vacuum is not required on the specimen side. If the luminescent film does not have enough strength for the separation, one may support the film with transparent thin film.

To verify feasibility of the high resolution EXA microscope, we used silicon nitride (SiN) film of 50 nm thickness as a luminescent material [23] and all optical components were inserted in vacuum chamber of scanning electron microscope (SEM) (JEOL, JSM-6390). SiN film emits blue to ultra-violet (UV) light by irradiation of electron beam. We confirmed in a preliminary experiment that SiN film of 50 nm thickness had enough strength to separate 1 atm air pressure from vacuum.

In the experiment, electrons were accelerated with 10 kV voltage and focused to a 8 nm diameter spot on the SiN film to excite nanometric light source. Scattered or transmitted light

from the specimen was collected by a lens with numerical aperture 0.65 and detected with a photomultiplier tube (PMT) (Hamamatsu Photonics, R7400-U20). Images were reconstructed from the signal detected with raster scanning of electron beam using a computer. We used polystyrene latex spheres dispersed on the SiN film directly as specimens for resolution verification. The latex spheres were dispersed in monolayer, which was confirmed with an atomic force microscope (Seiko, SPI-3800).

Figure 2(a) shows observation results of latex spheres of 50 nm diameter with EXA microscope. Figure 2(b) shows intensity distribution on the solid line indicated in Fig. 2(a). It is recognized that EXA microscope can resolve aligned spheres of 50 nm diameter clearly. We believe that the developed EXA microscope has a potential to achieve a few tens nanometer resolution because electron beam can be focused in a few nanometers.

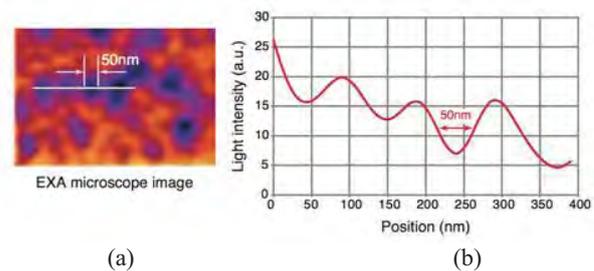


Fig. 2. (a) Observation image of 50nm diameter latex spheres with EXA microscope. (b) Intensity distribution on the solid line indicated in (A). The latex spheres were dispersed in a monolayer on SiN surface.

### III. 3. D-EXA MICROSCOPY FOR DIRECT EXCITATION

We also have developed a direct electron-beam excitation assisted optical microscope (D-EXA microscope) combining a scanning electron microscope (SEM) with a fluorescence microscope [24,25]. The D-EXA microscope is another type of the super-resolution fluorescence microscopes, which has the advantages of spatial resolution of a few tens of nanometers, and the ability to image dynamic behavior of nanoparticles in liquid conditions. In the microscope, fluorescent particles, which is can be used for labeling of biological specimens, are placed on the film used as the electron transparent window, and irradiated with a focused electron beam to directly excite luminescence. A high spatial resolution is achieved by direct electron beam excitation through the film, since the electron beam can be focused in a smaller region than that of light even if some of the electrons are scattered in the film. Specimens can be observed in their native state in a liquid environment, because the film is used to separate the environment of the specimen from the vacuum in the microscope. The excited luminescence with the electron beam is the so-called cathodoluminescence [26-29]. In this work, we observed the dynamic behavior of fluorescent nanoparticles in solution, and demonstrated the application to live cell imaging in culture

solution using a prototype D-EXA microscope in order to demonstrate the potential for live cell imaging.

Figure 3 shows the principle of direct excitation with a focused electron beam in the D-EXA microscope. Specimens are directly placed on a thin film, and irradiated with an electron beam through the thin film. The focused electron beam directly excites luminescence. The electron beam can be focused to an area of approximately 2 nm in diameter in vacuum [29], and the focus spot was broadened in a few tens nanometers region by electron scattering in the film and specimens. The scattering was estimated with Monte-Carlo simulation [30]. High spatial resolution can thus be realized by exciting with this focused electron beam.

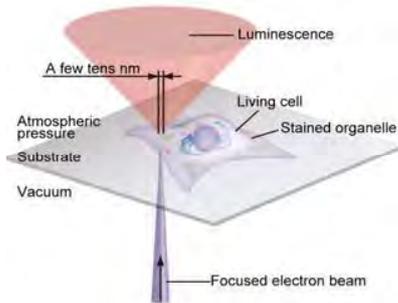


Fig. 3. Principle of the D-EXA microscope.

Since the thin film separates the vacuum from the environment such as air or liquid where the specimens are placed, the specimens do not need to be in vacuum and it is possible to observe the dynamic behavior under various conditions. The D-EXA microscope allows for the analysis of cell functions in the nanometer-scale under physiological conditions.

We selected 100 nm zinc oxide (ZnO) nanoparticles (SIGMA-ALDRICH, PN. 544906) as fluorescent materials that can be excited with an electron beam. The microscope also required an electron-transparent film to separate the vacuum section from atmospheric pressure to observe specimens in a liquid. A silicon nitride ( $\text{Si}_3\text{N}_4$ ) film was employed as the thin film. The thickness of the film was 50 nm with a size of  $50 \mu\text{m} \times 50 \mu\text{m}$ .

We observed the movements of ZnO nanoparticles in ultrapure water to demonstrate the potential to observe the dynamic behavior of nanoparticles in a liquid. ZnO nanoparticles move by convective flow in the droplet. The observation was started just after the droplet containing ZnO nanoparticles was dropped on the thin film. The dynamic behavior of the moving nanoparticles was observed and tracked by time lapse imaging.

The observation result is shown in Figs. 4(a)-4(e) show five frames from the video. The video was acquired at 3 fps with the size of  $256 \times 256$  pixels. Figures 4(f)-4(j) show magnified images of the respective areas indicated by the squares in Figs. 4(a)-4(e). In Figs. 4(b) and 4(c), the ZnO nanoparticles indicated by the dashed circle disappeared in the subsequent image. Since the electron beam was focused on the surface of

the thin film, nanoparticles move away from the surface of the film and the nanoparticles disappeared from the observed image. On the contrary, when the ZnO nanoparticles moved close to the surface of the film, the nanoparticles were observed in the luminescence image as shown within the solid circles in Fig. 4(c). Figures 4(f)-4(j) show ZnO nanoparticles moving along the surface of the film. As shown in Figs. 4(f)-4(j), the ZnO nanoparticle, indicated by an arrow in the figures, moved in a planar direction with changing luminescence intensity. Figure 4(k) shows a track of the moving ZnO nanoparticle. The ZnO nanoparticle moved a total of  $1 \mu\text{m}$  over 96 s. We also observed other nanoparticles randomly moving with the change in the luminescence intensity. The change in the luminescence intensity showed that the nanoparticles move up and down within the focal plane of the electron beam.

These results demonstrated that fluorescent materials and their movements in a liquid can be observed with direct electron beam excitation in the D-EXA microscope.

We observed living MARCO-expressing CHO cells, using the D-EXA microscope to confirm the potential for live cell imaging. In order to observe cells in our method, cells were directly cultured on the  $\text{Si}_3\text{N}_4$  film. After incubation, the culture dish was set to the specimen holder of the D-EXA microscope and observed.

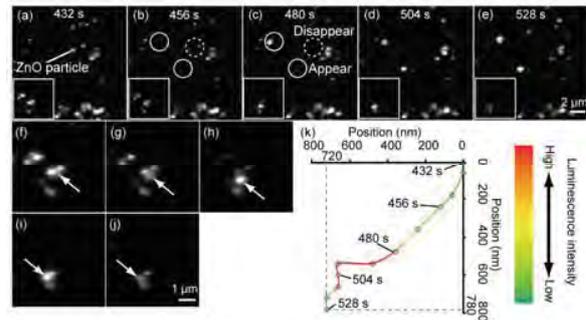


Fig. 4. Observation results of the movements of 100 nm ZnO nanoparticles in a water solution. (a)-(e) Time lapse images of the movements of ZnO nanoparticles. (f)-(j) Magnified images of the areas indicated by the squares in Figs. 4(a)-4(e). The ZnO nanoparticle indicated by the arrow moved along the surface of the film. (k) An analysis of the movement of the ZnO nanoparticle.

Figure 5(a) shows a luminescence image of the cells acquired with the D-EXA microscope, and Fig. 5(b) shows a phase contrast microscope image. Cells were observed in culture solution without any treatments, such as fixation and drying. The shape of each cell was clearly recognized and some bright spots were observed in cells. We believe that the bright spots indicated with arrows were auto-fluorescence of intracellular granules and light-grey regions were auto-fluorescence of cell membranes. It is clearly demonstrated that the D-EXA microscope is useful tool for observation of living biological cells in physiological conditions.

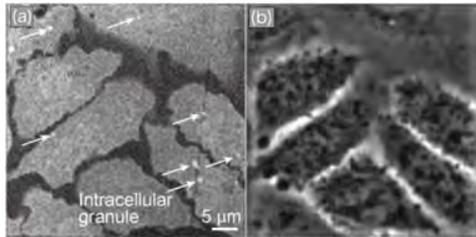


Fig. 5. Observation results of living cells using the D-EXA microscope. (a) A luminescence image of living MARCO-expressing CHO cells in culture solution without any treatments. The intracellular granules indicated with arrows are observed as white spots and the cell membranes are observed as light-gray contrast against the dark-gray background. (b) A phase contrast microscope image of the living cells. It represents the same area as Fig. 5(a).

#### IV. 4. CONCLUSION

We proposed a new type high-resolution optical microscope and demonstrated its resolution higher than 50 nm. The concept of EXA microscope is an integration of a high-resolution SEM and an optical microscopy suitable for observation of living biological specimens and spectroscopic analysis of materials. Due to the conversion of the electron beam to light source, specimens can be placed in air or liquids, as well as vacuum. Since electron beam can be scanned at a fast speed, it is possible to observe dynamic behavior of specimens with fast frame rate. We expect that the EXA microscope can resolve the scanning speed limitation of conventional NSOMs due to low signal-to-noise ratio at higher resolution, and difficulty of maintaining the probe-specimen distance.

It is possible to apply EXA microscope in a variety of research fields by using functionalized thin film as the light emission layer. Fluorescent imaging can be obtained with UV emission materials, and spectroscopic properties of specimens can be analyzed by using a luminescent layer emitting in a broad wavelength region. Dot-array structure [31,32], nanohole array [33] and nano-cylinder array structure [34] in luminescent films may be effective to reduce electron scattering in luminescent films.

We have also developed the D-EXA microscope as a technique with high spatial resolution beyond the diffraction limit of light. A spatial resolution greater than 100 nm was achieved for the D-EXA microscope and the dynamic behavior of moving nanoparticles in water was observed by time-lapse imaging. We also demonstrated luminescence image of living cells in culture solution without any treatments. The D-EXA microscope can be applied for the analysis of cell functions in live cells stained with fluorescent materials such as ZnO.

In future work, we need to evaluate the damage to the specimen by electron beam irradiation as well as optimization of the acceleration voltage of the electron beam, the film thickness and the material in order to minimize any damage to the sample and improve the spatial resolution. We believe that EXA and D-EXA microscopes open new microscopy

applications because it realizes a new tool in nano-technology and nano-science.

- [1] J. Lippincott-Schwartz, E. Snapp, and A. Kenworthy, "Studying protein dynamics in living cells," *Nat. Rev. Mol. Cell Biol.* 2(6), 444-456 (2001).
- [2] R. Y. Tsien, "Imagining imaging's future," *Nat. Rev. Mol. Cell Biol.* 5(Suppl), SS16-SS21 (2003).
- [3] M. Fernández-Suárez and A. Y. Ting, "Fluorescent probes for super-resolution imaging in living cells," *Nat. Rev. Mol. Cell Biol.* 9(12), 929-943 (2008).
- [4] B. Hein, K. I. Willig, C. A. Wurm, V. Westphal, S. Jakobs, and S. W. Hell, "Stimulated emission depletion nanoscopy of living cells using SNAP-tag fusion proteins," *Biophys. J.* 98(1), 158-163 (2010).
- [5] A. Dani, B. Huang, J. Bergan, C. Dulac, and X. Zhuang, "Superresolution imaging of chemical synapses in the brain," *Neuron* 68(5), 843-856 (2010).
- [6] A. Matsuda, L. Shao, J. Boulanger, C. Kervran, P. M. Carlton, P. Kner, D. Agard, and J. W. Sedat, "Condensed mitotic chromosome structure at nanometer resolution using PALM and EGFP-histones," *PLoS ONE* 5(9), e12768 (2010).
- [7] E. H. Synge, "A suggested method for extending microscopic resolution into the ultra-microscopic region," *Philos. Mag.* 6, 356-362 (1928).
- [8] E.A. Ash and G. Nicholls, "Super-resolution Aperture Scanning Microscope," *Nature* 237, 510-512 (1972).
- [9] D. Pohl, W. Denk, and M. Lanz, "Optical stethoscopy: Image recording with resolution  $\lambda/20$ ," *Appl. Phys. Lett.* 44, 651-653 (1984).
- [10] E. Betzig and M. Isaacson, "Collection mode near-field scanning optical microscopy," *Appl. Phys. Lett.* 51, 2088-2090 (1987).
- [11] E. Betzig and J. K. Trautman, "Near-field optics: microscopy, spectroscopy, and surface modification beyond the diffraction limit," *Science* 257, 189-195 (1992).
- [12] S. Mononobe, T. Saiki, T. Suzuki, S. Koshihara and M. Ohtsu, "Fabrication of a triple tapered probe for near-field optical spectroscopy in UV region based on selective etching of a multistep index fiber," *Opt. Commun.* 146, 45-48 (1998).
- [13] M. Ohtsu and H. Hori, *Near-Field Nano-Optics* (Kluwer Academic/Plenum Publishers, New York, 1999).
- [14] F. Zenhausern, M. P. O'Boyle, and H. K. Wickramasinghe, "Apertureless near-field optical microscope," *Appl. Phys. Lett.* 65, 1623-1625 (1994).
- [15] I. Inoué and S. Kawata, "Near-field scanning optical microscope with a metallic probe tip," *Opt. Lett.* 19, 159-161 (1994).
- [16] M. Guand P. C. Ke, "Image enhancement in near-field scanning optical microscopy with laser-trapped metallic particles," *Opt. Lett.* 24, 74-76 (1999).
- [17] J. G. Kim, T. H. Kim, H. Choi, Y. J. Yoon, Y. Jeong, N. C. Park, H. Yang and Y. P. Park, "Improved air-gap control for SIL-based near-field recording system," *IEEE Trans. on Magn.* 43, 811-813 (2007).
- [18] Y. Kawata, C. Egami, O. Nakamura, O. Sugihara, N. Okamoto, M. Tsuchimori, and O. Watanabe, "Non-optically probing near-field microscopy," *Opt. Commun.* 161, 6-12 (1999).
- [19] E. Betzig, P.L. Finn, and J.S. Weiner, "Combined shear force and near-field scanning optical microscopy," *Appl. Phys. Lett.* 60, 2484-2486 (1992).
- [20] R. Toledo-Crow, P.C. Yang, Y. Chen, and M. Vaez-Iravani, "Nearfield differential scanning optical microscope with atomic force regulation," *Appl. Phys. Lett.* 60, 2957-2959 (1992).
- [21] U. Fano, "A theory on cathodoluminescence," *Phys.Rev.* 58, 544-553 (1940).
- [22] F.J. G. de Abajo, "Optical excitations in electron microscopy," *Rev.Mod.Phys.* 82, 209-275 (2010).
- [23] A. R. Zanatta, C. T. M. Ribeiro and U. Jahn, "Photon and electron excitation of rare-earth-doped amorphous SiN films," *J. Non-Cryst. Solids* 338-340, 473-476 (2004).

- [24] W. Inami, K. Nakajima, A. Miyakawa, and Y. Kawata, "Electron beam excitation assisted optical microscope with ultra-high resolution," *Opt. Express* 18(12), 12897–12902 (2010).
- [25] Y. Nawa, W. Inami, A. Chiba, A. Ono, A. Miyakawa, Y. Kawata, S. Lin, and S. Terakawa, "Dynamic and high-resolution live cell imaging by direct electron beam excitation," *Opt. Express* 20 (5), 5629-5635 (2012).
- [26] U. Fano, "A theory on cathode luminescence," *Phys. Rev.* 58(6), 544–553 (1940).
- [27] J. Menniger, U. Jahn, O. Brandt, H. Yang, and K. Ploog, "Identification of optical transitions in cubic and hexagonal GaN by spatially resolved cathodoluminescence," *Phys. Rev. B Condens. Matter* 53(4), 1881–1885 (1996).
- [28] G. Arnold, ed., *Cathodoluminescence and Its Application in the Planetary Sciences*, 1st ed. (Springer, 2009).
- [29] F. J. G. de Abajo, "Optical excitations in electron microscopy," *Rev. Mod. Phys.* 82(1), 209–275 (2010).
- [30] D. C. Joy, *Monte Carlo Modeling for Electron Microscopy and Microanalysis* (Oxford Univ. Press, 1995).
- [31] T. Matsuyama and Y. Kawata, "Control of Alignment Regularity and Density of Nanodots by Changing Concentration and Molecular Weight of Self-Assembling Diblock Copolymer," *Jpn. J. Appl. Phys.* 45, L20–L22 (2006).
- [32] T. Matsuyama and Y. Kawata, "Fabrication of Fluorescent Nanodot Arrays on Metal Films for Application in Near-Field Optical Media," *Jpn. J. Appl. Phys.* 45, 1438–1441 (2006).
- [33] H. Masuda and K. Fukuda, "Ordered Metal Nanohole Arrays Made by a Two-Step Replication of Honeycomb Structures of Anodic Alumina," *Science* 268, 1466–1468 (1995).
- [34] H. Yu, T. Iyoda, and T. Ikeda, "Photoinduced Alignment of Nanocylinders by Supramolecular Cooperative Motions," *J. Am. Chem. Soc.* 128, 11010–11011 (2006).

# Piezoresistive Microcantilever-Based Gas Sensor using Dynamic Mode Measurement

Nuning Aisah, Lia Aprilia, Ratno Nuryadi  
 Center for Materials Technology  
 Agency for the Assessment and Application of Technology  
 South Tangerang, Indonesia  
 nuning.aisah@bppt.go.id, lia.aprilialia@ui.ac.id, ratno.nuryadi@bppt.go.id

**Abstract**— The purpose of this paper is to investigate an application of a piezoresistive microcantilever for gas sensor using a dynamic mode operation. The working principle of the microcantilever sensor is based on the measurement of microcantilever deflection or resonance frequency change due to the objects attached on the microcantilever surface. The measurement was performed by using Wheatstone bridge circuit, which is constructed by two piezoresistors in the microcantilever and two external resistors, in order to measure the resonance frequency shift of the microcantilever vibration. The result shows that the voltage of oscillation peak-to-peak from the output of Wheatstone bridge circuit, which represents the microcantilever vibrations, decreases with the time due to the gas detection. This occurs due to the resonance frequency shift caused by the addition of gas molecules mass on the microcantilever surface. This result indicates that the developed system can be used as gas sensor.

**Keywords**— *microcantilever; piezoresistive; gas sensor; dynamic mode; amplitude*

## I. INTRODUCTION

In a last decade, a development of a microelectromechanical system (MEMS) technology has promoted an innovative microcantilever-based sensors. Such sensors have big potential to replace many conventional sensor systems because of a relatively low cost of production, high sensitive, rapid response, and a reduced size of the active area (typically  $10^{-6}$  cm<sup>2</sup>) [1-3]. Moreover, the microcantilever sensors have been investigated in the fields of environment, medicine, chemistry, physics, and biology. Basic principle of the microcantilever sensor is a detection of the microcantilever bending, so called as deflection, due to the attachment of the objects (bacteria, virus, glucose, molecule gas, etc.) on the microcantilever surface.

Gas sensor is one of important issue in the industry. For many industries, monitoring and controlling gas are needed for efficient and safety of the production process. A rapid and accurate measurement of the gas have become a challenge for a long time. Recently, MEMS technology-based microcantilever sensor is very popular to miniaturize various kinds of sensors, including the gas sensor. However, to our knowledge, few experiment studies have been devoted on the detection of the gas [4-6]. Especially, Liquefied Petroleum Gas (LPG) detection has not been reported. So far, our group

have studied the detection of humidity using piezoresistive microcantilever and the design of the microcantilever for chemical object detection [7,8]. In this work, we investigate the possibility of piezoresistive microcantilever as the gas sensor using the dynamic mode measurements. Here, a Wheatstone bridge circuit is constructed in order to detect a change of piezoresistor in the microcantilever due to the gas molecules attached on the microcantilever surface.

## II. DYNAMIC MODE MEASUREMENT

The microcantilever sensor has two operation modes, i.e., static mode and dynamic mode. The static mode operation directly measures the deflection of the microcantilever. For the dynamic mode operation, the deflection of the microcantilever is not directly measured. The dynamic mode one measures the resonance frequency shift of the microcantilever vibration due to the object detection. In the experimental setup, the microcantilever is usually placed on the piezoelectric. When the microcantilever is vibrated by giving a signal generator to the piezoelectric, the resonance frequency of the microcantilever can be calculated by equation (1) [9].

$$f = \frac{1}{2\pi} \sqrt{\frac{k}{M}} \quad (1)$$

where  $k$  is the spring constant and  $M$  is the effective mass of the microcantilever.

Next, the addition of mass on the microcantilever surface will cause a decrease in the resonance frequency. Therefore, mass changes  $\Delta m$  can be obtained from the resonance frequency shift caused by molecular adsorption according to the equation (2) [9].

$$\Delta m = -2 \frac{m}{f} \Delta f \quad (2)$$

From the equation above, a mass sensitivity  $S$  of the microcantilever-based sensors is as follow,

$$S = \frac{\Delta m}{\Delta f} = -2 \frac{m}{f} \quad (3)$$

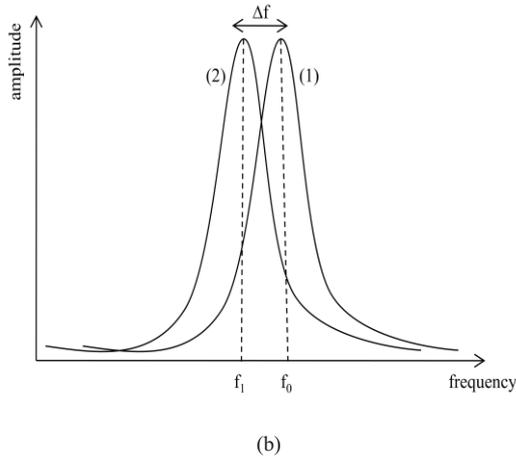
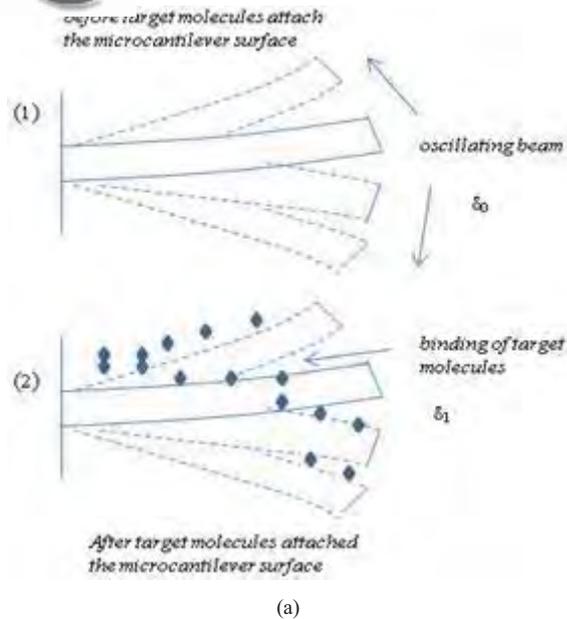


Figure 1. (a) Microcantilever vibration before and after molecules detection, (b) Resonance frequency shift due to the molecules detection

Figure 1(a) shows illustrations of the microcantilever vibration before (1) and after (2) the target molecules attach on the microcantilever surface. Before the molecules attach on the microcantilever surface (1), the microcantilever has the deflection of  $\delta_0$  and vibrates with a certain frequency of  $f_0$  [10]. The microcantilever then captures the target molecules (2), resulting in the change in both resonance frequency due to the additional mass ( $\Delta m$ ) of the microcantilever, as shown in Fig. 1(b). The resonance frequency shifts to lower value, after the target molecules are captured on the microcantilever surface.

### III. EXPERIMENTAL SETUP

In the experimental setup, the microcantilever sensor system consists of function generator, Wheatstone bridge, Op-Amp and oscilloscope, as shown in the Fig. 2 [7]. The Wheatstone bridge circuit was constructed by two

piezoresistors in the microcantilever and two external resistors. The piezoresistive microcantilever used here is commercially manufactured by Seiko Instrument Inc., Japan. Even the microcantilever was designed to be an atomic force microscope application, we suggest that the sensor system with same microcantilever structure in Fig. 2 can be used for chemical sensor, including gas detection. A long microcantilever has a length of  $110 \mu\text{m}$ , a width of  $50 \mu\text{m}$ , area  $9.80 \times 10^{-5} \text{cm}^2$  (both sides), weight  $46 \text{ng}$ , spring constant  $40 \text{N/m}$  and piezoresistor  $R_1$  of about  $630 \Omega$  [11]. The scanning electron microscope (SEM) image of this microcantilever can be seen in Fig. 3. It is noted that the short microcantilever with piezoresistor  $R_2$  of about  $630 \Omega$  is a reference cantilever, which was designed to be unchangeable during the measurement. Such reference cantilever is crucial in order to reduce background noise, such as thermal drift and gas turbulence [12].

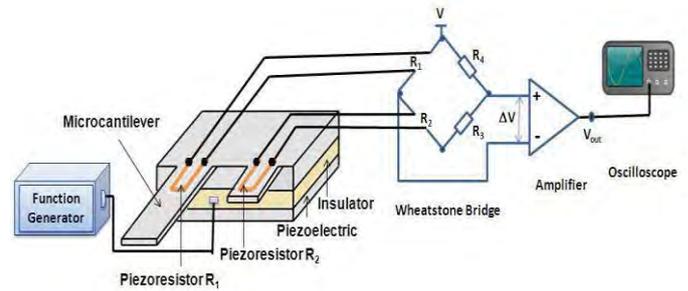


Figure 2. Block diagram of the whole sensor system

The output of Wheatstone bridge ( $\Delta V$ ) in Fig. 2 could be written as  $\Delta V = (R_1 R_3 - R_2 R_4) V / (R_1 + R_2)(R_3 + R_4)$ . Such  $\Delta V$  will be modified if the value of piezoresistor  $R_1$  changes due to the gas detection. The  $\Delta V$  is then amplified by amplifier instrument, resulting in  $V_{out}$ , which is monitored by oscilloscope. It is noted that the gas molecules attached on the microcantilever surface causes the microcantilever deflection, so that the stress on the base of the microcantilever increases. This results in the change in the piezoresistor, which is located in the base of microcantilever.

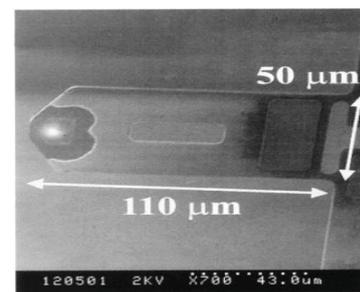


Figure 3. SEM image of the piezoresistive cantilever

In the measurement based on the dynamic mode operation, the activation of the piezoelectric will vibrate the microcantilever with a certain frequency. In our work, the sensor system is firstly placed inside the box, and the

resonance frequency of the microcantilever vibration was measured. Next, Liquefied Petroleum Gas (LPG) is introduced in box, and then the resonance frequency shift was measured by the oscilloscope.

#### IV. RESULTS AND DISCUSSION

In present experiment, we recorded the  $\Delta V$  oscillation peak-to-peak ( $V_{pp}$ ) which represents the microcantilever vibration change due to the gas flow into the box. The  $\Delta V$  oscillation is then analyzed by a Fast Fourier Transform (FFT). Figure 4(a) shows the FFT graph before LPG gas is introduced into the box. It is found that the resonance frequency of the microcantilever vibration is about 318 kHz.

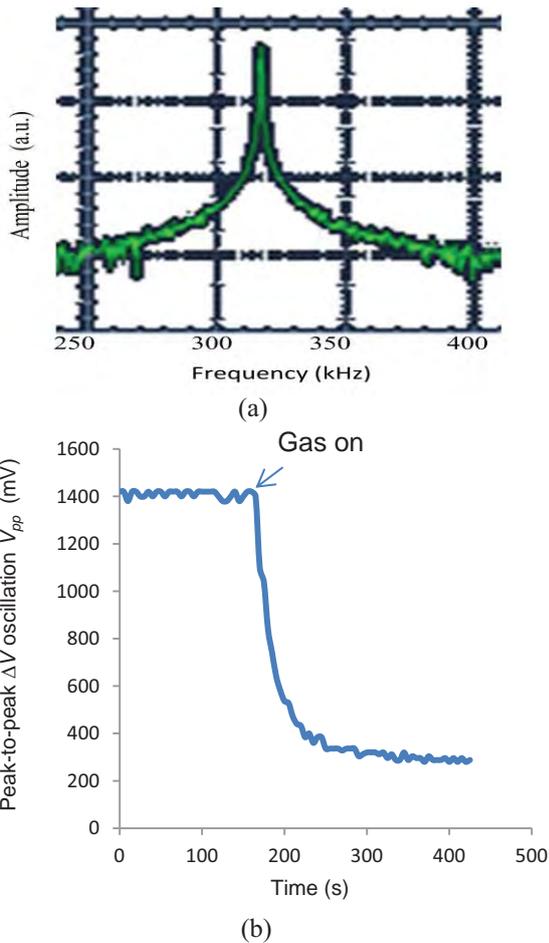


Figure 4. (a) FFT analysis of the initial resonance frequency and (b) change of peak-to-peak  $\Delta V$  oscillation due to gas detection

Next, the gas is introduced and then the change of  $\Delta V$  oscillation peak-to-peak ( $V_{pp}$ ) is recorded, as shown in Fig. 4(b). It can be seen that, before the gas is introduced, the  $V_{pp}$  is almost constant of about 1400 mV. When gas enters the box at the time of 155 s, the  $V_{pp}$  abruptly decreases. After the time of 200 s, the  $V_{pp}$  slowly decreases, and then there is no significant change in  $V_{pp}$ . We suggest that the decrease in the  $V_{pp}$  due to the gas flow corresponds to the resonance frequency shift, as our illustration in Fig. 5. In present experiment, since we

measured the  $\Delta V$  oscillation in the fixed frequency of 318 kHz, the detected  $V_{pp}$  is not always at the peak of the resonance frequency. The value of  $V_{pp}$ , which is indicated by A-F points (see Fig. 5(a)), changes may be due to the resonance frequency shift to the left (see Fig. 5(b)). When the resonance frequency shifts to the lower value, the detected  $V_{pp}$  reduces. After the time of 200 s, the attached gas molecules are saturated so that there is no  $V_{pp}$  change. We suggest that, since the value  $V_{pp}$  in Fig. 4(b) reached a constant after about 250 s, the resonance frequency shift is about 57.14 kHz, such shift represents the mass change  $\Delta m$  of about 16.5 ng due to the gas molecule on the microcantilever surface.

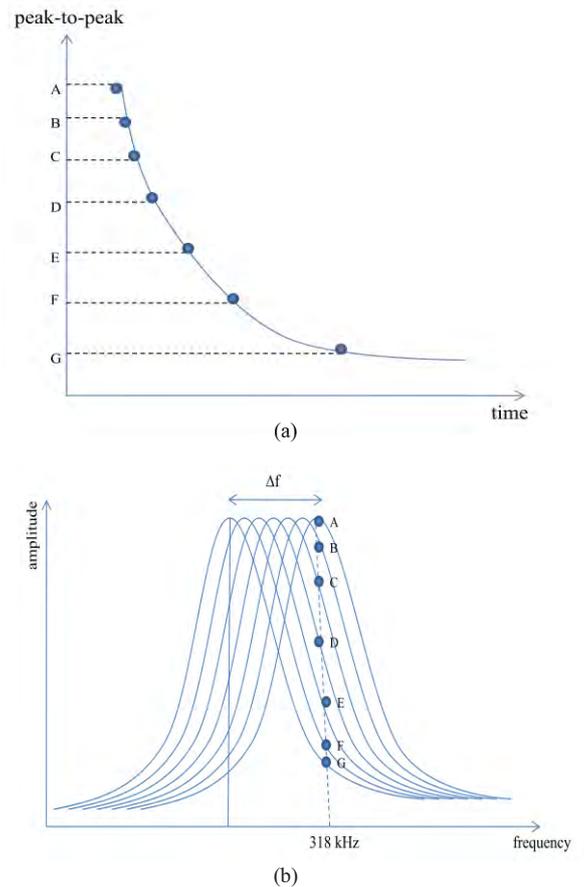


Figure 5. Illustration of relationship between the decrease in the  $V_{pp}$  and the resonance frequency shift

#### V. CONCLUSION

We have investigated the possibility of the piezoresistive microcantilever as the LPG gas sensor using the dynamic mode measurements. The Wheatstone bridge circuit was built in order to detect the resonance frequency shift due to the detection of the gas. The gas detection is indicated by the decrease in the microcantilever vibration amplitude, which represents the resonance frequency shift. Even the linearity of gas-cantilever response relation and the coating of the microcantilever surface need to be clarified, we believe that

such results open up the possibility of the gas detection using piezoresistive microcantilever-based sensor.

#### ACKNOWLEDGEMENT

This work was partially supported by incentive research grant from Indonesia State Ministry of Research and Technology, and by Indonesia Toray Science Foundation (ITSF) Science and Technology Research Grant.

#### REFERENCES

- [1] R. Raiteri, M. Grattarola, H. Butt, P. Skladal, "Micromechanical cantilever-based biosensor", *Sens. Actuators B.*, Vol. 79, 2001, pp. 115-126.
- [2] S.K. Vashist, "A review of Microcantilevers for Sensing Applications", *J. Nanotechnol.*, Vol. 3, 2007, pp. 1-15.
- [3] S. Dohn, R. Sandberg, W. Svendsen, A. Boisen, "Enhanced functionality of cantilever based mass sensors using higher modes", *Appl. Phys. Lett.*, Vol. 86, 2005, pp. 233501.
- [4] T.L. Porter, M.P. Eastman, D.L. Pace, M. Bradley, "Sensor based on piezoresistive microcantilever technology", *Sens. Actuators A.*, Vol. 88, 2001, pp. 47-51.
- [5] J. Zhou, P. Li, S. Zhang, Y. Huang, P. Yang, M. Bao, G. Ruan, "Self-excited piezoelectric microcantilever for gas detection", *Microelectro. Eng.*, Vol. 69, 2003, pp. 37-46.
- [6] A. Kooser, R.L. Gunter, W.D. Delinger, T.L. Porter, M.P. Eastman, "Gas sensing using embedded piezoresistive microcantilever sensors", *Sens. Actuators B.*, Vol. 99, 2004, pp. 474-479.
- [7] R. Nuryadi, A. Djajadi, R. Adiel, L. Aprilia, N. Aisah, "Resonance frequency change in microcantilever-based sensor due to humidity variation", *Materials Science Forum*, Vol. 737, 2013, pp. 176-182.
- [8] R. Nuryadi, "Modeling of I-, T-, and V-shaped microcantilever for virus detection", *Materials Science Forum*, Vol. 737, 2013, pp. 119-125.
- [9] C. Wang, "Ultrasensitive biochemical sensors based on microcantilevers of atomic force microscope", *Elsevier Inc.*, 2007.
- [10] Y. Lim, A. Z. Kouzani, W. Duan, and A. Kaynak. "Effects of Design Parameters on Sensitivity of Microcantilever Biosensors". *The 2010 IEEE/ICME International Conference on Complex Medical Engineering*, July 13-15, 2010, Gold Coast, Australia
- [11] H. Sone, A. Ikeuchi, T. Izumi, H. Okano and S. Hosaka, "Femtogram Mass Biosensor Using Self-Sensing Cantilever for Allergy Check". *Jpn. J. Appl. Phys.*, Vol. 45 No 3B, 2006, pp. 2301-2304.
- [12] H.P. Lang, R. Berger, C. Andreoli, J. Brugger, M. Despont, P. Vettiger, F. Battiston, J.P. Ramseyer, E. Meyer, T. Mezzacasa, L. Scandella, H. J. Guntherodt, Ch. Gerber, J.K. Gimzewski, "A chemical sensor based on a micromechanical cantilever array for the identification of gases and vapors", *Appl. Phys. A* 66, 1998, pp. S61-S64.

# Evolution of Photodetectors by Silicon-On-Insulator Material

Hiroshi Inokawa, Hiroaki Satoh, Atsushi Ono

Research Institute of Electronics, Shizuoka University  
 Hamamatsu, Japan

Dedy Septono Catur Putranto<sup>†</sup>

Graduate School of Sci. and Technol., Shizuoka University  
 Hamamatsu, Japan

Wei Du

Electrical Eng., Washington State University Vancouver  
 Vancouver, USA

Purnomo Sidi Priambodob, Djoko Hartanto

<sup>†</sup>Faculty of Engineering, University of Indonesia  
 Depok, Indonesia

**Abstract**—Silicon-on-insulator (SOI) provides distinctive characteristics to photodetectors based on optical confinement and carrier confinement, resulting in enhanced light absorption and sensitive detection of photo-generated carriers, respectively. Specifically, the waveguiding modes in the SOI photodiode can be induced by the diffracted light from the surface plasmon antenna on top to give an enhanced light sensitivity, and wavelength and polarization selectivities. The carrier confinement in the SOI body enables one-by-one detection of the photo-generated carriers in SOI MOSFET, leading to the single-photon detection. In this report, such new features of photodetectors attained by SOI will be introduced.

**Keywords**—silicon-on-insulator (SOI); photodetector; surface plasmon (SP) antenna; single-photon detection

## I. INTRODUCTION

Silicon-on-insulator (SOI) is a unique material comprising of a single-crystal silicon layer, buried silicon dioxide (BOX) underneath, and a supporting silicon substrate. It is widely used as a material for high-performance large-scale integrated circuits (LSIs) due to the low parasitic capacitance and complete electrical isolation between devices [1],[2]. In addition, extremely thin SOI MOSFET is regarded as a viable device structure for LSI scaling down to 20 nm node and beyond because of the superior short-channel characteristics, etc.[3] Considering these, it is worthwhile to develop SOI-compatible photodetectors to give new function to LSIs.

In addition, SOI also provides distinctive characteristics to photodetectors based on optical confinement and carrier confinement, which lead to enhanced light absorption and sensitive detection of photogenerated carriers, respectively. In this report, such new features of photodetectors attained by SOI will be discussed.

## II. OPTICAL CONFINEMENT

Thickness of the silicon layer used in high-performance SOI LSIs is thin (usually less than 200 nm), and the light absorption efficiency is low. In order to solve this problem, surface plasmon (SP) antenna was applied to lateral pn-junction photodiode. Surface plasmon is a charge density wave propagating on the surface of noble metal (e.g. Au, Ag), which can be resonantly excited by the incident light if a periodic grating structure is made of the metal. Because of the intense near field generated by the surface plasmon, light can be

efficiently absorbed by the Si photodiode placed nearby. Based on such an idea, SOI photodiode with SP antenna in Fig. 1(a) was designed [4], in which thickness of the gate oxide separating the antenna and the Si was minimized (~5 nm) insofar as the leakage current through the oxide is prevented.

According to the finite-difference time domain (FDTD) simulation, the proposed photodiode exhibited high light absorption efficiency at the wavelength determined by the period of the SP antenna grating, and one order of magnitude higher quantum efficiency (QE) than that of the case without SP antenna was expected. For example, efficiency of 37% was expected for 550 nm wavelength light with 100 nm thick Si

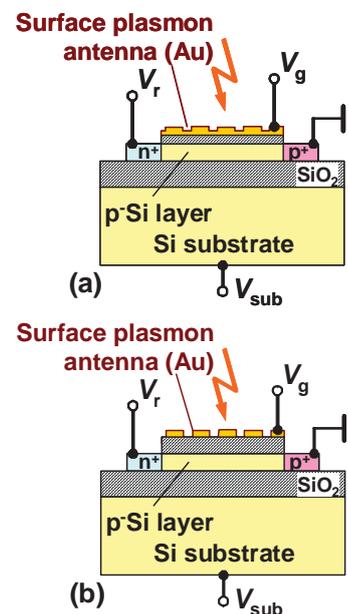


Fig. 1. Schematic cross-section of the lateral pn-junction SOI photodiode with surface plasmon (SP) antenna [4],[5]. (a) Continuous-grating antenna with thin (~5 nm) gate oxide, and (b) separate-grating antenna with thick (~100 nm) gate oxide [6],[8].

and 200 nm period Au antenna grating [4].

However, expected enhancement was not experimentally achieved due to the optical loss in the Ti adhesion layer inserted between Au antenna and the gate insulator SiO<sub>2</sub> [5].

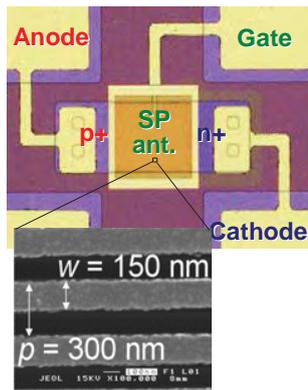


Fig. 2. Fabricated SOI photodiode with surface plasmon (SP) antenna corresponding to the structure in Fig. 1(b).

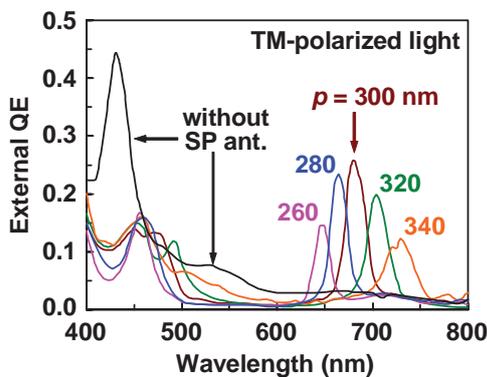


Fig. 3. Spectroscopic external quantum efficiency (QE) of the fabricated photodiode. SOI thickness is 95 nm.

This problem was later solved by adopting the separate-grating antenna with thick (~100 nm) gate oxide shown in Fig. 1(b) [6],[8].

Fig. 2 shows the optical and electron micrographs of the fabricated photodiode according to Fig. 1(b) [6]. The lateral pn-junction photodiode has a metal-oxide-semiconductor (MOS) structure, and the SP antenna also works as a gate electrode. By applying appropriate voltages to the gate and substrate, nearly entire  $p^-$  area can be made depleted, and the QE is maximized.

Fig. 3 shows the spectroscopic sensitivity of the fabricated photodiode for various grating periods. The QE peaks at a specific wavelength determined by grating period of the SP antenna. For instance, QE of 25% (enhancement by a factor of 8.2) can be obtained at 680 nm wavelength with a 300 nm period grating.

Fig. 4 shows the polarization angle dependence of the external QE. TM polarization is the condition in which the grating direction is parallel to the magnetic field of the incident light, and the surface plasmon can be excited most efficiently by the grating coupling. As is expected, QE becomes maximum at TM polarization, and the extinction ratio to the minimum at TE polarization is as high as 46.

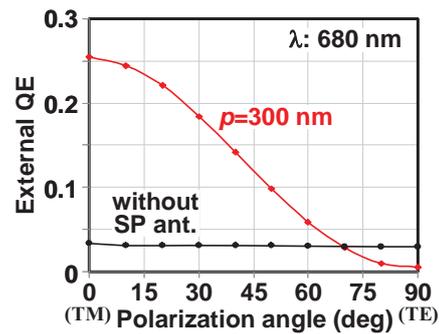


Fig. 4. Polarization angle dependence of external quantum efficiency (QE).

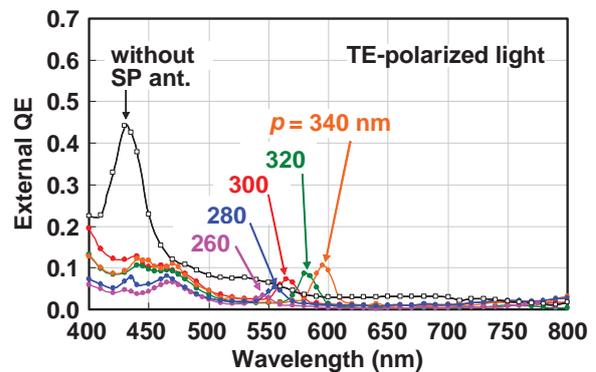


Fig. 5. Spectroscopic quantum efficiency (QE) for TE-polarized light.

SP antenna has functions of wavelength and polarization filters, and more importantly, diodes with different characteristics can be integrated easily in one chip since the filter characteristics can be tailored only by the layout design without changing the materials. This feature brings a new opportunity to spectroscopic and polarization imaging.

In terms of efficient use of the near field, the device structure with thick gate oxide in Fig. 1(b) is not necessarily appropriate. Moreover, due to the separate-grating structure, propagation of the surface plasmon across the grating is less likely. In order to understand the mechanism behind the separate-grating structure, the spectroscopic QE for TE-polarized light, which is not favorable to excite surface plasmon, is measured. As shown in Fig. 5, new QE peaks are found at wavelengths different from those for TM-polarized light.

This phenomenon can be explained based on the dispersion relationship (i.e. propagation wavelength  $\lambda_g$  in the waveguide vs. free-space wavelength) for the Si slab waveguide of SOI layer sandwiched with infinitely thick  $\text{SiO}_2$ . The theoretical dispersion (solid lines in Fig. 6) [7] coincides well with the experimental relationship between the grating period and the peak wavelength (symbols in Fig. 6) [8], indicating that the QE is enhanced by the coupling of the diffracted light from the antenna grating with the waveguide modes in the Si slab. This

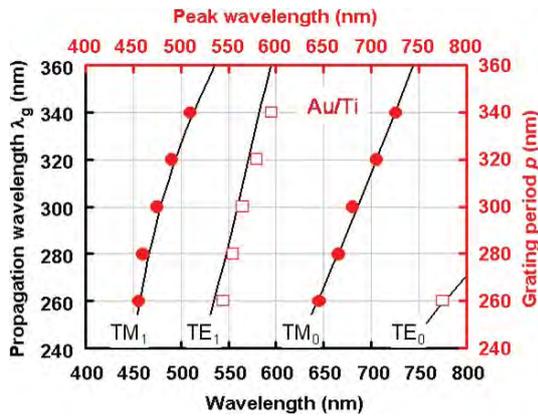


Fig. 6. Dispersion relationship for the Si slab waveguide of SOI layer sandwiched with infinitely thick SiO<sub>2</sub> (black solid lines, left/bottom scales), and relationship between peak wavelength and grating period for the photodiode (red symbols, right/top scales).

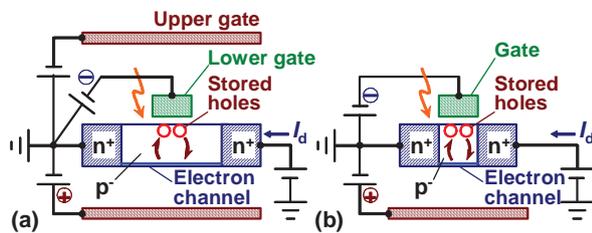


Fig. 7. Schematic cross-section of the SOI MOSFET single-photon detector. (a) Double-layer-gate type, and (b) single-layer-gate type.

is unique to SOI structure, where the light can be confined in the Si with high refractive index surrounded by the SiO<sub>2</sub> with low refractive index.

### III. CARRIER CONFINEMENT

In the SOI MOSFET, generation of minority carriers in the Si body leads to the change in the threshold voltage (floating body effect), since the carriers cannot be drained easily. Due to the down scaling of the device, threshold voltage change caused by a single carrier becomes large enough to be observed, realizing a new type of single-photon detector that counts photo-generated carriers one by one without multiplication.

Fig. 7 shows the verified device structures with an n-type channel. The double-layer-gate device in Fig. 7(a) confines the photo-generated holes in the potential well created by the applied voltages to upper and lower gates [9],[10]. In this case, electron current in the bottom channel is modulated by the stored hole below the lower gate. The single-layer-gate device in Fig. 7(b) confines holes in the potential well formed by the npn junction [11]. Similarly, the stored holes are detected by the electron current in the bottom channel.

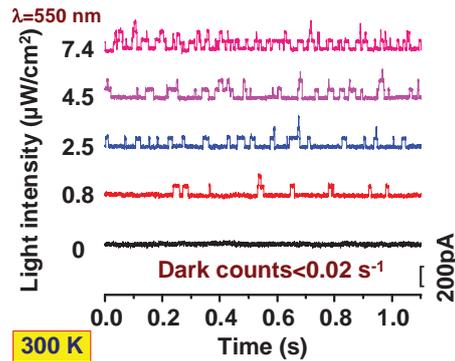


Fig. 8. Drain current waveforms for different light intensities for double-layer-gate SOI MOSFET with  $I_{soi} = 50$  nm,  $L = 65$  nm and  $W = 105$  nm.

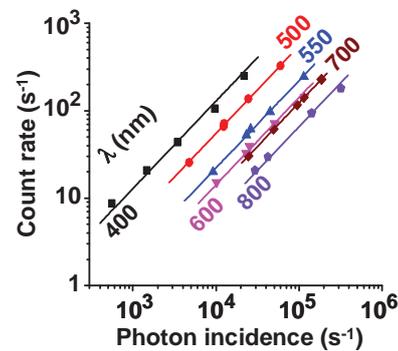


Fig. 9. Pulse count rate with respect to the photon incident rate. The later is the nominal value obtained by multiplying areal light intensity and the area of p<sup>-</sup> region.

The double-layer-gate device has merits of higher sensitivity to the stored holes due to the smaller potential well, and larger photosensitive area corresponding to the p<sup>-</sup> offset region, but has a drawback of the complex structure. The single-layer-gate device has a simple structure similar to that for ordinary LSI. Hereafter, we will focus on the former device [10].

Fig. 8 shows the drain current waveforms for different levels of light intensity. Current levels are discrete, and correspond to the number of stored holes of 0, 1, 2, 3 ... from the lowest level. The rise of the current is caused by the hole generation by photo-excitation, and the fall is caused by the hole recombination. As the light intensity increases, the pulse frequency increases, and at the same time, probability of the higher current levels increases. Dark counts at zero illumination intensity is less than 0.02 s<sup>-1</sup>, which is about four orders of magnitude lower than that of avalanche photodiode. Low operation voltage around 1 V is another superior point.

Fig. 9 shows the relationship between the pulse count of drain current and the photon incident rate for various wavelengths. Count rate increases proportionally to the photon incident rate, supporting the single-photon detection, and the proportionality constant is the QE for each wavelength. The

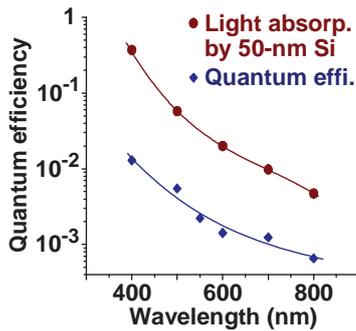


Fig. 10. Wavelength dependence of the quantum efficiency.

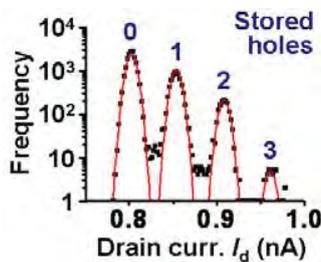


Fig. 11. An example of the drain current histogram corresponding to the waveform for  $4.5 \mu\text{W}/\text{cm}^2$  in Fig. 8. Solid lines are Gaussian fitting curves.

wavelength dependence of the QE is shown in Fig. 10, together with the light absorption by the Si layer with the same thickness (50 nm) as that of MOSFET, calculated using absorption coefficient. The QE and light absorption curves are parallel to each other indicating that the spectroscopic characteristics of the QE is governed mainly by the Si absorption coefficient. One order of magnitude smaller QE than the light absorption is caused by the opaque metallic upper gate, and could be improved by replacing the gate with transparent one.

Thanks to the extremely small dark counts, minimum detectable optical power (NEP) is as low as  $7.7 \times 10^{-18} \text{ W}/\sqrt{\text{Hz}}$ , although the QE is low (1.3% at 400 nm). However, due to the small light receiving area, the detectivity  $D^*$  is calculated to be  $4.3 \times 10^{12} \text{ cm}^2/\sqrt{\text{Hz}}/\text{W}$ , which is comparable to that of pin photodiode.

It is possible to extract the lifetime of a few holes by analyzing the drain current waveforms. Specifically, histogram of the drain current is made as shown in the example of Fig. 11. Here, the peaks from the left correspond to the number of stored holes of 0, 1, 2 and 3, and the probability of state for each number of holes can be calculated from the peak height.

Fig. 12 shows the relationship between the probability of state and the count rate (i.e. hole generation rate), and solid lines are theoretical curves obtained from the steady-state rate equations. By optimizing the hole lifetimes  $\tau_1$ ,  $\tau_2$  and  $\tau_3$  for

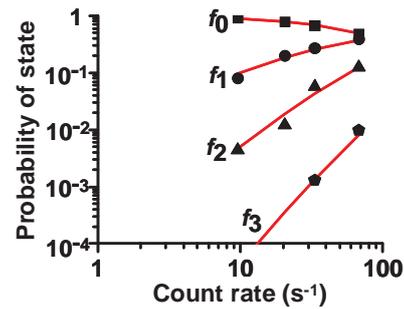


Fig. 12. Relationship between probability of state and count rate (hole generation rate) for different numbers of stored holes. Solid lines are theoretical curves based on the rate equation.

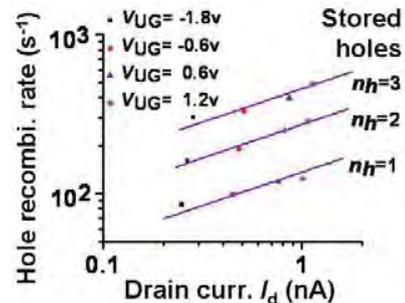


Fig. 13. Hole recombination rate (inverse of hole lifetime) with respect to the drain current for different numbers of stored holes.

hole numbers 1, 2 and 3 to minimize error, 11, 5 and 2 ms are obtained, respectively.

Fig. 13 shows the hole recombination rate (inverse of hole lifetime) vs. drain current controlled by the upper gate voltage  $V_{UG}$ . The recombination rate is nearly proportional to the number of stored hole  $n_h$ , and electron current to the power 0.41. This result contradicts the previous report [9] of the direct proportionality to the current, suggesting the indirect recombination of holes via traps.

#### IV. CONCLUSION

In this report, an SOI photodiode with SP antenna and SOI MOSFET single-photon detector are introduced. In the former, optical confinement effect specific to SOI contributes to the enhancement of QE, and in the later, carrier confinement effect (floating body effect) enables the detection of single holes generated by the incident light. The unique characteristics utilized in these photodetectors, along with the evolution of SOI-based LSIs, will open up new opportunities of optoelectronic integrated circuits.

#### ACKNOWLEDGMENT

The Authors are indebted to Keisaku Yamada of University of Tsukuba, Toyohiro Chikyo of National Institute of Materials and Science, Tetsuo Endoh of Tohoku University, Hideo

Yoshino and Shigeru Fujisawa of Semiconductor Leading Edge Technologies, Inc. for their cooperation in the device fabrication.

#### REFERENCES

- [1] J.-P. Colinge, *Silicon-On-Insulator Technology: Materials to VLSI*, 2nd ed., 1997, Kluwer Academic, Massachusetts.
- [2] S. Cristoloveanu and S. S. Li, *Electrical Characterization of Silicon-On-Insulator Materials and Devices*, 1995, Kluwer Academic, Massachusetts.
- [3] Kangguo Cheng, "Extremely Thin SOI (ETSOI) – a Planar CMOS Technology for System-on-chip Applications," International Conference on Solid State Devices and Materials (SSDM), pp. 867-868 (Nagoya, Japan, 2011)
- [4] H. Satoh and H. Inokawa, "Surface Plasmon Antenna with Gold Line and Space Grating for Enhanced Visible Light Detection by Silicon-On-Insulator Metal-Oxide-Semiconductor Photodiode," *IEEE Trans. Nanotechnol.*, Vol. 11, No. 2, pp. 346-351, 2012.
- [5] H. Satoh and H. Inokawa, "Spectroscopic Response of SOI Photodiode with Gold Line-and-Space Surface Plasmon Antenna," IEEE Silicon Nanoelectronics Workshop (SNW) pp. 117-118 (Kyoto, Japan, 2009)
- [6] H. Satoh, H. Inokawa and A. Ono, "Enhancement of Light Sensitivity of Thin SOI photodiode by Gold Line-and-Space Grating for Selected Wavelength and Polarization," IEEE Silicon Nanoelectronics Workshop (SNW) pp. 33-34 (Kyoto, Japan, 2011)
- [7] J. M. Liu, *Photonic Devices*, Cambridge University Press, 2005, pp. 95-99.
- [8] H. Satoh, A. Ono, and H. Inokawa, "Enhanced Visible Light Sensitivity by Gold Line-and-Space Grating Gate Electrode in Thin Silicon-On-Insulator p-n Junction Photodiode," *IEEE Trans. Electron Devices*, Vol. 60, No. 2, pp. 812-818, 2013.
- [9] A. Fujiwara, K. Yamazaki and Y. Takahashi, "Detection of single charges and their generation-recombination dynamics in Si nanowires at room temperature," *Appl. Phys. Lett.* Vol. 80, No. 24, pp. 4567-4569, 2002.
- [10] W. Du, H. Inokawa, H. Satoh and A. Ono, "SOI metal-oxide-semiconductor field-effect transistor photon detector based on single-hole counting," *Optics Letters*, Vol. 36, No. 15, pp. 2800-2802, 2011.
- [11] W. Du, H. Inokawa, H. Satoh and A. Ono, "Single-Photon Detection by a Simple Silicon-on-Insulator Metal-Oxide-Semiconductor Field-Effect Transistor," *Jpn. J. Appl. Phys.*, Vol. 51, No. 6, pp. 06FE01\_1-4, 2012.

# Observation of nanosize effect in lateral nanoscale *p-n* and *p-i-n* junctions

Arief Udhiarto, Sri Purwiyanti

Electrical Engineering Department, Faculty of Engineering  
 Universitas Indonesia  
 Depok, Indonesia  
 arief.udhiarto@ui.ac.id

Daniel Moraru, Takeshi Mizuno, Michiharu Tabé

Research Institute of Electronics  
 Shizuoka University, 3-5-1 Johoku, Naka-ku,  
 Hamamatsu, 432-8011, Japan

**Abstract**— We study nanosize-effect in lateral nanoscale *p-n* and *p-i-n* junction devices under light illumination. Current versus voltage (*I-V*) and current versus time (*I-time*) characteristics were investigated at low and at room temperature. At low temperature, only *p-n* junction devices show a photon sensitivity in *I-V* characteristics due to co-existence of donor-acceptor pair. At room temperature, both devices show photovoltaic nature, i.e., increase of reverse current is observed under light illumination. In addition, devices with narrow channel-width tend to produce larger photocurrent which is ascribed to the nanosize effect.

**Keywords**— Nanoscale *p-n* and *p-i-n* junctions; individual dopants; nanosize effect

## I. Introduction

Silicon based *p-i-n* and *p-n* devices have been commonly used for a variety of photonic and electronic applications along with semiconductor history [1]. Taking advantages of present fabrication technology, recently, novel properties of nanoscale *p-i-n* and *p-n* junctions have been studied and their advantages have been demonstrated [2–7]. Co-axial *p-i-n* and *p-n* nanowires are reported to be highly efficient in solar cell applications [2,3]. Two-dimensional (2D) *p-n* junctions are known to have a higher breakdown voltage and a lower capacitance than conventional *p-n* junctions [6]. Also, 2D *p-n* junctions have enhanced photoluminescence and electroluminescence efficiency, because of quantum-mechanical confinement effect of carriers [7]. Thus, nanoscale *p-i-n* and *p-n* diodes are of increasing importance for novel photodevices.

It is important to be noted that as devices are scaled down into nanometer scale, the number of dopant atoms is limited and countable. In this nanoscale regime, individual dopant atom potential may influence the device operation. In fact, nanoscale MOSFETs with doped-channels have been intensively studied [8–15]. In those single-dopant devices, individual potentials of dopant atoms are intentionally utilized as miniaturized quantum dots. The role of individual dopant atoms in nanoscale lateral *p-n* junctions at low temperature has also been reported [16]. Since room temperature operation is the main goal for more practical application, it is important to study room temperature behavior of nanoscale lateral *p-n* and

*p-i-n* junctions and their characteristics under light illumination. The effects of nanosize also need to be clarified.

In this work, we first present a review of low temperature characteristics of nanoscale lateral *p-n* and *p-i-n* junction devices. Next, we study room temperature characteristics and the effect of channel width. The devices are characterized in dark and under light illumination. As a result, at low temperature, only *p-n* junction devices show a photon sensitivity in *I-V* characteristics which is ascribed to the charging and discharging of donor-acceptor pair by photogenerated carrier. At room temperature, we found that both *p-n* and *p-i-n* devices show photovoltaic nature, i.e., current is enhanced in the reverse bias condition under light illumination. It is even more important that, narrow channel-width devices show higher photo response and it is ascribed to the nanosize effects.

## II. Methodology

We fabricated and studied two types of nanoscale diode, *p-n* and *p-i-n*. Schematic device structure, bias configuration and schematic top view for both devices are shown in Fig. 1. The nanodiode was patterned on silicon-on-insulator (SOI) structure using electron beam lithography. The width, length, and thickness are estimated to be 15, 1000, and 5 nm, respectively. Boron and phosphorus atoms were selectively diffused to create lateral *p-n* junction and *p-i-n* devices. In *p-n* junction devices, a co-doped region was doped with phosphorus and boron simultaneously. Boron concentration is higher than phosphorus concentration. For both devices, final phosphorous and boron concentration derived from secondary ion mass spectrometry (SIMS) are estimated to be  $N_D \approx 1 \times 10^{18} \text{ cm}^{-3}$  and  $N_A \approx 1.5 \times 10^{18} \text{ cm}^{-3}$  respectively. In the *p-i-n* devices, an area in the middle part of the nanowire was kept un-doped. The nanowire is covered with a 10-nm-thick  $\text{SiO}_2$  layer. The *p*-Si substrate ( $N_A \approx 1.5 \times 10^{15} \text{ cm}^{-3}$ ) is used as a backgate. The thickness of the buried oxide layer is 150 nm.

Devices were measured in a vacuum chamber of an electrical measurement system. *p*-type region was connected to the voltage source, while *n*-type region and substrate were kept grounded. Light is illuminated onto the device from a halogen, light emitting diode (LED), or a monochromatic light source in the visible wavelength range. Light source is connected with optical fibers through a quartz window. The

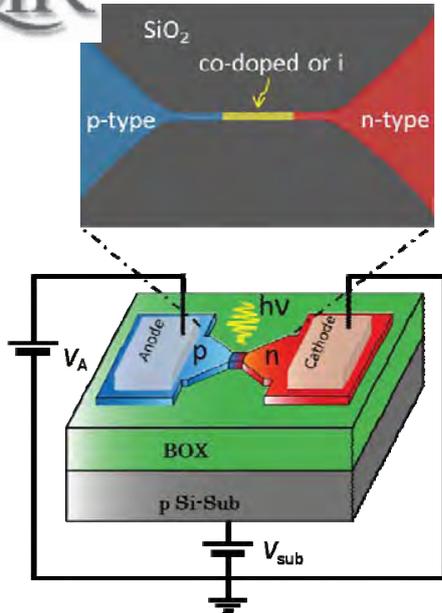


Fig. 1. Schematic device structure, bias configuration and schematic top view of *p-n* and *p-i-n* junction area.

illumination area in the device has a diameter of about 3.2 mm. By dividing the measured optical power at the sample surface over the illumination area and the photon energy, the incident photon flux is estimated.

For analysis, we performed low temperature (~20 K) and room temperature measurement (~296 K). In both conditions, the devices were measured in dark and under light illumination.

### III. Experintal Results and Discussion

#### A. Low temperature measurement

We measured anode current versus voltage ( $I-V_A$ ) characteristics at  $T \sim 20$  K. Anode voltage was swept from negative to positive while substrate voltage ( $V_{sub}$ ) was kept constant at 0 V. The main results of low temperature characteristics had been reported in our previous work [16] and will be briefly summarized in this paper. Typical  $I-V_A$  characteristics in semi logarithmic scale for *p-i-n* and *p-n* devices at low temperature are shown in Fig. 2 (a) and (b) respectively. Both devices show current enhancement under light illumination indicating that both devices are photosensitive. Although both devices show similar photosensitive behavior, it is apparent that only *p-n* junctions device show noise feature under light illumination. For further analysis, we focused on *p-n* junction devices and performed current versus time (*I-time*) measurement for fixed  $V_A$  and  $V_{sub}$  in the noisy region. In dark, current is constant, while under light illumination, current switch between two or more levels and is observed as random telegraph signal (RTS). By increasing photons intensity ( $\Phi$ ), we found that the number RTS increases, indicating that the RTS is triggered by

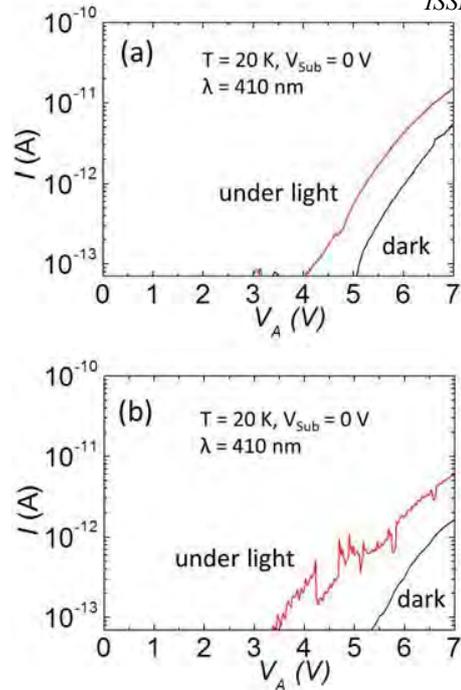


Fig. 2. Low temperature  $I-V_A$  characteristics of (a) *p-i-n* devices and (b) *p-n* junction devices. Only *p-n* junction devices show noise feature under light illumination [16].

photons. *I-time* characteristics in dark and under light illumination of several photon fluxes are shown in Fig. 3. As reported detail in our previous work, the noise feature is ascribed to the charging and discharging of photoexcited carrier by donor-acceptor pair in the depletion region. It is known that, at low temperature, most dopants are freeze-out [17]. The ionized donors and acceptors create a potential landscape with hills and valleys allowing electrons and holes to flow as diffusion current. The diffusion current in this device is used as a sensor to sense potential fluctuation in the channel. In dark, current is constant with time indicating no potential fluctuation. Under light illumination, photogenerated carriers can be trapped by ionized dopants causing a sudden potential change. This is sensed as anode current fluctuation (RTS) in the *I-time* characteristics. Since individual dopants basically can only accommodate a single photogenerated carrier, we suggest that, at low temperature, the nanoscale *p-n* junction devices can be utilized as single photon detectors.

#### B. Room temperature measurement

As low temperature characteristics have been clarified, it is important to analyze room temperature behavior for more practical application. For that purpose, we increased the temperature up to 296 K.  $I-V_A$  characteristics were measured in dark and under light illumination. Typical  $I-V_A$  characteristics in dark and under halogen light illumination for several photon fluxes ( $\Phi$ ) for *p-i-n* devices (a) and *p-n* devices (b) are shown in Fig. 4. Current, in absolute value, is plotted in a semi logarithmic scale; horizontal axis is applied voltage from negative (reverse) to positive (forward).

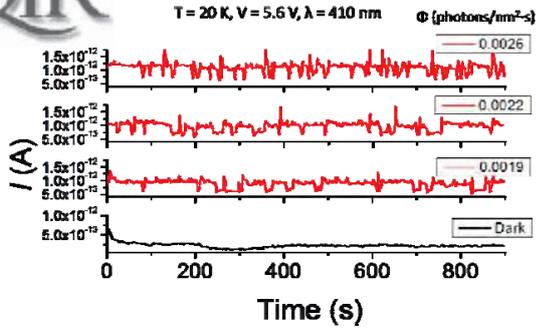


Fig. 3. *I*-time characteristics in dark and under light illumination. Under light illumination, current switch between two or more levels. By increasing incident photon flux ( $\Phi$ ), from bottom to up, number of RTS increases, suggesting that current jumps are triggered by photons [16].

In dark, both *p-i-n* and *p-n* devices show rectifying nature which is typical characteristics of conventional diodes, i.e., current flow in forward bias and is blocked in reverse bias condition. Although both devices have different structure, *p-i-n* and *p-n* devices show identical *I-V<sub>A</sub>* characteristics. Lower current in the *p-n* junction devices in the forward bias condition comes from the fact that *p-n* junction devices tend to have narrower channel size due to multiple etching processes during device fabrication. Under light illumination, both devices show photovoltaic effect, i.e., reverse current increases in negative direction by increasing photon flux ( $\Phi$ ), as shown in Fig. 4.

Although both devices show the same photovoltaic effect, apparently some differences can be observed. At larger forward bias condition, *p-n* junction devices show strong dependence on  $\Phi$ . On the other hand, *p-i-n* junction devices show almost photon-independence. These results indicate that *p-n* junction devices are more sensitive to  $\Phi$ . The origin behind this behavior most likely comes from the fact that final dimension of the *p-n* junction devices are narrower compared to *p-i-n* junction devices. This is caused by additional consumption of silicon by the double doping process in the co-doped region in *p-n* junction devices, as previously stated. The origin of the photocurrent enhancement under forward bias in *p-n* junction devices can be described as follows.

Due to narrow channel width in the *p-n* junction devices, resistance of the channel becomes high and the channel becomes insulator-like. Under bias condition, potential along the channel is tilted allowing electrons and holes to flow. Under light illumination, additional electrons and holes are generated in the channel. A small number of electrons and holes which are generated in the depletion region are immediately drifted in the opposite direction from the main diffusion current. As a result, the diffusion current is slightly reduced. On the other hand, large number of photo-carriers generated in the channel beyond the depletion region is

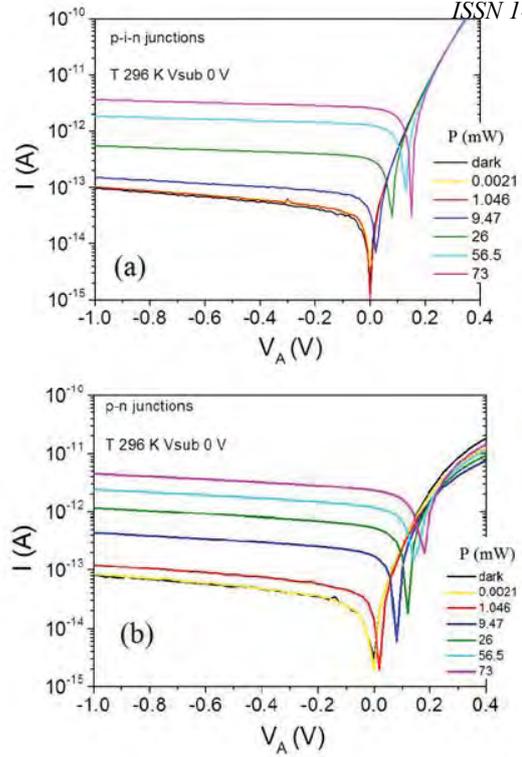


Fig. 4. Typical room temperature *I-V<sub>A</sub>* characteristics of (a) *p-i-n* and (b) *p-n* junctions in dark and under light illumination. Both devices show photovoltaic effect under halogen light illumination, i.e., reverse current increases by increasing photon flux.

flowing in the same direction with the main diffusion current due to potential difference. This photo current increases the diffusion current.

Next, we study the effect of channel-width on device characteristics. Since both *p-i-n* and *p-n* devices show identical behavior, we focus only on the *p-n* junction devices. Fig. 5 shows typical *I-V<sub>A</sub>* characteristics in dark (a) and under light illumination (b) for devices with channel length of 1000 nm and channel width varied from 275 to 1000 nm. From Fig. 5 (a), it is apparent that, in dark, current level increases by increasing channel width. These results are consistent with theoretical prediction. It is well known that dark current in *p-n* junction devices is proportional to the device area (*A*). Increasing the device width will eventually increase the dark current as well. Observation of reverse bias current under light illumination, however, is surprising. As shown in Fig. 5 (b), for *V<sub>A</sub>* below 0 V, devices with narrow channel-width tend to have larger current enhancement under the same  $\Phi$ . The trend of current enhancement for several devices with different channel width is plotted in Fig. 6.

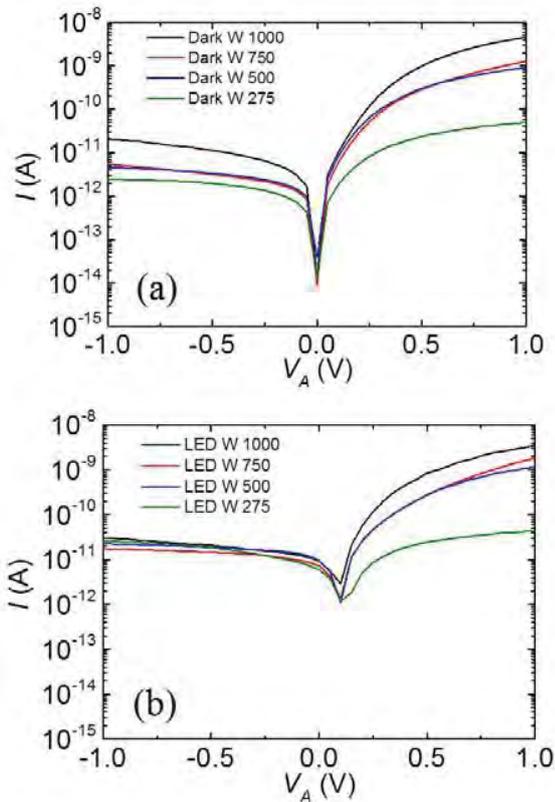


Fig. 5.  $I$ - $V_A$  characteristics of  $p$ - $n$  junction devices in (a) dark and (b) under LED illumination for several devices with different channel width. Under LED illumination, narrow channel-width devices show higher photosensitivity.

As shown in Fig. 6, the current enhancement, i.e., the different current measured in dark and under light illumination, due to photovoltaic effect is larger for devices with narrow channel width. These results suggest that narrow devices are more effective in generating current under the same photon flux. Although the reason behind this trend has not been fully clarified, it is most likely that narrow devices, due to nanosize effect, have wider space-charge region as theoretically predicted by Petrosyan [18].

In conclusion, we experimentally studied nanosize effect in nanoscale lateral  $p$ - $n$  and  $p$ - $i$ - $n$  junction devices at low and at room temperature. At low temperature, due to nanosize effect, individual donor-acceptor atom in  $p$ - $n$  junction devices plays an important role for photon detection. At room temperature, narrow channel-width devices have larger current enhancement under light illumination. Thus, nanoscale  $p$ - $n$  junction devices are promising for future photonic application.

### Acknowledgment

We thank S. Miki for his support during experiment and R. Nowak for helpful discussions.

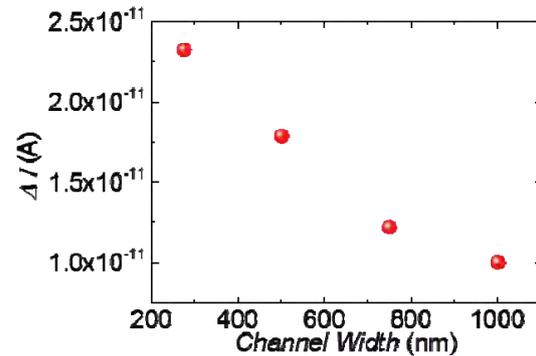


Fig. 6. Current enhancement ( $\Delta I$ ) due to light illumination for several devices with different channel-width. Narrow devices have larger  $\Delta I$  indicating that they are generating current from photons efficiently.

### References

- [1] S.M. Sze, Physics of Semiconductor Devices, 2nd ed. (John Wiley & Sons, New York, 1981), p. 63.
- [2] B. Tian, X. Zheng, T.J. Kempa, Y. Fang, N. Yu, G. Yu, J. Huang, and C.M. Lieber, "Coaxial silicon nanowires as solar cells and nanoelectronic power sources.," *Nature*, 449, pp. 885–9, 2007.
- [3] E. Garnett and P. Yang, "Light trapping in silicon nanowire solar cells.," *Nano Lett.*, 10, pp. 1082–7, 2010.
- [4] C. Yang, C.J. Barrelet, F. Capasso, and C.M. Lieber, "Single p-type/intrinsic/n-type silicon nanowires as nanoscale avalanche photodetectors.," *Nano Lett.*, 6, pp. 2929–34, 2006.
- [5] M.E. Reimer, M.P. van Kouwen, M. Barkelid, M. Hocevar, M.H.M. van Weert, R.E. Algra, E.P. a. M. Bakkers, M.T. Björk, H. Schmid, H. Riel, L.P. Kouwenhoven, and V. Zwiller, "Single photon emission and detection at the nanoscale utilizing semiconductor nanowires," *J. Nanophoton.*, 5, p. 053502, 2011.
- [6] D. Reuter, C. Werner, a. D. Wieck, and S. Petrosyan, "Depletion characteristics of two-dimensional lateral p-n-junctions," *Appl. Phys. Lett.*, 86, p. 162110, 2005.
- [7] S. Saito, D. Hisamoto, H. Shimizu, H. Hamamura, R. Tsuchiya, Y. Matsui, T. Mine, T. Arai, N. Sugii, K. Torii, S. Kimura, and T. Onai, "Electro-Luminescence from Ultra-Thin Silicon," *Jpn. J. Appl. Phys.*, 45, pp. L679–L682, 2006.
- [8] H. Sellier, G.P. Lansbergen, J. Caro, and S. Rogge, "Transport Spectroscopy of a Single Dopant in a Gated Silicon Nanowire," *Phys. Rev. Lett.*, 97, p. 206805, 2006.
- [9] Y. Ono, K. Nishiguchi, A. Fujiwara, H. Yamaguchi, H. Inokawa, and Y. Takahashi, "Conductance modulation by individual acceptors in Si nanoscale field-effect transistors," *Appl. Phys. Lett.*, 90, p. 102106, 2007.
- [10] G.P. Lansbergen, R. Rahman, C.J. Wellard, I. Woo, J. Caro, N. Collaert, S. Biesemans, G. Klimeck, L.C.L. Hollenberg, and S. Rogge, "Gate-induced quantum-confinement transition of a single dopant atom in a silicon FinFET," *Nat. Phys.*, 4, pp. 656–661, 2008.
- [11] M. Pierre, R. Wacquez, X. Jehl, M. Sanquer, M. Vinet, and O. Cueto, "Single-donor ionization energies in a nanoscale CMOS channel.," *Nature nanotechnology*, 5, pp. 133–7, 2010.
- [12] M. Tabe, D. Moraru, M. Ligowski, M. Anwar, R. Jablonski, Y. Ono, and T. Mizuno, "Single-Electron Transport through Single Dopants in a Dopant-Rich Environment," *Phys. Rev. Lett.*, 105, p. 016803, 2010.
- [13] E. Hamid, D. Moraru, J.C. Tarido, S. Miki, T. Mizuno, and M. Tabe, "Single-electron transfer between two donors in nanoscale thin silicon-

- on-insulator field-effect transistors," *Appl. Phys. Lett.*, 97, p. 262101, 2010.
- [14] E. Prati, M. Belli, S. Cocco, G. Petretto, and M. Fanciulli, "Adiabatic charge control in a single donor atom transistor," *Appl. Phys. Lett.*, 98, p. 053109, 2011.
- [15] A. Udhiarto, D. Moraru, T. Mizuno, and M. Tabe, "Trapping of a photoexcited electron by a donor in nanometer-scale phosphorus-doped silicon-on-insulator field-effect transistors," *Appl. Phys. Lett.*, 99, p. 113108, 2011.
- [16] A. Udhiarto, D. Moraru, S. Purwiyanti, Y. Kuzuya, T. Mizuno, H. Mizuta, and M. Tabe, "Photon-Induced Random Telegraph Signal Due to Potential Fluctuation of a Single Donor-Acceptor Pair in Nanoscale Si p-n Junctions," *Appl. Phys. Express*, 5, p. 112201, 2012.
- [17] D.P. Foty, "Impurity ionization in MOSFETs at very low temperatures," *Cryogenics*, 30, pp. 1056-1063, 1990.
- [18] A.S. Achoyan, A.É. Yesayan, É.M. Kazaryan, and S.G. Petrosyan, "Two-dimensional p-n junction under equilibrium conditions," *Semiconductors*, 36, pp. 903-907, 2002.

# Lung Tuberculosis Identification Based on Statistical Feature of Thoracic X-ray

Ratnasari Nur Rohmah

Dept. of Electrical Eng. and Information Technology  
 University of Gadjah Mada, Yogyakarta, Indonesia  
 Dept. of Electrical Engineering  
 UMS, Surakarta, Indonesia

Adhi Susanto, Indah Soesanti

Dept. of Electrical Eng. and Information Technology  
 University of Gadjah Mada  
 Yogyakarta, Indonesia

**Abstract**—This paper presents experiments and results on lung tuberculosis (TB) identification by using computer. This research's attempt is to reduce patient waiting time in obtaining X-ray diagnosis result on lung TB disease due to the mismatch the ratio of radiologist to the number of patients, especially in remote areas in Indonesia. To imitate radiologist which make visual examination on textural feature of thoracic X-ray images to make diagnosis, we exploit textural features calculated by computer to be used as descriptor in classifying images as TB or non-TB. We used statistical feature of image histograms by calculate five features: mean, standar deviation (std), skewness, kurtosis, and entropy. Features calculated where then reduced to two and one principal feature using Principal Componen Analysis (PCA) method. Finally, we used minimum distance classifier as classifier method based on two and one principal feature as descriptor. This experiment results shown that it is possible to classify TB and non-TB images based on statistical features on image histogram.

**Keywords**— X-ray image; Tuberculosis; statistical feature; PCA; minimum distance classifier

## I. INTRODUCTION

Rapid computer applications in medical areas provide many advantages in healthcare applications. Some applications include: telemedicine, medical image analysis, and databases on medical information such as medical record or medical image. Medical image analysis is related to the specific purposes of medical image that is one of diagnostic tools. X-Ray image is one kind of medical images used as diagnostic tools. Our previous research on making identification on disease based on X-Ray image was a research on Osteoporosis Image of proximal femur X-Ray Image [1], [2].

A thoracic X-Ray image commonly is used by physician as diagnostic tool to find some diseases related to human lung, such as lung TB. Tuberculosis is a disease caused by an infection of *Mycobacterium tuberculosis* [3]. It is a systemic disease that can strike any part of human organs with lung as the primary infection. In 2009, World Health Organization reported that Indonesia was the world's fifth largest TB patients population.

To make an X-Ray image, the patient will need several days before receiving the result. X-Ray image need to be examined, diagnosed, and notated by radiologist before given

to the patient. In Indonesia, the number of radiologist expert doesn't match the number of patient [4]. This condition makes the waiting time for patient to receive X-Ray images result relatively longer than those in advanced countries, especially for patient from remote areas in Indonesia.

Our research is to develop an application based on pattern recognition to identify lung TB using computer. Identification using computer in this research is conduct using thoracic X-ray image of the patient. The images classification of TB image and non-TB image will be based on their image textural feature. This application is expected to give benefit to TB lung patients to reduce the waiting time in obtaining the result.

## II. UDERLYING THEORY

### A. Statistical Image Feature

If  $u$  is a random variable that represent of image grey level, probability of one level occurance from grey level is defined as [5]:

$$p_u(x) \cong \frac{\text{the number of pixel with grey level } x}{\text{the number of pixel in an image}} \quad (1)$$

Statistical features can be derived from the equation above as:

$$\text{Moment: } m_i = E[u^i] = \sum_{x=0}^{L-1} x^i p_u(x), \quad i = 1, 2, \dots \quad (2)$$

$$\text{Center moment: } \mu_i = E\{[u - E(u)]^i\} = \sum_{x=0}^{L-1} (x - m_1)^i p_u(x) \quad (3)$$

$$\text{Entropy: } H = E[-\log_2 p_u] = -\sum_{x=0}^{L-1} p_u(x) \log_2 p_u \text{ bits} \quad (4)$$

From those formula, the most common histogram feature are: mean =  $m_1$ , varians =  $\mu_2$ , std =  $\sqrt{\mu_2}$ , skewness =  $\mu_3$ , kurtosis =  $\mu_4 - 3$ , and entropy.

### B. PCA for Feature Vector Dimension Reduction

Feature vector dimensions reduction by PCA method is to specify as many varians as possible using as few variables as possible [6]. In PCA, the original data are transformed into new

lower dimension coordinate systems. These new coordinate systems can remove redundancies. However, we have to consider between efficiency achievement must and sufficient information result in this features extraction. Fig.1 shown flowchart on PCA algorithms for dimension reduction used in this research.

### C. Minimum Distance Classifier

The Minimum distance classifier is one of the decision-theoretic approaches to recognition that based on the use of decision (or discriminates) function [7]. Let  $\mathbf{x} = (x_1, x_2, \dots, x_n)^T$  represent the n-dimensional descriptor vector for  $W$  descriptor

classes:  $\omega_1, \omega_2, \dots, \omega_w$ . Suppose that we define the prototype of each descriptor class to be the mean vector of the descriptor of that class:

$$\mathbf{m}_j = \frac{1}{N_j} \sum_{\mathbf{x} \in \omega_j} \mathbf{x}_j \quad j = 1, 2, \dots, W \quad (5)$$

where  $N_j$  is the number of pattern vectors from class  $\omega_j$

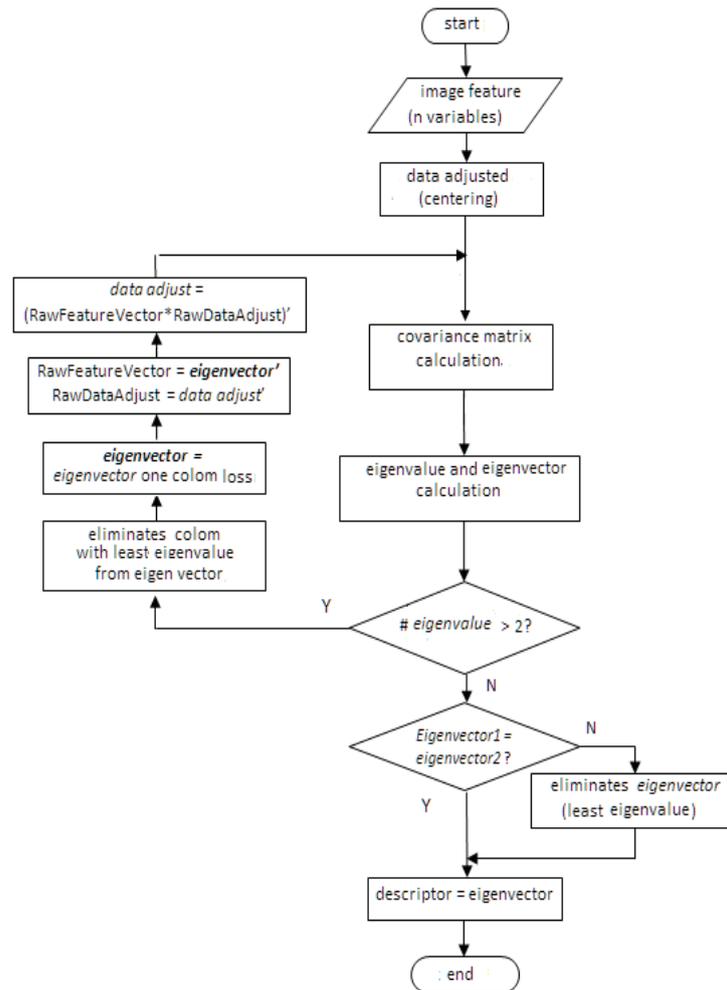


Fig.1. Flowchart of PCA feature dimension reduction from n to 1.

The distance between descriptor vector  $\mathbf{x}$  and the mean vector can be computed using the Euclidean distance:

$$D_j(\mathbf{x}) = \|\mathbf{x} - \mathbf{m}_j\| \quad j = 1, 2, \dots, W \quad (6)$$

Then descriptor  $\mathbf{x}$  is assigned to be the member of class  $\omega_i$  if  $D_j(\mathbf{x})$  is the smallest distance. Selecting the smallest distance means evaluating the function:

$$d_j(\mathbf{x}) = \mathbf{x}^T \mathbf{m}_j - \frac{1}{2} \mathbf{m}_j^T \mathbf{m}_j \quad j = 1, 2, \dots, W \quad (7)$$

and assigning  $\mathbf{x}$  to class  $\omega_i$  if  $d_j(\mathbf{x})$  yields the largest numerical value.

The decision boundary between classes  $\omega_i$  and  $\omega_j$  for minimum distance classifier is:

$$d_{ij}(\mathbf{x}) = d_{ij}(\mathbf{x}) - d_{ij}(\mathbf{x}) = 0 \quad (8)$$

Using this decision boundary function, substitution of any descriptor from class  $\omega_i$  would yield  $d_{ij}(\mathbf{x}) > 0$  and substitution of any descriptor from class  $\omega_j$  would yield  $d_{ij}(\mathbf{x}) < 0$ .

### III. MATERIALS AND METHODS

The data used in this research are the copy of digital X-ray thoracic images from Dr. Sardjito Hospital Yogyakarta. We used 50 thoracic X-Ray images to design this application; i.e. 25 images of healthy persons and 25 images of patients with Lung TB. All images were previously identified by radiologist. The design was broken down into two major steps: to find the image descriptor and to build an application for lung TB identification. Finding descriptor was performed on pre-

processing image and feature extraction processes. The pre-process image was useful to reduce non-uniformity data. Feature image extraction process was consisted of: features image calculation, features image dimension reduction, and features image selection as image descriptor. The application for lung TB identification based on image descriptor selected was built using minimum distance classifier method. Tests on identification accuracy of this application was done for 70 test images; i.e. 30 images of healthy persons without disease, 10 images of bronchitis-infected persons, and 30 images of Lung TB patients.

#### A. Pre-processing

The raw data acquired from Radiology Unit of Sardjito Hospital are not-uniform data. The non-uniformity the images covered in qualities, sizes, and body position X-Ray images. Fig. 2 shows data images and their histograms. Pre-processes was performed before image feature extraction to reduce the non-uniformities. Steps on this process are shown in Fig. 3. Image pre-process was consisted of image quality enhancement and object isolation. Image quality enhancement is conduct by using spatial filtering and histogram equalization of image. Spatial filtering is for noise reduction and pixel intensity transformation using histogram equalization is used to enhance image quality and make intensity level of all data in uniformity. Object isolation was aimed to select the region of interest (ROI) of the image. The ROI was an image area which its feature will be measured. ROI image taken to deal with non-uniformity in data size and human body pose of raw data image.

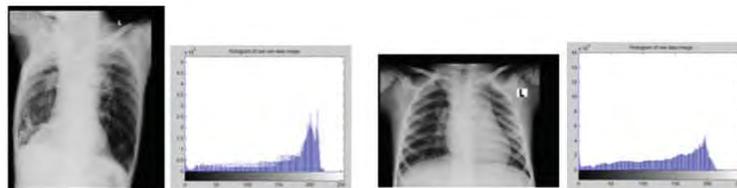


Fig. 2. Raw data images and their histogram.

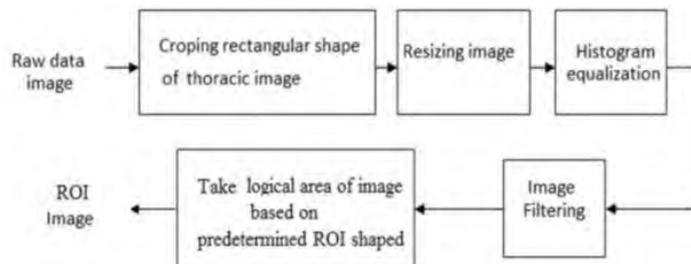


Fig. 3. Block diagram of raw data images pre-processes

Proper ROI image had an important role on calculating the best image feature for image classification. Getting ROI image in this experiment was broken down into three steps: cropping rectangular shape of thoracic images, resizing images and take

logical area of ROI images based on pre-determined shape. Fig. 4 shown raw data image (a) and image after cropping process (b). This process eliminated image and image area without pulmonary part from X-Ray thoracic image at once.

Pre-determined shape of ROI in this experiment was used four different shapes as shown in Fig. 5.

### B. Features Images Extraction

Radiologist searched specific features to diagnose Lung TB by examining X-ray image visually [3]. To imitate this work, this experiment calculated textural features based on statistical feature of image histogram. Five statistical image features are calculated from 50 image sample, that are mean, standard deviation (std), skewness, kurtosis, and entropy. From feature image calculation we have 5 dimension feature vectors. Feature dimension reduction and selection is conduct to reduce features vectors from 5 to 2 and 1. We used PCA method in this process to make sure that selected feature is the most principal feature of image. These two dimensions of principal features and one dimension principal feature will be used as image descriptors.

We also chose the best ROI from four pre-defined ROIs to be used in image identification. Image data plotted based on descriptor for all ROI template used in image pre-processing step. Selection was then made by comparing Euclidean distance and Mahalanobis distances between TB class and normal class for each ROI. The ROI showed the longest distances between classes was chosen as the best ROI and was be used as ROI in the next process.

### C. Images Identification

We used minimum distance classifier method in image identification application. We made two applications: image identification based on one image descriptor and based on two image descriptors, and compared them. Decision function in minimum distance classifier was made based on feature vector resulted from feature image extraction. Test on image identification as TB diseased image and normal image application was performed by making image identification of 70 sample thoracic X-ray image. In this research, application performance evaluated by its accuracy, fault acceptance rate (FAR), and fault rejection rate (FRR) [8].

$$\text{Accuracy} = \frac{\# \text{ True identification}}{\# \text{ Sampel}} \quad (9)$$

$$\text{FAR} = \frac{\# \text{ Fault Accepted Elements}}{\# \text{ Sampel}} \quad (10)$$

$$\text{FRR} = \frac{\# \text{ Fault Rejected Elements}}{\# \text{ Sampel}} \quad (11)$$

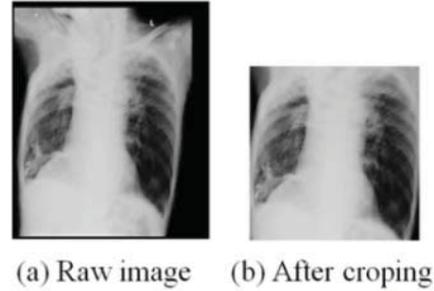


Fig. 4. Image data before and after cropping.

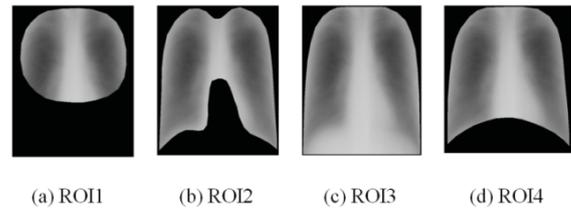


Fig. 5. Pre-determined shapes of ROI image.

## IV. RESULTS AND DISCUSSIONS

### A. Feature Extraction on Raw Images

Experiment in raw image feature extraction performed by extracting feature from raw data image without pre-process step. Five statistical features of image histogram were calculated in feature extraction; i.e. mean, standar deviation (std), skewness, kurtosis, and entropy. This calculation yielded 50 X 5 feature matrix. Based on this matrix, PCA was aimed to reduce five dimension feature vectors down to two, and then down to one feature. These component features would become the descriptor of image. Fig. 6 shows plots of raw image data based on two descriptors from PCA feature dimension reduction. Fig. 7 shows raw images data plots based on one descriptor (plots on image feature line).

Experiment in image feature extraction from raw data image showed extracted features could not be used as specific feature to classify image as TB or non-TB image. Those figure showed that many image data were overlapped between two classes. This was caused by the non-uniformity of raw data images.

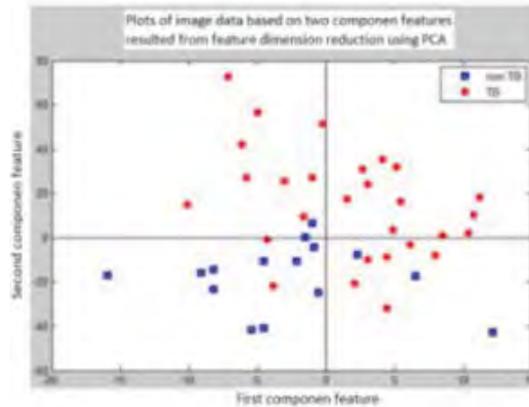


Fig. 6. Plots of raw images data based on two descriptors.

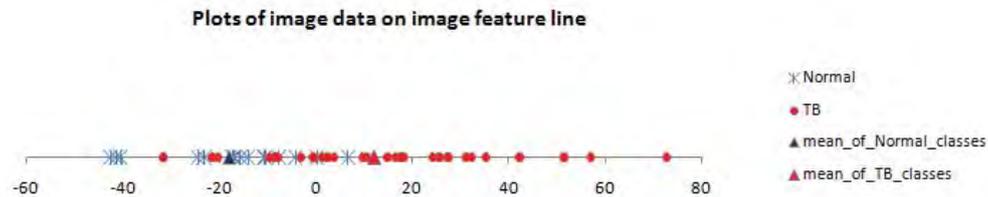


Fig. 7. Plots of raw images data on image feature line.

### B. Features extraction on pre-processed images

In this experiment, raw data image was pre-processed before feature extraction. Pre-processed was aimed to reduce the non-uniformities. As mentioned above, we used four pre-determined ROI images in pre-processing. Fig. 8 shows a clustering achieved from pre-processed image plots based on two descriptors for each ROI shape. Fig. 9 shows pre-processed image plots based on one descriptor, for each ROI image.

Fig. 9 and Fig. 10 shows that ROI2 and ROI4 gave better performance in clustering data image then other ROIs. Table 1 shown Euclidean distances and Mahalanobis distances calculated from image plots based on two image descriptor of each ROI and Table 2 for image plots based on one descriptor. Those table shows that ROI2 template gave the longest distance. From this calculation results we took ROI2 as ROI templates in further process.

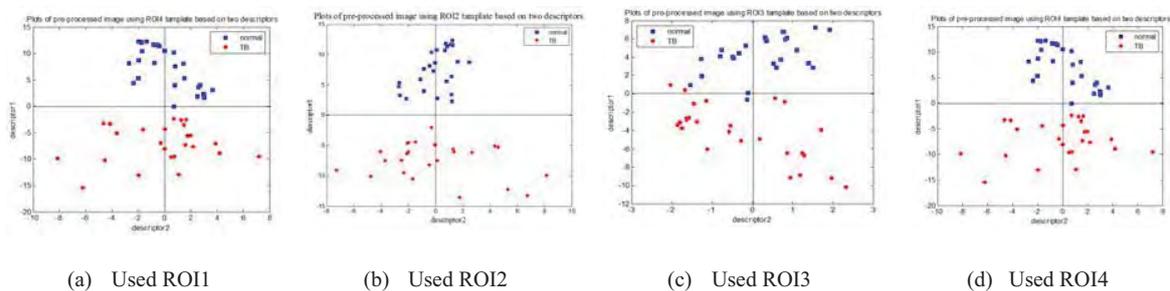


Fig. 8. Plots of pre-processed data image based on two descriptors from PCA feature dimension reduction for each ROI.

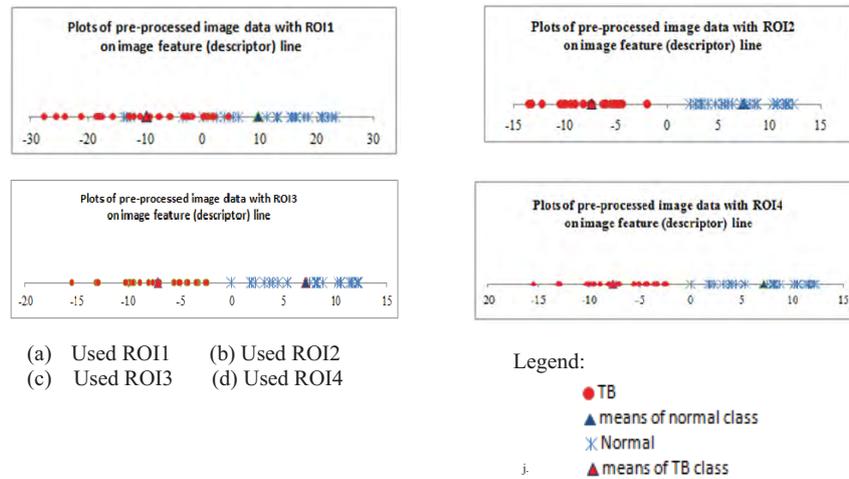


Fig. 9. Plots of pre-processed images data above one component feature for each pre-determined ROI

TABLE 1. EUCLIDEAN DISTANCE AND MAHALANOBIS DISTANCES BETWEEN TWO DIMENSIONAL DESCRIPTORS OF TB CLASS AND NORMAL CLASS FOR EACH ROI TEMPLATE

Distances	ROI1	ROI2	ROI3	ROI4
Euclidean between mean descriptor two classes	19.6091	<b>14.8860</b>	8.4277	14.3275
Mahalanobis distance between descriptor mean of TB class and all descriptors of normal class	3.6106	<b>25.6790</b>	18.6382	24.8969
Mahalanobis distance between descriptor mean of normal class and all descriptors of TB class	4.1437	<b>27.0854</b>	16.9891	16.2793

TABLE 2. EUCLIDEAN DISTANCE AND MAHALANOBIS DISTANCES BETWEEN ONE DESCRIPTOR OF TB CLASS AND NORMAL CLASS FOR EACH ROI TEMPLATE

Distances	ROI1	ROI2	ROI3	ROI4
Euclidean between mean descriptor two classes	19.6029	<b>14.8859</b>	8.4148	14.3219
Mahalanobis distance between descriptor mean of TB class and all descriptors of normal class	3.0227	<b>20.0858</b>	15.9174	13.4158
Mahalanobis distance between descriptor mean of normal class and all descriptors of TB class	4.0796	<b>25.5369</b>	7.4206	16.0064

### C. Image Identification

Image classification in this experiment is conducted using ROI2 for object isolation in pre-processing image. We use minimum distance classifier method in classifying image data based on two image descriptors and one image descriptor. We define boundary decision in minimum distance classifier using two components and one component feature of 50 sources of data image. Fig. 10 shows decision boundary line for minimum distance classifier based on two image descriptors and Fig. 11

shows decision boundary point for minimum distance classifier based on one image descriptor. Decision boundary line for minimum distance classifier based on two descriptors image is defined by equation:

$$descriptor2 = (0.0081) \cdot descriptor1 + 2.5287 \cdot 10^{-4} \quad (12)$$

Decision boundary point for minimum distance classifier based on one descriptor is defined by as:

$$descriptor = 4 \cdot 10^{-6} \quad (13)$$

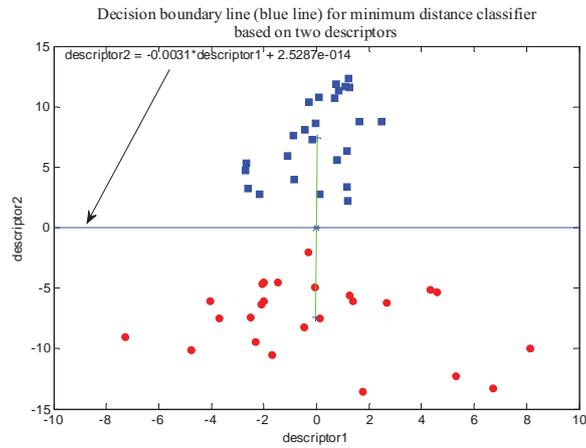


Fig. 10. Decision boundary line (blue line) for minimum distance classifier based on two descriptors.

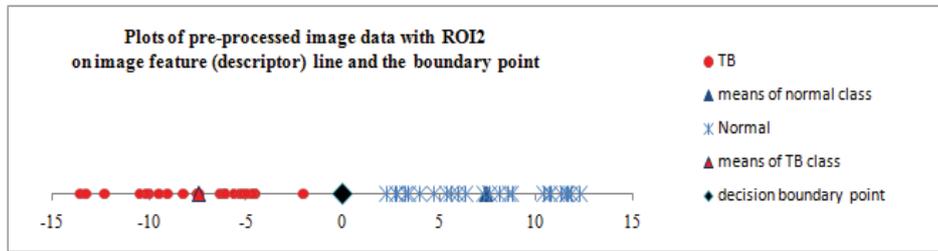


Fig. 11. Decision boundary point (black point) for minimum distance classifier based on one descriptor.

TABLE 3. IMAGE IDENTIFICATION RESULTS

Images sample test	Identification result	
	Positive TB	Negatif TB
30 images of healthy persons	0	30
30 images of Lung TB patients	28	2
10 images of Bronchities patients	1	9

We used test images; i.e. 30 images of healthy persons without disease, 10 images of bronchitis-infected persons, and 30 images of Lung TB patients. All images data had been examined and been diagnosed by radiologist. Tests result shown in table 3. Classification performance wereshown from its accuracy, fault acceptance rate (FAR), and fault

rejection rate (FRR). Experiment on image identification using two and one principal component image feature shows same results. The systems classification performance test results are: accuracy: 95.7%, FAR: 3.33%, FRR = 6.67%.

## V. CONCLUSION

1. Pre-processed images before feature extraction with filtering, histogram equalization, and image segmentation could be used to reduce non-uniformity on raw data image to improve image clustering.
2. Feature dimension reduction using PCA assure that selected feature is the most principal feature on image.
3. The best ROI shape on image segmentation was ROI2 which is shows lung area with as few as possible of non-lung area.
4. The results on identification of 70 image tests using two and one descriptors were: accuracy: 95,7%, FAR: 3.33%, FRR = 6.67%. These results indicate the possibility on identifying lung TB automatically based on image textural features.

## ACKNOWLEDGMENT

The first author would like to thank to: Prof. Dr.dr. Maesadji T., Sp.RAD(K)ONK and the Dr.Sardjito hospital, Yogyakarta for supporting in digital X-ray image data accuision. I would also like to thank to my former Promotor, Prof. Dr. Ir. Thomas Sri Widodo, for supervising my PhD research; and Electrical Engineering and Technology Information Department, University of Gadjah Mada, for permitting to carry my PhD work in UGM.

## REFERENCES

- [1] Rohmah, R. N, L. E. Nugroho, Th. S. Widodo, A. Susanto, Nurokhim, "Design and preliminary result on Content-Based Image Retrieval (CBIR) system for osteoporosis X-ray image database," Proceeding of International Conference on Rural Information and Communication Technology 2009, pp. 199-202, June 2009.
- [2] Rohmah, R. N, L. E. Nugroho, Th. S. Widodo, A. Susanto, Nurokhim, "Content-Based Image Retrieval (CBIR) web-based system for osteoporosis X-ray image Database: A preliminary result, Proceeding of The 11<sup>th</sup> International Conference on QIR (Quality in Research), pp. 258 – 262, August 2009.
- [3] Pusponegoro, Hardiono D., dkk, Standar Pelayanan Medis Kesehatan Anak, first ed., Badan Penerbit IDAI, 2005.
- [4] Faisal A., "Radiologi dapat Digunakan untuk Terapi Belum Semua RS Miliki Alat Radiologi," Pusat Data & Informasi PERSI, <http://www.pdpersi.co.id>, accessed October 17<sup>th</sup>, 2011.
- [5] Jain Anil K., Fundamentals of Digital Image Processing, Prentice-Hall, Inc, 1989.
- [6] Partridge, M., & Calvo, R. A. "Fast dimensionality reduction and simple PCA," Intelligent Data Analysis, 2(1-4), pp. 203-214, 1998.
- [7] Gonzalez, R. C. and R. E. Woods, Digital Image Processing, third ed., Pearson Education, New Jersey, 2008.
- [8] Kachanubal, T., Udomhunsakul, S., " Rock textures classification based on textural and spectral features," World Academy of Science, Engineering and Technology 39, pp. 110 – 116, 2008

# Substrate Bias Effects on Noise and Minority Carrier Lifetime in SOI MOSFET Single-Photon Detector

Dedy Septono Catur Putranto<sup>a,b</sup>, Hiroaki Satoh<sup>b</sup>,  
 Atsushi Ono<sup>b</sup>, and Hiroshi Inokawa<sup>b,\*</sup>

<sup>a</sup>Graduate School Science and Technology

<sup>b</sup>Research Institute of Electronics

Shizuoka University,

3-5-1 Johoku, Naka-ku, Hamamatsu 432-8011, Japan

E-mail: inokawa06@rie.shizuoka.ac.jp

Purnomo Sidi Priambodo<sup>c</sup>, Djoko Hartanto<sup>c</sup>, and Wei  
 Du<sup>d</sup>

<sup>c</sup>Faculty of Engineering, University of Indonesia  
 Depok, Indonesia

<sup>d</sup>Electrical Engineering, Washington State University  
 Vancouver, USA

**Abstract**— Operation speed of the single-photon detector based on the silicon-on-insulator (SOI) metal-oxide-semiconductor field-effect transistor (MOSFET) is affected by the noise and minority carrier lifetime, both of which are found to be dependent on the substrate bias. The noise spectrum are obtained at various substrate voltages in dark condition while keeping the average drain current constant. The noise becomes minimum at around the transition point between front- and back-channel operations, and in the back-channel region near the transition point. On both negative and positive sides of the substrate voltage, the noise shows peculiar Lorentzian spectra. Minority carrier lifetime is evaluated by the analysis of drain current histogram at different substrate voltages. It is found that the peaks in the histogram corresponding to the larger number of stored holes become higher as the substrate bias becomes more positive. This can be attributed to the prolonged lifetime presumably caused by the higher electric field inside the body of SOI MOSFET. It can be concluded that, once the inversion channel is induced for detection of the photo-generated minority carriers, the small absolute substrate bias is favorable for short lifetime and low noise, leading to high-speed operation.

**Keywords**— Substrate bias effect, Low-frequency noise, SOI MOSFET, single-photon detector, minority carrier lifetime  
**Introduction**

## I. INTRODUCTION

It has been reported that a short- and narrow-channel silicon-on-insulator (SOI) metal-oxide-semiconductor field-effect transistor (MOSFET) can operate as a single-photon detector, featuring dark counts several orders of magnitude smaller than that of conventional avalanche photodiode (APD), and low operation voltage less than a few volts [1], [2]. Although this SOI MOSFET had a special double-gate structure with a short lower gate (LG) and a long upper gate (UG) covering the p-doped offset area between LG and n<sup>+</sup>-doped source/drain, it was later found that the ordinary SOI MOSFET with LG-source/drain overlap can operate as a single-photon detector with the same feature [3]. In order to improve the performance of this detector low-frequency noise in the output and lifetime of the photo-generated holes stored in the body of the MOSFET must be analyzed, which are closely related to the dark count rate and the operation speed of the single-photon detection. In this paper, we will describe the behavior of the drain current noise and the hole lifetime under different

substrate biases in search of optimum operation condition of the SOI MOSFET single-photon detector.

## II. EXPERIMENTS

This time, we focus on the ordinary n-channel SOI MOSFET without offset region as shown in Fig. 1. It has n<sup>+</sup> poly-Si-gate and p<sup>+</sup> channel region with dopant concentration less than 10<sup>15</sup> cm<sup>-3</sup>. The SOI is of a wafer-bonding type supplied by Soitec [4]. Thicknesses of buried oxide, SOI and gate oxide are 145, 50 and 5 nm, respectively. The gate length is fixed at 300 nm, and the channel width is varied among 90, 95 and 110 nm. In the noise measurement and the hole lifetime analysis, we changed  $V_{sub}$ , while keeping the drain current at the constant level of 1 nA by adjusting the front gate voltage  $V_g$ . The drain current noise was measured in dark condition at 300 K, and the hole lifetime was evaluated by the analysis of drain current histograms for different levels of light intensity also at 300 K.

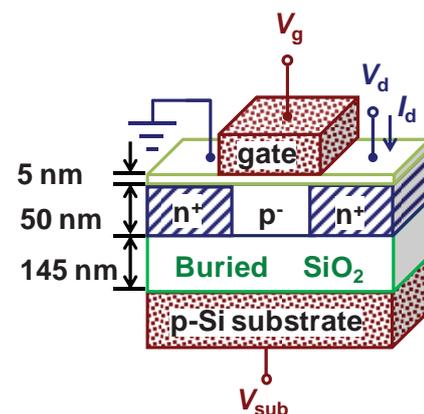


Fig. 1 Schematic diagram of the SOI MOSFET. Thicknesses of buried oxide, SOI and gate oxide are 145, 50 and 5 nm, respectively.

## III. RESULT AND DISCUSSION

### A. Analysis of drain current noise

Figure 2 shows an example of  $I_d$ - $V_g$  characteristics with  $V_{sub}$  as a parameter ranging from -10 to 10 V. Drain voltage  $V_d$  is kept at 50 mV. From these data, front-gate threshold voltage  $V_{th}$  corresponding to the  $I_d$  of 1 nA is extracted for setting the operation condition and further analysis. Figure 3 shows noise power for the bandwidth of 5 Hz, and the threshold voltage  $V_{th}$  plotted against the substrate voltage for various channel widths. In the  $V_{th}$ - $V_{sub}$  characteristics, the deflection point 1 corresponds to the transition point between front- and back-channel operations, and the deflection point 2 to the transition between inversion and accumulation conditions at the buried oxide/substrate interface [5]. The noise levels show horseshoe shape, and become low at around the deflection point 1 and in the back-channel region between deflection points 1 and 2.

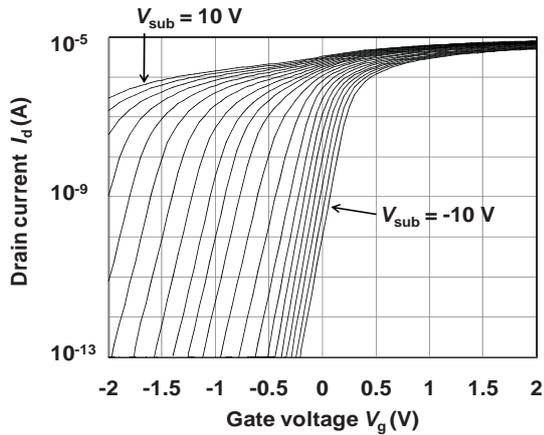


Fig. 2  $I_d$ - $V_g$  characteristics with  $V_{sub}$  as a parameter. Drain voltage  $V_d$  is kept at 50 mV. Device sizes are  $L=300$  nm and  $W=110$  nm.

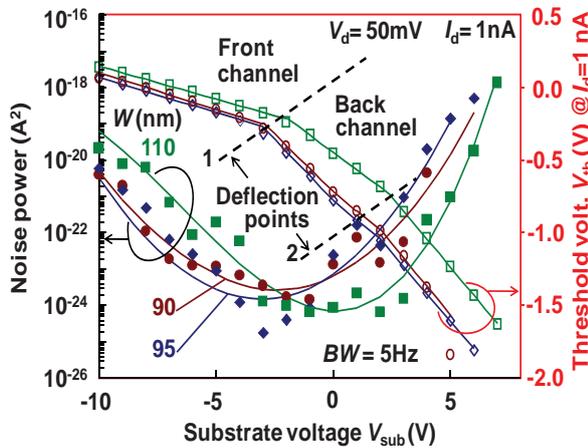


Fig. 3 Noise power and front-gate threshold voltage  $V_{th}$  at 1 nA as a function  $V_{sub}$ . The gate length is fixed at 300 nm, channel width is varied among 90, 95 and 110 nm.

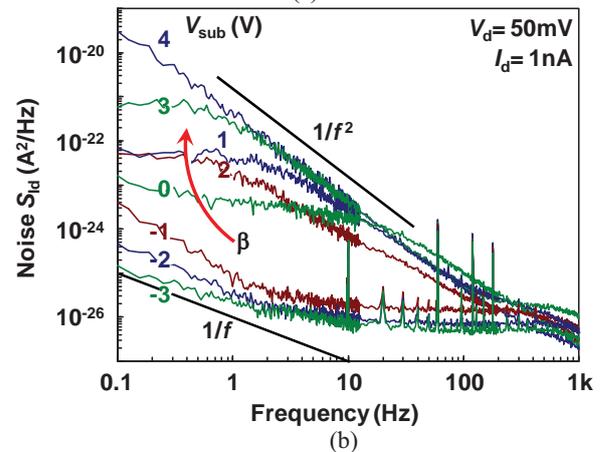
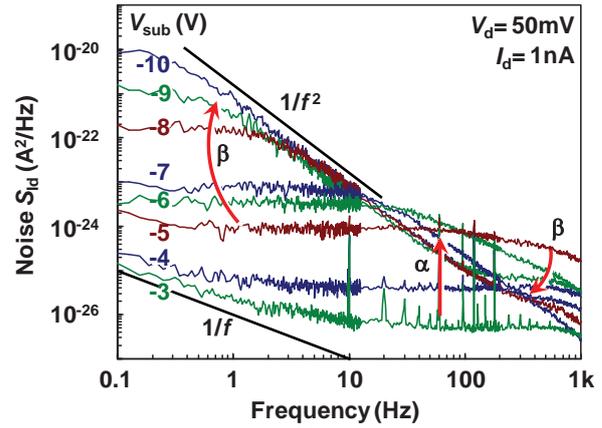


Fig. 4 Drain current noise spectra for (a) front-channel ( $-10 \leq V_{sub} \leq -3$  V), and (b) back-channel ( $-3 \leq V_{sub} \leq 4$  V) operations. Device sizes are  $L=300$  nm and  $W=95$  nm.

Figure 4(a) shows the drain current noise spectra for front-channel operation in  $-10 \leq V_{sub} \leq -3$  V. It can be seen that, as the  $V_{sub}$  decreased, the Lorentzian noise at high frequency increases only in the plateau level at first ( $\alpha$ ), and after that, the noise spectra asymptotically approaches a single  $1/f^2$  line ( $\beta$ ), indicating that the plateau level increases and the cut-off frequency decreases simultaneously. The similar noise behavior was found by D. S. Ang, et al. in the nearly fully depleted SIMOX SOI n-MOSFET operating at a low drain voltage, and they attributed this to the generation and recombination (GR) of carriers via bulk electron traps [6]. It is interesting to see the resemblance regardless of the difference in SOI material. Figure 4(b) shows the noise spectra for back-channel operation in  $-3 \leq V_{sub} \leq 4$  V. The similar behavior of the evolution of the GR noise can be observed ( $\beta$ ), but the initial increase only in the plateau level ( $\alpha$ ) cannot be seen.

### B. Analysis of hole lifetime

Figure 5 shows typical drain current waveforms for different levels of light intensity at the wavelength of 550 nm. Baseline

current is adjusted to 1 nA by  $V_g$ , and each waveform is shifted for clarity.  $V_d$  and  $V_{sub}$  are 0.05 and 1.49 V, respectively. In this figure, we can clearly see that the photo-generated holes modulate the drain current to discrete levels corresponding to the number of stored holes below the gate, while the operating condition is set to  $V_g < 0$  and  $V_{sub} > 0$ , so that the electrons flow in the back-channel.

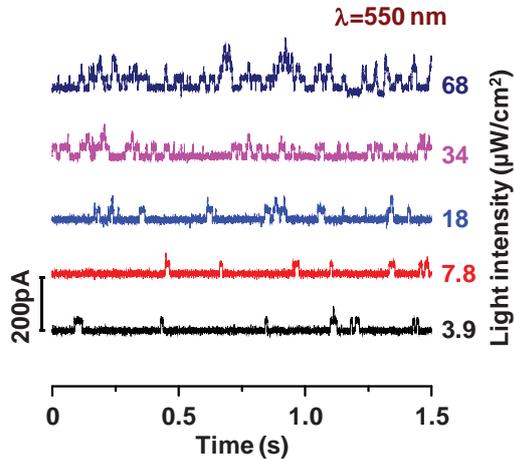


Fig. 5 Typical drain current waveforms at 300 K for different levels of light intensity at the wavelength of 550 nm. Baseline current is adjusted to 1 nA by  $V_g$ , and each waveform is shifted for clarity.  $V_d$  and  $V_{sub}$  are 0.05 and 1.49 V, respectively. Device sizes are  $L=300$  nm and  $W=110$  nm.

Figure 6 shows the histograms of drain current for (a)  $V_{sub}=1.27$  V, (b)  $V_{sub}=1.49$  V, (c)  $V_{sub}=1.72$  V, and (d)  $V_{sub}=1.93$  V with different  $V_g$  to keep the baseline drain current at the same level of 1 nA. The closed symbols are obtained data and solid lines are fitting curves with Gaussian distribution. The peaks from left to right correspond to the number of stored holes of 0, 1, 2 and 3. It can be seen that the peaks in the histogram corresponding to the larger number of stored holes become higher as the  $V_{sub}$  increases. This may be caused by the longer hole lifetime, higher light absorption efficiency or higher collection efficiency of the photo-generated holes. In order to understand the bias dependence of the light absorption and hole collection, hole generation rate is plotted against the light intensity in Fig. 7. There is proportionality between hole generation rate and incident light intensity regardless of  $V_{sub}$ , indicating that light absorption or hole collection efficiencies is not much changed by the bias condition. This also means that the hole lifetime can be controlled without affecting the nominal QE, which amounts to 5% in this case assuming the photosensitive area of  $300 \times 110$  nm<sup>2</sup>.

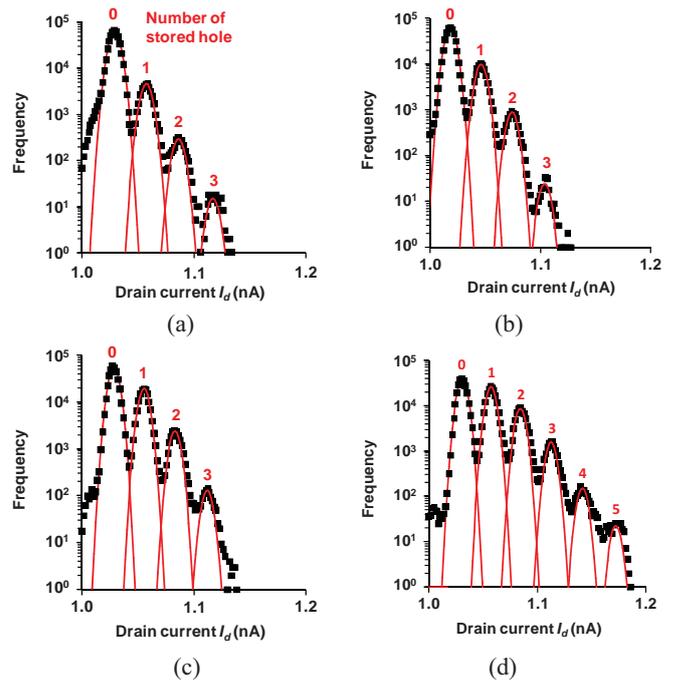


Fig. 6 Histograms of drain current for (a)  $V_{sub}=1.27$  V, (b)  $V_{sub}=1.49$  V, (c)  $V_{sub}=1.72$  V, and (d)  $V_{sub}=1.93$  V with different  $V_g$  to keep the baseline drain current at the same level of 1 nA under the continuous light illumination of  $34 \mu\text{W}/\text{cm}^2$ . The first, second, third, and fourth peaks correspond to the number stored holes of 0, 1, 2 and 3, respectively. Data acquisition time period and time step are 2.45 s and  $49 \mu\text{s}$ , respectively, and 50000 ( $=2.45\text{s}/49\mu\text{s}$ ) data points (current values) are classified into bins with a width of 2 pA. Device sizes are  $L=300$  nm and  $W=110$  nm.

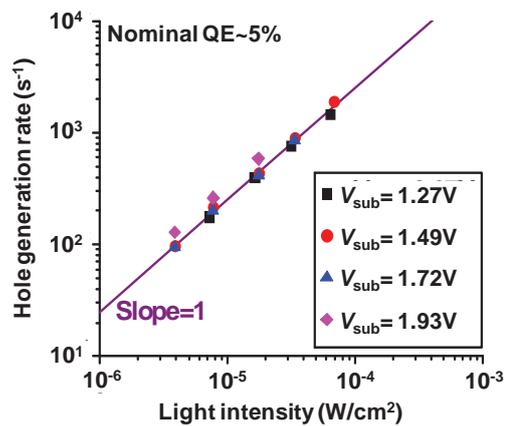


Fig. 7 Hole generation rate as a function of incident light intensity for each bias condition. Slope of the fitting line is one.

The hole lifetimes are obtained as fitting parameters to describe the evolution of drain current histogram based on the rate equation under steady state conditions,  $f_i / \tau_i = f_{i-1} R$  and  $\sum f_i = 1$ , where  $\tau_i$  and  $f_i$  are hole lifetime and probability of state corresponding to hole number  $i$ , and  $R$  is hole generation rate [2]. The hole lifetimes at different  $V_{\text{sub}}$  are depicted in Fig. 8. It can be seen the hole lifetime increases significantly as  $V_{\text{sub}}$  increases. It is estimated that higher  $V_{\text{sub}}$  (higher transverse electric field) separates the stored hole and electron more effectively, and reduces the probability of recombination, leading to the longer lifetime.

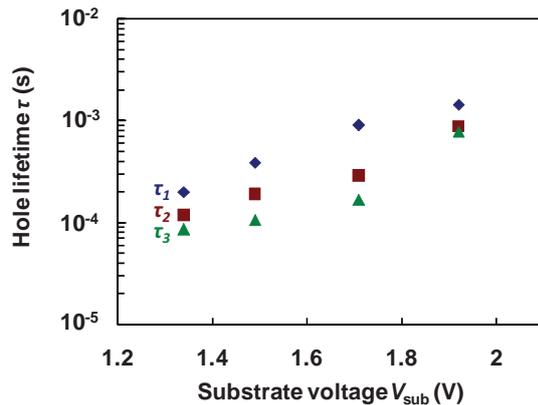


Fig. 8 Hole lifetime as a function of  $V_{\text{sub}}$ .  $\tau_1$ ,  $\tau_2$  and  $\tau_3$  are the lifetimes when the number of the stored holes are one, two and three, respectively.

#### IV. CONCLUSION

Low-frequency current noise in SOI MOSFET was analyzed for single-photon detection under different substrate biases in dark condition while keeping the average drain current constant. It was found that the noise in the SOI MOSFET became low at the transition point between the front- and back-channel operations, and in the back-channel region near the transition point. On both sides, the noise spectra asymptotically approached a single  $1/f^2$  line, indicating that the active trap density and carrier lifetime increased simultaneously. In order to understand the substrate bias dependence of hole lifetime, the drain current histograms of the SOI MOSFET single-photon detectors were analyzed under different substrate voltages and different light intensity. It was found that the peaks in the histogram corresponding to the larger number of stored holes became higher as the substrate bias decreased. This was attributed to the prolonged hole lifetimes caused by the higher electric field inside the body of SOI MOSFET. It can be concluded that, once the inversion channel is induced for detection of the photo-generated minority carriers, the small absolute substrate bias is favorable for short lifetime and low noise, leading to high-speed operation.

#### ACKNOWLEDGMENT

The author are indebted to Keisaku Yamada of University of Tsukuba, Toyohiro Chikyo of National Institute of Materials and Science, Tetsuo Endoh of Tohoku University, Hideo Yoshino and Shigeru Fujisawa of Semiconductor Leading Edge Technologies, Inc. for their cooperation in the device fabrication.

#### REFERENCES

- [1] A. Fujiwara, K. Yamazaki, and Y. Takahashi, *Appl. Phys. Lett.*, **80**, 4567 (2002).
- [2] W. Du, H. Inokawa, H. Satoh and A. Ono, *Optics Letters*, **36**, 2800, (2011).
- [3] W. Du, H. Inokawa, H. Satoh and A. Ono, *Jpn. J. Appl. Phys.*, **51**, 06FE01 (2012).
- [4] Soitec S.A., Parc Technologique des Fontaines, 38190 Bernin, France.
- [5] S. Horiguchi, A. Fujiwara, H. Inokawa, Y. Takahashi, *Jpn. J. Appl. Phys.* **43**, 2036 (2004).
- [6] D. S. Ang, Z. Lun, and C. H. Ling, *IEEE Trans. Electron Devices*, **50**, 2490 (2003).

# Microplate Luminescence Automated Digital Analyzer for Medicinal Plants Evaluation on Quorum Sensing Inhibition

Kestrilia Rega P

Department of Informatics Engineering  
MaChung University  
Malang, Indonesia

[kestrilia.rega@machung.ac.id](mailto:kestrilia.rega@machung.ac.id)

Sulistyo Emantoko

Faculty of Biotechnology  
University of Surabaya  
Surabaya, Indonesia

[emantoko@ubaya.ac.id](mailto:emantoko@ubaya.ac.id)

Eryanto

Department of Informatics Engineering  
University of Surabaya  
Surabaya, Indonesia

**Abstract**—Quorum sensing is a mechanism used by most of pathogenic bacteria to coordinate their gene expression. Through this kind of mechanism the bacteria could detect the density of their local population until at a certain level they will act together to emerge virulence which cause disease in their host organism. Thus, the inhibition ability to quorum sensing mechanism is commonly used as an indicator to evaluate the potentiality of extracts from plants as antibacterial in drugs development. The quorum sensing activity could be detected using luminescence method. When the colony of bacteria reach the quorum and express certain activity, the luminescence will be produced. Microplate is a kind of experiment media which is used to conduct such experiment. The luminescence as the experiment result were captured as a digital image. The luminescence then examined to determine the plant performance to inhibit the bacteria virulence activity. Regarding most of the researcher's experience, it is believed that manual evaluation of those luminescence images is hard to interpret due to subjectivity factor and also inefficiency in time, especially when working with a large number of experiments. Therefore, in this research we developed a computer application to run quantification of the luminescence automatically. The automation process begin with gridding algorithm followed by object recognition and segmentation algorithm based on neural network learning. In order to improve the accuracy, image enhancement module were also attached to the system. In the output section, the quantification report presented using some statistical parameter to simplify interpretation and facilitate the researcher to run additional data analysis. With this application, the potentiality of extracts from plants as antibacterial agent could be inferred quickly, easily and accurately.

**Keywords**—digital image processing; artificial neural network; automation; luminescence; quorum sensing

## 1. Introduction

Quorum sensing is bacterial mechanisms which is regulating some specific proteins expressions by calculating population density in their environment. Genes which are regulated by quorum sensing mechanism will only express (activated) at the time the bacteria population reached certain level of density. Some examples of genes whose expression

was regulated by this mechanism are genes that regulate the formation of flagella and biofilm, and genes associated with virulence properties [1]. The fact that the virulence factor is also regulated by quorum sensing mechanism raises new hope to discover many techniques and/or agents to inhibit virulence of pathogenic bacteria. In this research, extracts from some Indonesian Medicinal plants was evaluated for their performance to inhibit quorum sensing mechanism of *Pseudomonas aeruginosa* (one of the pathogenic bacteria which have resistance to many antibiotics). The evaluation was done by measuring the level of luminescence which is produced by the colony of *Pseudomonas aeruginosa* when they reach the quorum and express certain activity. This experiment was conducted in a microplate which is a flat plate with multiple holes/wells used as small test tubes. Both of the bacteria colony and the extracts from plants was loaded into the holes. The level of luminescence then captured and transformed into digital image [2]. Next task is comparison of the result. Brighter luminescence indicates weak inhibition to the *Pseudomonas aeruginosa* quorum sensing mechanism. Most of the researcher use manual comparison to evaluate these luminescence images. Unfortunately, this method is not the best way to get good inference of the result. Manual comparison has many weaknesses due to subjectivity of the evaluator and also inefficiency in time when run multiple experiments. Hence, we propose the application of automatic digital image processing to quantify the luminescence images in the form of software named Microplate Luminescence Automated Digital Analyzer (MILDA). Therefore, the researcher could run various statistical data processing to get accurate and fast conclusion.

The first generation of MILDA was developed using hough transform algorithm for the segmentation (separation of the luminescence and the background area) procedure. But, due to the problem of imprecise circular form of the luminescence area, this method is found to be ineffective [3]. In this research, the artificial neural network algorithm was applied to improve the segmentation result.

## II. Materials and methods

Input of the software are luminescence images using microplate as experiment media. Fig. 1 is the examples of the input images. The bright round shapes are the luminescence produces by the experiment in the round shape wells. Each well was loaded with the *Pseudomonas aeruginosa colony* and extract from particular medicinal plant. The medicinal plants used in this experiment are fennel, lawang, selasih, temu ireng, temu putih, temu giring and temu lawak. When the quorum sensing mechanism was totally inhibits by the extracts, the well will not produce any luminescence and will appears as black round shape. The micro plate could contain various numbers of wells, such as 36, 96, 384 and 1536.

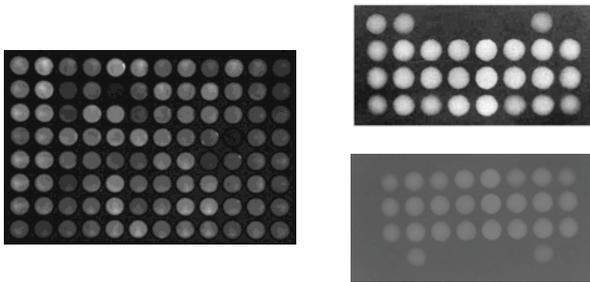


Fig. 1. Examples of the input images

The first step of the MILDA's system is preprocessing the input image to enhance its quality, the second step is run gridding procedure. In this procedure the system will automatically make a pattern of regularly spaced horizontal and vertical lines forming squares on the input image with modified fixed spot position algorithm.. At the end of the procedure, each square will only contain one round shape. Next, segmentation procedure was applied to each square. The aim of this procedure is to classify each pixel in the square as object (the luminescence) or background. Classification was done using neural network algorithm. Finally, the last step is quantification of the object pixels. In order to simplify the quantification result, MILDA was equipped with the statistical report feature. Fig. 2 depict the flowchart of the system. Details algorithm of each step will be explained in the next sections.

## III. system design

### A. Preprocessing

In order to improve the accuracy of the luminescence value as the systems output, preprocessing the input image is one of the important step. Input image could have various quality due to its clarity, color intensity, color contrast or symmetricalness. Preprocessing will reduce the complexity of the algorithm in the next procedures. Some of the image

enhancement algorithms was applied in preprocessing step which are noise reduction, image rotation and normalization. Noise reduction was conducted using median or wiener filtering algorithm. Median filtering reduced salt and pepper noise and wiener filtering reduced Gaussian noise [4].

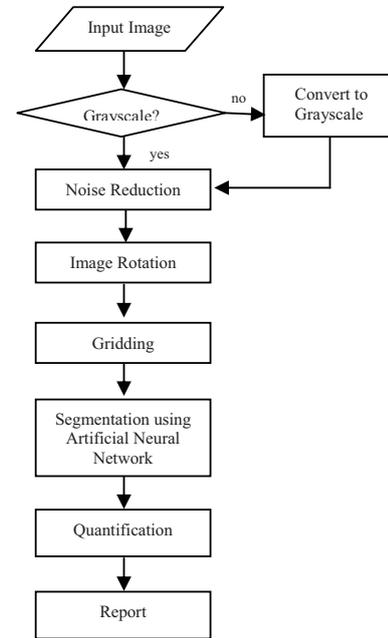


Fig. 2. Flowchart of the system

Fig. 3 depict the example of noise reduction result on the input image. Image rotation was applied due to symmetricalness problem of the input image. Asymmetric image will cause problems in the gridding procedure. Therefore radon transformation [5] algorithm used to transform asymmetric image into a symmetric one. Fig. 4 depict the example of image rotation to fix asymmetric image.

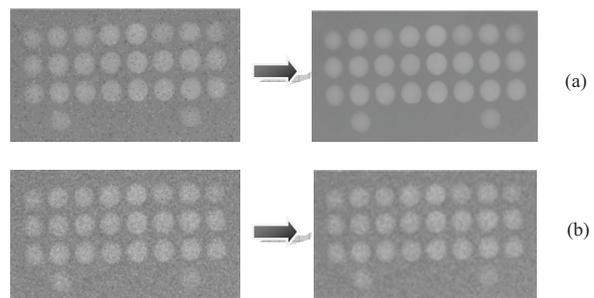


Fig. 3. Example of noise reduction, (a) Salt and Pepper, (b) Gaussian

Finally, the normalization algorithm was applied to adjust the color intensity range, such adjustment will increase the color

contrast as shown in Fig. 5. Normalization was done using (1),  $O$  is intensity value before normalization and  $N$  is intensity value after normalization.

$$N_{x,y} = \frac{N_{max} - N_{min}}{O_{max} - O_{min}} \times (O_{x,y} - O_{min}) + N_{min} \quad \forall x,y \in 1,N \quad \dots(1)$$

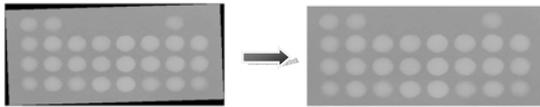


Fig. 4. Example of image rotation

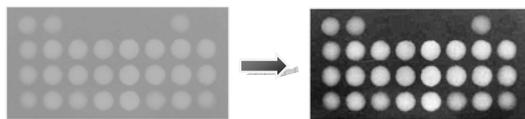


Fig. 5. Example of image normalization

### B. Gridding Procedure

This procedure contain techniques to find the location of the objects (the round shape luminescence) automatically. In general, the basic concept is iteratively creates vertical and horizontal lines on the input image such that in the final step each object will be placed exactly on the center of a square. The algorithm used for this process is fixed spot position [6] with some modification. Formerly the input image should be transform into grayscale type and followed by application of particular intensity threshold value to identify each pixel as object or background. Vertical and horizontal line will divide two objects in equal distance regarding the edge pixels of both objects. Fig. 6 is the example of the gridding procedure result. Now, each square carried out one object.

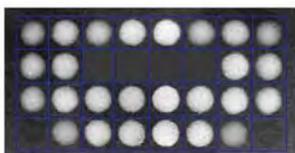


Fig. 6. Result of the gridding procedure

### C. Segmentation Procedure

After gridding procedure, the system will save position of each square with the object inside. Thus, the extraction of the objects is ready to be proceeded. The first step to extract the object is finding all the object's pixels. To find those pixels, the system should have the ability to well recognize the characteristic of the color intensity of the object pixels as well as the background pixels. In order to increase this ability, neural network (NN) method was applied here. Intensity

histogram was chosen as the input of the NN architecture. Therefore, 256 nodes are used in the input layer. For the hidden layer it is found that one layer with 6 node give the best output prediction. One output node represents the color intensity threshold value that will classify each pixel as object or background. Fig. 7 depict the best NN architecture implemented in the system. At the end of the process, the system will store the position of each object pixel and the corresponding intensity value in its database.

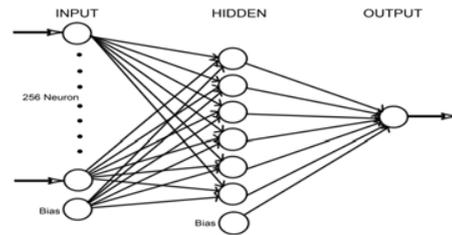


Fig. 7. Neural network architecture for segmentation process

### D. Quantification

This is the step to summarize all object pixels intensity values (from the segmentation procedure) in the database and represent them in more sophisticated format. Quantification of each object luminescence should appear as single value. For this purpose, the system provide option button such that user could choose the method of summarization which is mean, median, maximal or minimal value. Fig. 8 shows example of the quantification process result using mean value.

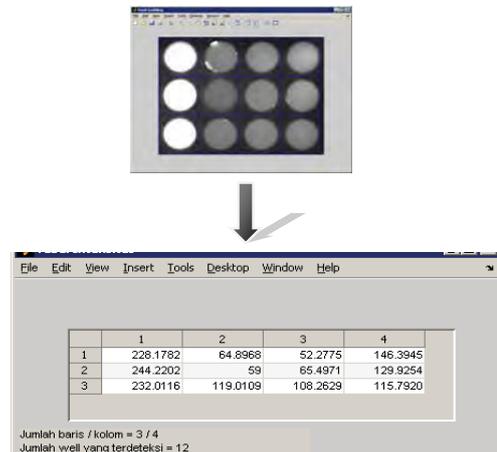


Fig. 8. Example of the quantification process result

E. Report

Report feature was attached to the system to facilitate user for advance data processing. The report will be in .xls format which is contains the position and luminescence intensity of each object pixels. By this feature the researcher could easily prepare raw data to run various kinds of statistical data processing such as testing hypothesis, ANOVA, regression and cluster analysis.

#### IV. result and discussion

In general the performance of the system is good. The quantification performance of the intensity value is depends the input image. From all input images sample with various level of quality, the system could give reasonable quantification result for 87.5% among them. The system only fail on very low quality of input image. For this kind of input image, the systems already fail in gridding process thus no intensity value reported on the output interface. The accuracy of the system was proven too by changing the concentration of the plant extract. In theory, the increasing concentration of quorum sensing inhibitors will result on decreasing luminescence intensity [7]. The quantification result shows exactly the same tendency in almost all of the samples as shown in Table 1. In the matter of time, the run time depend on the number of the microplate wells. MILDA could run all the process less than 15 second. This result is better than previous system using circular hough transform for its segmentation process [3].

TABLE I. THE ABILITY OF PLANTS EXTRACT IN VARIOUS CONCENTRATION TO INHIBIT THE LUMINESCENCE

Plant	Concentration (mg/ml)	Luminescence Inhibition (%)
Fennel	23.8	59.2
	19.0	65.4
	14.3	53.9
Lawang	23.8	34.1
	19.0	19.2
	14.3	-3.2
Selasih	23.8	59.8
	19.2	47.9
	14.3	44
Temu Ireng	38.1	44.1
	19.0	39.7
	9.5	7.7
Temu Giring	38.1	16.3
	19.0	3.9
	9.5	7.9
Temu Putih	38.1	-0.3
	19.0	4.9
	9.5	28.8
Temulawak	38.1	16.5
	19.0	23.5
	9.5	6.3

#### V. conclusion

Although this system could perform good quantification result, it is known that the quality of input image still bring major difficulties. Therefore, for the future works we propose to design a customized media to capture the luminescence directly from the microplate. This media then integrated to the MILDA software such that the quantification could run in real time.

#### References

- [1] Dong YH and Zhang LH, "Quorum sensing and quorum-quenching enzymes", *J Microbiol*, vol. 43, pp. 101-109, 2005.
- [2] Lucyana Suryaputra, "The influence of Agaricus Mushrooms Extracts to Pseudomonas Aeruginosa PA01 Autoinducer Using Eschericia Coli XL1 pSB1075 as Biosensor", Final Project, University of Surabaya, 2008.
- [3] A. Yohan, "Development of Automatic Quantification for Luminescence Image on Microplate Media Using Structural Object Identification", Final Project, University of Surabaya, 2011.
- [4] Rafael C. Gonzalez and Richards E. Woods, "Digital Image Processing, 3<sup>rd</sup> Edition", Prentice Hall, 2007.
- [5] P. Bajcys, L. Liu, and M. Band, "DNA Microarray Image Processing", in *DNA Array Image Analysis: Nuts&Bolts*, Ed. Gerda Kamberova, DNA Press, 2005.
- [6] Alhadidi, H.N. Fakhouri, O.S. Al Mousa, "cDNA Microarray Genome Image Processing Using Fixed Spot Position", *American Journal of Applied Sciences*, vol. 2, pp. 1730-1734, 2006.
- [7] T.B. Rasmussen, M. Manefield, JB Andersen, L. Eberl, U. Anthoni, C. Christophersen, P. Steinberg, S. Kjelleberg, and M. Givskov, "How Delisea pulchra furanones Affect Quorum Sensing and Swarming Motility in Serratia liquefaciens MG1", *Microbiology*, 146 pp. 3237-3244. 2000.

# KFM Evaluation of Seebeck Coefficient in Thin SOI Layers

Hiroya Ikeda, Yuhei Suzuki, Kazutoshi Miwa, Faiz Salleh

Research Institute of Electronics  
 Shizuoka University  
 Hamamatsu, Japan  
 ikeda@rie.shizuoka.ac.jp

Faiz Salleh

Research Fellow of the Japan Society for the Promotion of Science  
 Tokyo, Japan

**Abstract**—Although the introduction of nanostructures into thermoelectric materials is one of key technology for enhancement in thermoelectric conversion efficiency, a technique for characterizing the nanometer-scale materials is required. With the aim of evaluating Seebeck coefficient of nanostructured thermoelectric materials, we propose a new technique by Kelvin-probe force microscopy (KFM) which gives us local surface potential corresponding to the Fermi energy difference of a sample relative to the cantilever. Hence, thermoelectromotive force and temperature difference are obtained from the surface potentials and temperatures at the high- and low-temperature regions on the sample, which leads to evaluation of Seebeck coefficient. First of all, the Seebeck coefficients of bulk Si wafers and Si-on-insulator (SOI) layers were measured. At present, the Seebeck coefficient is evaluated to be  $-2.8\text{mV/K}$  for a SOI layer, which is larger than the value obtained by a conventional method.

**Keywords**—thermoelectric material; nanostructure; Seebeck coefficient; Kelvin-probe force microscopy

## I. Introduction

The introduction of nanometer-scale structures into thermoelectric materials has been expected to lead to breakthroughs for enhancing the thermoelectric figure-of-merit [1-4]. A number of researchers are engaged in characterizing nanometer-scale thermoelectric materials [5-8]. However, it is very difficult to measure the thermoelectric characteristics of these nanostructured materials because of the very small dimensions. For evaluating the Seebeck coefficient, external disturbances such as lead-wire contact essential to the conventional thermoelectromotive force (TEMF) measurement affect accurate evaluation. Recently, probe microscopy techniques have attracted significant attention for the thermoelectric characterization of nanometer-scale materials [9-11]. In these techniques, a probe is contacted with the sample surface and the thermoelectric characterization is performed on the basis of the vertical temperature difference (i.e. normal to the sample surface). Therefore, contact of the metallic probe with the sample surface cannot be avoided, and specially-customized equipment is needed.

With the aim of measuring the Seebeck coefficient on a nanometer scale, we propose a new technique using Kelvin-probe force microscopy (KFM), which allows non-contact

measurement. Another advantage of the proposed technique is that, by adjusting the sample holder, commercial KFM equipment can be used. In the present paper, it is demonstrated that the construction and improvement of the measurement technique through Seebeck-coefficient evaluation for Si and Si-on-insulator (SOI) wafers [12-14].

## II. Measurement Principle

The KFM is a powerful tool for measuring the electric potential of nanometer-scale structures. Using this technique, it is possible to obtain the surface potential corresponding to the work-function difference between the cantilever and the sample, that is, the Fermi energy of the sample relative to that of the cantilever metal. Figure 1 shows the band diagram of the cantilever (Au-coated Si) and the n-type Si sample under a temperature difference across the sample parallel to the surface. When the temperature difference is applied to the sample, the Fermi energy of the Si will be spatially distributed. Generally, the Fermi energy in the high-temperature region  $E_{FH}$  is lower than that in the low-temperature region  $E_{FL}$  in the n-type Si, as shown in Fig. 1.

The Seebeck coefficient  $S$  is expressed as follows:

$$S = -\Delta V/\Delta T = -1/q \cdot (E_{FH} - E_{FL}) / (T_H - T_L) = (\phi_H - \phi_L) / (T_H - T_L), \quad (1)$$

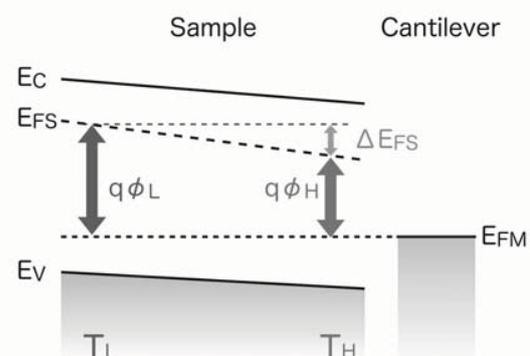


Fig. 1. Fermi energy positions of n-type semiconductor under a temperature difference.

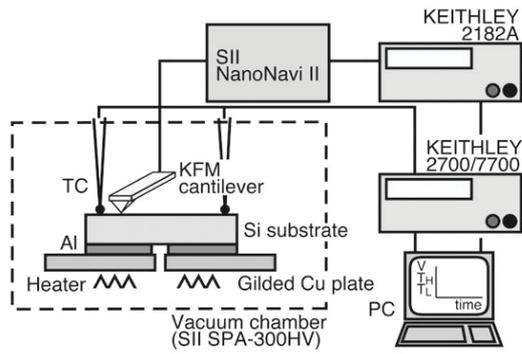


Fig. 2. Schematic diagram of KFM apparatus for measuring Seebeck coefficient.

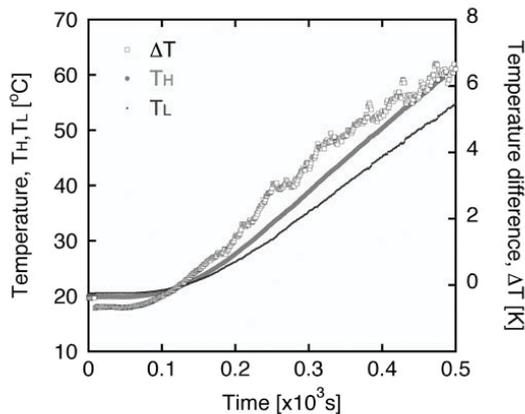


Fig. 3. Time evolution of temperature and temperature difference.

where  $q$  is the elemental charge.  $\Delta V$  is the TEMF defined as  $\phi_H - \phi_L$ , where  $\phi_H$  and  $\phi_L$  are respectively the surface potentials in the high- and low-temperature region measured from the cantilever Fermi energy, as shown in Fig. 1.  $\Delta T$  is the temperature difference  $T_H - T_L$ , where  $T_H$  and  $T_L$  are the temperature in the high- and low-temperature regions, respectively. Consequently, the Seebeck coefficient can be evaluated from the measurement of the surface potential for each region under a given temperature difference across the sample parallel to the surface.

### III. Improvements in Equipment and Sample Structure

Figure 2 depicts a schematic diagram of the experimental setup, where we introduced the new KFM control unit (Seiko Instruments Inc., NanoNavi II) and the measurement devices. The surface potential of the sample was monitored using a nanovoltmeter (KEITHLEY, 2182A), and the temperatures of

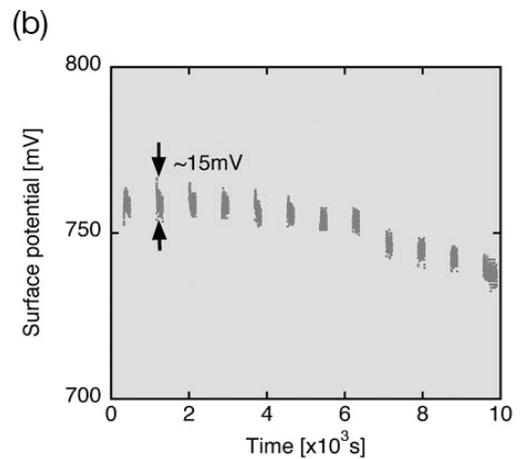
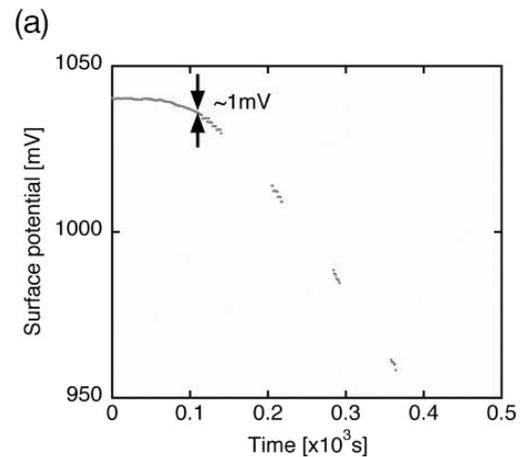


Fig. 4. Time evolution of surface potential obtained by (a) the improved system and (b) the previous system.

the sample were measured using a digital multimeter (KEITHLEY, 2700). A sample was bridged over two gilded Cu plates separated by a gap of 3 mm. Joule heaters were applied to each Cu plate. The temperature difference was applied to the sample by individually flowing a current to the heaters. Two K-type thermocouples were directly attached to both ends of the sample surface in order to measure the temperature. At the high- and low-temperature regions of the sample surface, the time evolutions of temperature and surface potential were measured simultaneously. Measurements were performed in a vacuum chamber (Seiko Instruments Inc., SPA-300HV) at a pressure of  $4 \times 10^{-5}$  Pa.

In the present study, we measured an n-type Si wafer with an impurity concentration of  $1 \times 10^{13} \text{ cm}^{-3}$ . In our previous paper, the analysis for evaluating the Seebeck coefficient from the KFM data was complicated because of the influence of the Schottky contact at the n-type Si/Ag paste interface [12]. In order to avoid such a troublesome analysis, an ohmic contact

was formed at the bottom of the Si sample, which leads to the direct determination of surface potential from the KFM data.

The time evolution of the temperature in the high- and low-temperature regions and the obtained temperature difference  $\Delta T$  are shown in Fig. 3. The temperature difference

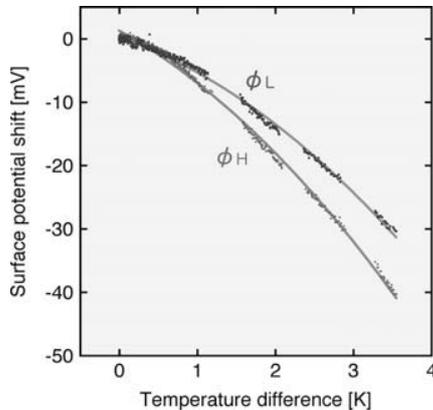


Fig. 5. Relationship between surface potential shift and temperature difference in the high- and low-temperature regions.

was found to increase with increasing sample temperature. In this case, the temperature difference was more than 6 K, which is sufficient to produce a large TEMF. Figure 4(a) is the time evolution of the surface potential obtained simultaneously with the temperatures in Fig. 3. There are spaces between the measured surface-potential values because the measurement could not sufficiently follow the time evolution of the surface potential due to an overflow in the vertical piezoelectric-control (z-gain) during the temperature evolution. This phenomenon originates from the thermal expansion of the sample. Therefore, we kept the cantilever away from the sample and brought it near the sample surface again only when the z-gain overflowed.

The surface potential was found to decrease with increasing time (or  $\Delta T$ ). In Fig. 4(a), the measured values are scattered within 1 mV, which is greatly reduced compared to the scatter of the previous values, which was within 15 mV, as shown in Fig. 4(b). Moreover, Fig. 4 indicates that the time spent for the measurement is shortened by 5% owing to the improvement in the measurement accuracy.

#### IV. Characterization of SOI Seebeck Coefficient

When Si nanostructures such as a Si nanowire are fabricated, the SOI wafer will be preferably used for the fabrication. Hence, we evaluated the Seebeck coefficient of an 85-nm-thick SOI layer with a P concentration of  $1 \times 10^{17} \text{ cm}^{-3}$  by our new technique. The measurement was performed by the same procedure as mentioned above, except for an electric earth. In the KFM measurement, the sample must be electrically earthed with the sample holder (gilded Cu plates in

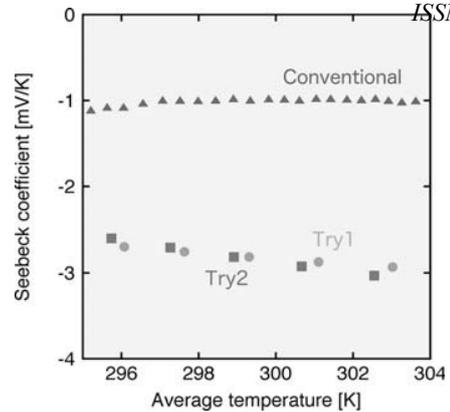


Fig. 6. Seebeck coefficient as a function of average temperature. The measurement by KFM system was performed two times (Try 1 and 2). Seebeck coefficient obtained by a conventional method is also shown.

our system). However, the SOI layer is insulated from the sample holder by the buried oxide. In the present study, therefore, we deposited an Al electrode on the SOI surface and connected a lead-wire between the electrode and the Cu plate. The wire was positioned away from the cantilever-scanned region and therefore the thermal disturbance was unlikely to influence the measurement.

Figure 5 is the relationship between surface potential shift and temperature difference obtained from the time evolutions of surface potentials and temperatures. The TEMF is given by  $(\phi_H - \phi_L)$  at the same temperature difference. It is found from Fig. 5 that the experimental TEMF is well expressed by a quadratic function of  $\Delta T$ . According to (1), the Seebeck coefficient is evaluated from the fitted lines, which is plotted in Fig. 6 as a function of average temperature. The circle and square data are the value evaluated using KFM, and the diamond data are obtained by a conventional method [15]. The Seebeck coefficient is obtained to be -2.8 mV/K for the KFM technique, which is about 2.5 times as large as the values for the conventional method. Unfortunately, the reason of the disagreement is not clear yet. Thus, we are now making sure of the certainty and the validity of evaluated Seebeck coefficient.

#### V. Conclusion

We proposed and improved a new technique for evaluating the Seebeck coefficient on a nanometer scale using KFM. The Seebeck coefficient of a thin SOI layer by this technique was evaluated to be -2.8 mV/K. However, there was disagreement between the Seebeck coefficients obtained by the KFM technique and the conventional method. Therefore, the certainty and the validity of the KFM evaluation is now under investigation.

#### Acknowledgment

The present study was supported by a Grant-in-Aid for Scientific Research (No. 19560701 and 21360336), a Grant-in-Aid for Challenging Exploratory Research (No. 24651168) and a Grant-in-Aid for JSPS Fellows (No. 23-6002) from the Japan Society for the Promotion of Science.

## References

- [1] L.D. Hicks and M.S. Dresselhaus, "Effect of quantum-well structures on the thermoelectric figure of merit," *Phys. Rev. B*, vol. 47, pp. 12727-12731, 1993.
- [2] L.D. Hicks and M.S. Dresselhaus, "Thermoelectric figure of merit of a one-dimensional conductor," *Phys. Rev. B*, vol. 47, pp. 16631-16634, 1993.
- [3] A.A. Balandin and O.L. Lazarenkova, "Mechanism for thermoelectric figure-of-merit enhancement in regimented quantum dot superlattice," *Appl. Phys. Lett.*, vol. 82, pp. 415-417, 2003.
- [4] M.V. Simkin and G.D. Mahan, "Minimum thermal conductivity of superlattices," *Phys. Rev. Lett.*, vol. 84, pp. 927-930, 2000.
- [5] T.C. Harman, P.J. Taylor, M.P. Walsh, and B.E. LaForge, "Quantum dot superlattice thermoelectric materials and devices," *Science*, vol. 84, pp. 2229-2232, 2002.
- [6] D. Li, Y. Wu, P. Kim, L. Shi, P. Yang, and A. Majumdar, "Thermal conductivity of individual silicon nanowires," *Appl. Phys. Lett.*, vol. 83, pp. 12934-12936, 2003.
- [7] A.I. Hochbaum, R. Chen, R.D. Delgado, W. Liang, E.C. Garnett, M. Najarian, A. Majumdar, and P. Yang, "Enhanced thermoelectric performance of rough silicon nanowires," *Nature*, vol. 451, pp. 163-167, 2008.
- [8] A.I. Boukai, Y. Bunimovich, J.T. Kheli, J.K. Yu, W.A. Goddard III, and J.R. Heath, "Silicon nanowires as efficient thermoelectric materials," *Nature*, vol. 451, pp. 168-171, 2008.
- [9] C.C. Williams and H.K. Wickramashinghe, "Microscopy of chemical-potential variations on an atomic scale," *Nature*, vol. 344, pp. 317-319, 1990.
- [10] H.-K. Lyeo, A.A. Khajetoorians, L. Shih, K.P. Pipe, R.J. Ram, A. Shakouri, and C.K. Shih, "Profiling the thermoelectric power of semiconductor junctions with nanometer resolution," *Science*, vol. 303, pp. 816-818, 2004.
- [11] Y. Zhang, C.L. Hapenciuc, E.E. Castillo, T. Borca-Tasciuc, R.J. Mehta, C. Karthik, and G. Ramanath, "A microprobe technique for simultaneously measuring thermal conductivity and Seebeck coefficient of thin films," *Appl. Phys. Lett.*, vol. 96, pp. 062107-1-3, 2010.
- [12] H. Ikeda, F. Salleh, and K. Asai, "Seebeck coefficient measurement by Kelvin-probe force microscopy," *J. Autom. Mobile Rob. Intell. Syst.*, vol. 3, pp. 49-51, 2009.
- [13] H. Ikeda, K. Miwa, and F. Salleh, "Construction of Seebeck-coefficient measurement by Kelvin-probe force microscopy," *AIP Conf. Proc.*, vol. 1449, pp. 377-380, 2012.
- [14] K. Miwa, F. Salleh, and H. Ikeda, "Improvement in measurement system of Seebeck coefficient by KFM," *J. Adv. Res. Phys.*, vol. 3, pp. 021205-1-4, 2012.
- [15] F. Salleh, K. Asai, A. Ishida, and H. Ikeda, "Seebeck coefficient of ultrathin silicon-on-insulator layers," *Appl. Phys. Express*, vol. 2, pp. 071203-1-3, 2009.

# Observation of Negative Differential Conductance in Nanoscale $p$ - $n$ Junctions

Sri Purwiyanti\*, Daniel Moraru, Takeshi Mizuno, and Michiharu Tabe  
 Research Institute of Electronics  
 Shizuoka University, Japan  
 \*E-mail : yanti@rie.shizuoka.ac.jp

Sri Purwiyanti, Djoko Hartanto  
 Faculty of Engineering  
 University of Indonesia, Indonesia

**Abstract**—Recently,  $p$ - $n$  junction characteristics in nanometer scale have been investigated in relation with photonics and electronics applications. In this paper, we report the experimental observation of negative differential conductance (NDC), the basic indication of tunneling, in nanoscale  $p$ - $n$  junctions under forward bias condition. The NDC has been observed only at low temperatures, suggesting that tunneling is mediated by some states in the band gap, most likely by individual dopants with deeper energy levels compared to bulk. Furthermore, we also observed random telegraph signal (RTS) at low temperatures, which is ascribed to sudden changes of charge states of an individual dopant. These results illustrate the nature of individual dopants in nanoscale  $p$ - $n$  junctions and their impact on device characteristics.

**Keywords**—NDC; tunneling; nanoscale  $p$ - $n$  junction; individual dopant.

## I. Introduction

Reduction in Si MOSFET dimensions brings several difficulties in conventional device operation [1]. By decreasing device size, operating voltage will be lowered, but it is difficult to appropriately maintain a good on/off current ratio. In order to overcome this problem, it is proposed that the transport mechanism must be drastically changed from the conventional thermionic-emission transport and that tunnel field-effect transistors (TFETs) are promising candidates for improving the operation conditions.

Tunneling is a quantum mechanical effect, where electrons (holes) have a finite probability of transmission through an energy barrier and this effect becomes most pronounced in nanometer-scale structures. In  $p$ - $n$  junctions, tunneling mechanism can be observed both under reverse and forward bias. Tunneling mechanism under reverse-bias mode, so-called Zener tunneling, is inter-band tunneling, as indicated by a rapid increase of current. It is basically the main tunneling mechanism in TFETs [2-4].

Under forward bias for heavily doped (degenerated)  $p$ - $n$  junctions, there is another inter band tunneling mechanism, which is the basis of Esaki tunneling diodes [5]. The tunneling in forward-bias mode can be seen as negative differential conductance (NDC), i.e, a negative slope in current-voltage ( $I$ - $V$ ) curve. So far, tunneling in nanometer-scale  $p$ - $n$  junctions has been reported in vertical nanowires in forward-bias mode [6,7] and in lateral gated  $p$ - $n$  junctions in reverse-bias mode [8]. In this work, we study nanoscale lateral  $p$ - $n$  junctions in forward-bias mode and report the experimental observation of NDC at low temperatures. RTS has also been observed at low temperatures, indicating the effect of a single charge trap. We

ascribe these phenomena to the influence of individual dopants on the electrical characteristics.

## II. DEVICE STRUCTURE AND MEASUREMENT SETUP

We fabricated nanoscale silicon-on-insulator (SOI)  $p$ - $n$  junctions. Figure 1 shows schematically the device structure and  $I$ - $V$  measurement setup. Nanowires were patterned on the SOI layer by an electron beam (EB) lithography technique. Then, a selective doping technique was used to create the  $n$ -type (phosphorus-doped) and  $p$ -type (boron-doped) regions. The channel thickness is about 10 nm, while the device length and width are 1000 nm and 150 nm, respectively. Aluminum contact pads were formed as electrodes.

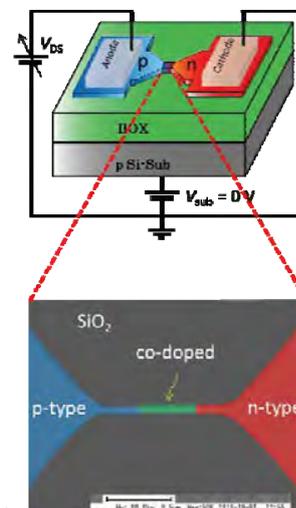


Fig. 1. (a) Device structure and bias configuration for electrical characterization. (b) Co-doped devices, based on SEM images. Co-doped region is located within the thin and narrow nanowire.

The  $n$ -type region was doped with phosphorus (P) to the concentration  $N_D \approx 1.0 \times 10^{18} \text{ cm}^{-3}$ , while the  $p$ -type region was doped with boron (B) to the concentration  $N_A \approx 1.5 \times 10^{18} \text{ cm}^{-3}$ . A co-doped region, doped with both P and B, is designed in the center of the nanowire. The  $p$ -Si substrate was weakly  $p$ -type, doped with boron ( $N_A \approx 1.5 \times 10^{15} \text{ cm}^{-3}$ ).

The thickness of the buried oxide layer between the nanowire and the substrate is 150 nm. The nanowire is covered with a 10-nm-thick SiO<sub>2</sub> layer, grown by thermal oxidation. Devices were measured in a vacuum chamber of an electrical measurement system. The *p*-type region is positively biased for these measurements, i.e., the *p-n* junction is forward-biased, while the *n*-type region and substrate are grounded.

### III. EXPERIMENTAL RESULTS AND DISCUSSIONS

We measured current versus applied bias (*I-V*) characteristics in the dark condition. The measurement results are shown in Fig. 2. *I-V* characteristics at room temperature (*T* = 300 K), as shown in Fig. 2(a), are similar to the conventional diode behavior, although parasitic resistance due to the narrow wire dimension causes suppression of current and shift the current onset.

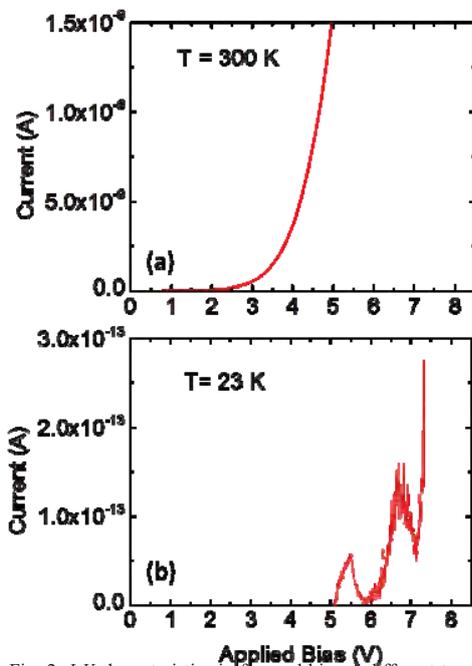


Fig. 2. *I-V* characteristics in forward bias at different temperatures: (a) *T* = 300 K and (b) *T* = 23 K. For *T* = 23 K, NDC can be observed.

At low temperatures, as shown in Fig. 2(b), the voltage for the current onset is further shifted compared to the room temperature behavior. This is caused by the dopant freeze-out effect [9], which leads to an effectively smaller dopant concentration. However, it is even more important to note that, at *T* = 23 K, *I-V* characteristics exhibit NDC. This behavior, except for the observation of a second peak, is similar to Esaki-diode characteristics, suggesting that the observed features are most likely due to resonant tunneling phenomena

in the *p-n* junction. However, since doping concentration of our devices is lower than the doping levels known for Esaki diodes, NDC may occur by a different mechanism. Based on the fact that NDC has been observed just at low temperature, it is likely that tunneling is mediated by some states in the band gap, most likely by individual dopants.

In other devices, a different type of behavior could be also observed. We measured *I-V* characteristic at room temperature and several temperatures below 100 K in the dark condition. Figure 3(a) shows the *I-V* characteristics at *T* = 300 K and at low temperature (*T* = 10 K). We observed current fluctuations in *I-V* characteristics at temperatures below 30 K. These current fluctuations can be ascribed to charge trapping and de-trapping by a single trap site. At different temperatures, time dependence of the current was measured as a function of applied bias. The data at 10 K are shown in Fig. 3(b). Random telegraph signals (RTS) with two levels were clearly observed, suggesting that the trap is most likely a single dopant, which can have only two possible states. The RTS frequency is increased by increasing the forward bias, indicating that the RTS (trapping and de-trapping) is sensitive to the change of electric field near the *p-n* junction. Therefore, a single dopant located in the depletion region may be responsible for the RTS.

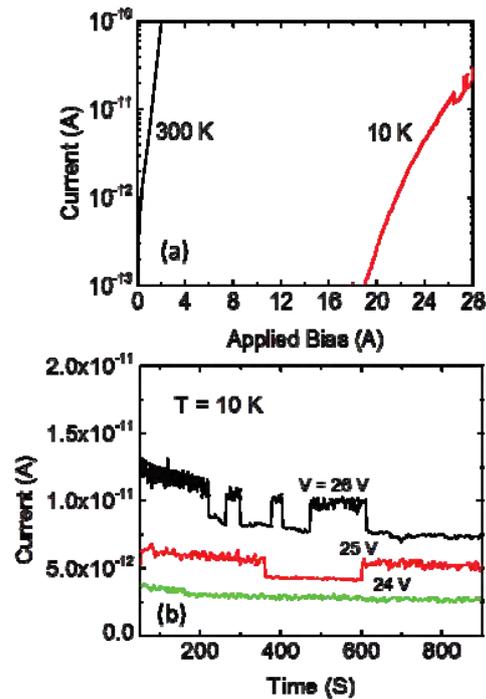


Fig. 3. (a) *I-V* characteristics in forward bias at temperature 300 K and 10 K. For *T* = 23 K, current fluctuations has been observed. (b) Examples of *I-time* characteristics at *T* = 10 K for different applied biases. Two-level RTS can be seen above a certain forward bias.

As mentioned above, we observed NDC and RTS in *I-V* characteristics in the low-temperature measurements. These behaviors may show the nature of individual dopant under forward bias in nanoscale *p-n* junctions. We can analyze the

origin of both behaviors from the energy diagram of the devices, as schematically shown in Fig. 4. In thermal equilibrium, the Fermi levels in the  $p$ -type and  $n$ -type are aligned. When positive bias is applied to the  $p$ -type region, as in the forward-bias case, the Fermi level of the  $p$ -type will be shifted downwards and current starts to flow. Starting from this situation, we can analyze two different cases. The first case is the existence of a pair of deep dopants in the depletion layer, as shown in Fig. 4(a). An electron moving from the  $n$ -type to the  $p$ -type region, as part of the diffusion current, may be trapped by an ionized deep donor in the depletion layer. A similar behavior may also occur for a hole, which may be trapped by a deep acceptor. In a certain forward bias, the ground states of the deep donor and the deep acceptor are aligned and, therefore, the electron can resonantly recombine with the hole. By further increasing the forward bias, the resonant recombination condition turns off, resulting in the reduction of the forward current, i.e., NDC. The second peak, which has been observed at different applied bias, may indicate the existence of a second pair of deep dopants. This second pair of dopant, with different energy level, provide different noise feature, as shown in Fig. 2(b). The background current increasing with applied forward bias is an ordinary diffusion current in the  $p$ - $n$  diode.

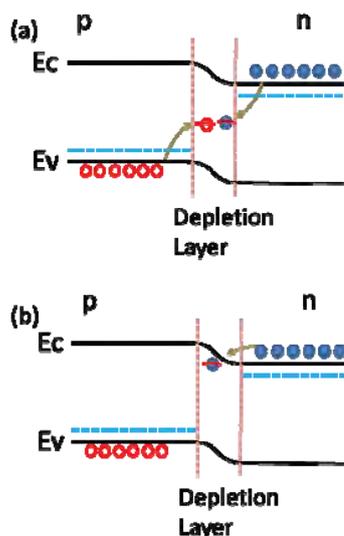


Fig. 4. Band diagrams of  $p$ - $n$  junction under forward bias. Two different cases are illustrated: (a) when a pair of opposite-type deep dopants mediates transport and (b) when one type of dopant, located in depletion layer, works as a charge trap.

A second case, shown in Fig. 4(b), is when a single dopant in the depletion layer works as a charge trap. In this situation, a pair of a donor and an acceptor is not relevant, but only a single dopant nearby the edge of the depletion layer works as a charge trap. The trapped carrier can escape from the dopant due to thermal activation [9]. These trapping and de-trapping events of a carrier cause potential fluctuations, i.e., RTS.

Further investigation is required to fully clarify the origin of this phenomenon.

As illustrated above, the observations of NDC features and discrete-level RTS can be associated with the effects of discrete dopants on the nanoscale  $p$ - $n$  junction's electrical characteristics. These results provide further evidence about the enhanced importance of the discrete dopants in the transport mechanisms in nanoscale devices, as we reported previously [10-13]. These findings also suggest that there is a rich variety of phenomena emerging when the basic structure of the  $p$ - $n$  junction is scaled down into nanometer-order dimensions. This is promising for future applications that combine the well-established conventional  $p$ - $n$  junction theory and technology with novel physics phenomena specific to the nanoscale.

## IV. CONCLUSIONS

We report negative differential conductance and random telegraph signals observed in nanoscale  $p$ - $n$  junctions under forward bias condition. These features are most likely caused by the effects of individual dopants, suggesting the important role that the discreteness of dopant distribution plays in nanoscale. The present results may contribute to the development of dopant-based tunneling FETs on the basis of the nanostructured  $p$ - $n$  junctions.

## Acknowledgment

We thank S. Miki for his assistance in the preliminary experiments and A. Udhiarto for useful discussions and support.

## References

- [1] *The International Technology Roadmap for Semiconductors (ITRS)*, available at <http://www.itrs.net/> (2011).
- [2] A. C. Seabaugh and Q. Zhang, "Low-voltage tunnel transistors for beyond CMOS logic," *Proc. of IEEE*, vol. 98, no. 12, pp. 2095-2110, Dec. 2010.
- [3] A. M. Ionescu and H. Riel, "Tunnel field-effect transistors as energy-efficient electronic switches," *Nature*, vol. 479, pp. 329-337, Dec. 2011.
- [4] K. Tomioka, M. Yoshimura, and T. Fukui, "A III-V nanowire channel on silicon for high-performance vertical transistors," *Nature*, vol. 448, pp. 189-192, Aug. 2012.
- [5] L. Esaki, "New phenomenon in narrow germanium p-n junctions," *Phys. Rev.*, vol. 109, pp. 603-604, Oct. 1958.
- [6] H. Schmid, C. Bessire, M. T. Bjork, A. Schenk, and H. Riel, "Silicon nanowire Esaki diodes," *Nano Letters*, vol. 12, no. 10, pp. 699-703, Jan. 2012.
- [7] S. Sedlmaier, K. K. Bhuiwala, A. Ludsteck, M. Schmidt, J. Schulze, W. Hansch, and I. Eisele, "Gate-controlled resonant interband tunneling in silicon," *Appl. Phys. Lett.*, vol. 85, pp. 1707-1709, Sept. 2004.
- [8] C. Aydin, A. Zaslavsky, S. Luryi, S. Cristoloveanu, D. Mariolle, D. Fraboulet, and S. Deleonibus, "Lateral interband tunneling transistor in silicon-on-insulator," *Appl. Phys. Lett.*, vol. 84, no. 10, pp. 1780-1782, March 2004.
- [9] D. Foty, "Impurity Ionization in MOSFETs at very low temperatures," *Cryogenics*, vol. 30, pp. 1056-1063, Dec. 1990.

- [10] M. Tabe, D. Moraru, M. Ligowski, M. Anwar, R. Jablonski, Y. Ono, and T. Mizuno, "Single-electron transport through single dopants in a dopant-rich environment," *Phys. Rev. Lett.*, vol. 105, no. 1, pp. 016803-1 – 016803-4, July 2010.
- [11] A. Udhiarto, D. Moraru, T. Mizuno, and M. Tabe, "Trapping of a photoexcited electron by a donor in nanometer-scale phosphorus-doped silicon-on-insulator field-effect transistors," *Appl. Phys. Lett.*, vol. 99, no. 11, pp. 113108-1 – 113108-3, Sept. 2011.
- [12] A. Udhiarto, D. Moraru, S. Purwiyanti, T. Mizuno, and M. Tabe, "Photon-induced random telegraph signal due to potential fluctuation of single donor-acceptor pair in nanoscale Si p-n junctions," *Appl. Phys. Express*, vol. 5, pp. 112201-1 – 112201-2, Oct. 2012.
- [13] M. Tabe, A. Udhiarto, D. Moraru, and T. Mizuno, "Single-photon detection by Si single-electron FETs," *Phys. Status Solidi A*, vol. 208, no. 3, pp. 646-651, Mar. 2011.

# Development of Multi-gated Field Emitters

Hidenori Mimura, Toru Aoki, and Yoichiro Neo  
 Research Institute of Electronics, Shizuoka University  
 Hamamatsu, 432-8011, Japan

Tomoya Yoshida, and Masayoshi Nagao  
 National Institute of Advanced Industrial Science and  
 Technology  
 Tsukuba, 305-8568, Japan

**Abstract**— We have developed a multi-gated field emitter (FE) such as a quadruple-gated FE with a three-stacked electrode lens and a quintuple-gated FE with a four-stacked electrode lens. Both the FEs can focus the electron beam. However, the quintuple-gated FE has a stronger electron convergence than the quadruple-gated FE, and a beam crossover is clearly observed for the quintuple-gated FE.

**Keywords**— beam crossover; electron beam; focusing; micro-column; multi-gated field emitter

## I. Introduction

A field emitter array (FEA) with a focusing electrode is an attractive device for applications, such as a scanning electron microscope and electron beam lithography and so on. As the FEAs with a focusing electrode, double-gated FEAs have been proposed. However, the double-gated FEA has a problem that the emission current decreases under the strong focusing conditions. This is due to the lowered field enhancement at the emitter tip caused by the low potential of a vicinal focusing electrode. [1] To solve such the problem, we have reported the other approach that uses the focusing electrode located below the extraction gate electrode in a volcano structure. [2, 3] However, we observed that some electrons cannot penetrate the potential barrier formed by the focusing electrode potential under strong focusing conditions. These electrons go back to the extraction gate electrode. To overcome these problems simultaneously (field enhancement and potential barrier), an electrostatic lens using a multistacked-electrode should be integrated at the emitter tip, and at least three additional electrodes are necessary. The first electrode (near the emitter tip) is used to maintain the potential at the emitter tip; therefore, a voltage higher than the extraction gate voltage is applied. The second electrode is used to focus the electron beam; therefore, a voltage lower than the extraction gate voltage is applied. The third electrode is used to inhibit the generation of a potential barrier on the electron trajectory; therefore, a voltage higher than the second electrode voltage is applied. In this paper, we have developed a multi-gated field emitter (FE) with a four-stacked gate electrode, and a FE with a five-stacked gate electrode, that is, quadruple-gated FE with a three-stacked electrode lens and quintuple-gated FE with a four-stacked electrode lens.

## 1. Fabrication of The Multi-gated Field Emitters

The fabrication process for the multi-gated FEs is schematically shown in Fig. 1. (a) An emitter cone is formed from single crystalline Si by reactive ion etching (RIE) using a SiO<sub>2</sub> dot as an etching mask. The apex radius of the tip is 5-10 nm. (b) A SiO<sub>2</sub> insulating layer is deposited by plasma-enhanced chemical vapor deposition (PE-CVD) using tetraethoxysilane (TEOS) gas followed by Nb deposition. (c) After the deposition of SiO<sub>2</sub> and Nb films, a photoresist is spin coated on the Nb film. The thickness of the photoresist on the top of the mountain structure becomes thinner than that on the flat surface. (d) Therefore, the Nb electrode at the tip is selectively etched by the following RIE step without precise lithography. The electrode height can be controlled by the etching time and is adjusted to be the same as that of the emitter tip. The first Nb electrode acts as an extraction gate electrode. (e) In the quadruple-gated FE, three additional electrodes, which form an electrostatic lens, are stacked by repeating the steps from (b) to (d) three times. In the quintuple-gated FE, four additional electrodes, which form an electrostatic lens, are stacked in the similar way. (f) Finally, the emitter tip is opened by the buffered hydrofluoric acid (BHF).

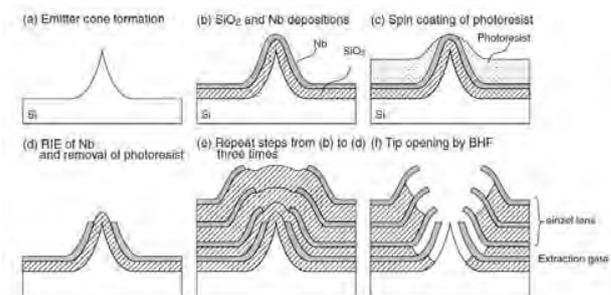


Fig.1 Fabrication process for the quadruple-gated FE with a three-stacked electrode lens.

Figures 2 (a) and (b) show cross sectional SEM images of the quadruple-gated FE and quintuple-gated FE, respectively. In the both FEs, the first Nb electrode acts as an extraction gate electrode. In the quadruple-gated FE, the G<sub>1</sub> and G<sub>2</sub> among the three-stacked electrostatic lens are set at the same voltage. In the quintuple-gated FE, G<sub>1</sub> and G<sub>4</sub> among the four-stacked electrostatic lens are set at the same voltage. G<sub>2</sub> and

$G_3$  ( $G_{2,3}$ ) are connected through a contact hole, and are set at the same voltage. Therefore, both the three-stacked and four-stacked electrostatic lenses form an eizel lens.

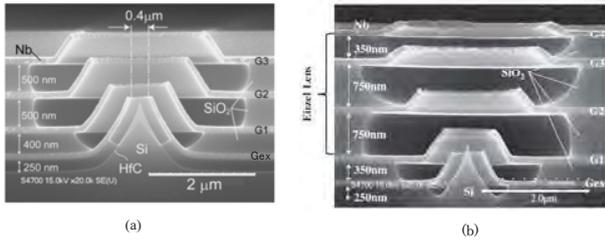


Fig. 2 Cross-sectional SEM images of the quadruple-gated FE (a) and the quintuple-gated FE (b).

Figure 3 shows the top-view micrograph of the quadruple-gated FE. The dotted line in the micrograph shows that the electrode holes from accurate concentric circles with the emitter tip as a center pole. This is due to the full self-aligned process. The alignment of electrode holes is very important for the electrostatic lens to avoid an aberration.

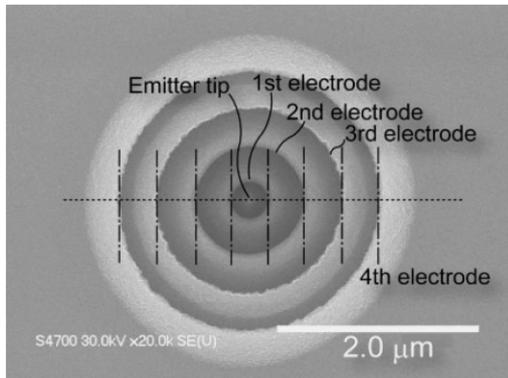


Fig. 3 Top-view SEM image of the quadruple-gated FE.

## II. Electron Emission Characteristics

The electron emission from both the quadruple-gated FE and quintuple-gated FE were measured in a high-vacuum chamber at a pressure of  $1 \times 10^{-7}$  Pa. Figures 4 (a) and (b) show extraction-gate-voltage ( $G_{ex}$ ) versus anode-current characteristics of the quadruple-gated FE and quintuple-gated FE, respectively. An anode phosphor screen biased at 1 kV was located 1 mm above the FE substrate. For the simple anode-current characteristics, the all potentials of the electrostatic lens were set equal to that of the extraction gate electrode, as schematically shown in the insert of Figs. 4 (a) and (b). In the quadruple-gated FE, emission started at 20 V and reached 3 μA at an extraction voltage of 60 V, while in the quintuple-gated FE, emission started at 30 V and reached 100 nA at an extraction voltage of 60 V. In the quintuple-gated FE, more electrons entered the gate electrodes in nonfocusing condition, because the lens size is larger than that of the quadruple-gated FE.

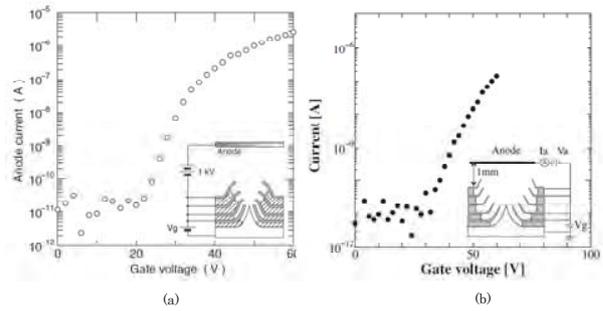


Fig. 4 Emission characteristics of the quadruple-gated FE (a) and the quintuple-gated FE (b).

Figure 5 shows the beam spots measured from the anode phosphor screen images for the quadruple-gated FE and quintuple-gated FE. In the quadruple-gated FE, the voltages of  $G_{ex}$ ,  $G_1$  and  $G_3$  were fixed at 50, 100, and 100 V, respectively. The voltage of  $G_2$  was changed from 100 V (nonfocusing condition) to -20 V (focusing condition). In the quintuple-gated FE, the voltages of  $G_{ex}$ ,  $G_1$ , and  $G_4$  were fixed at 50, 100, and 100 V, respectively. The voltage of  $G_{2,3}$  was changed from 100 V (nonfocusing condition) to -10 (focusing condition). Figure 5 also shows the phosphor images at  $G_{2,3} = 100, 10,$  and  $-10$  V for the quintuple-gated FE. For the quadruple-gated FE, the beam spot monotonously decreases as the  $G_2$  voltage decreases from 100 to -30 V. On the other hand, for the quintuple-gated FE, the beam spot decreases as the  $G_{2,3}$  voltage decreases from 100 to 10 V, but then the beam spot increases as the  $G_{2,3}$  voltage go from 10 to -10 V. This indicates that a beam crossover (a beam focal point) is formed between the anode and the field emitter. Since the field emitter and anode are 1 mm apart and the crossover is formed immediately in front of the field emitter, the beam spot size shown in Fig. 5 are not exact size, and real beam size of the crossover is expected less than 50 nm. The results in Fig. 5 also show that the lens function for the quintuple-gated FE is stronger than that of the quadruple-gated FE.

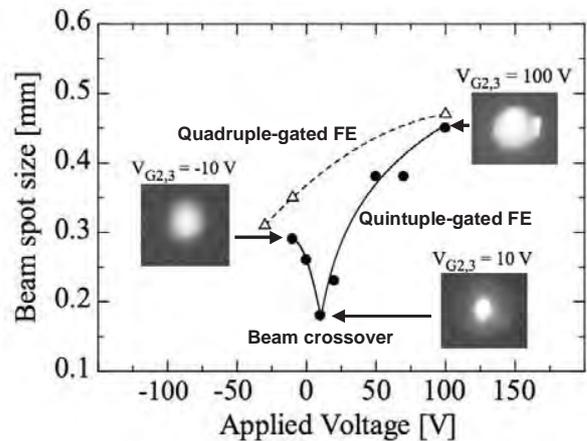


Fig. 5 Beam spots measured from phosphor screen images for the quadruple-gated FE and the quintuple-gated FE. Solid and dashed lines are the least-

square estimations for the quadruple-gated FE and the quintuple-gated FE, respectively.

### III. Conclusions

We have successfully fabricated a multi-gated FE such as quadruple-gated FE with a three-stacked electrode lens and a quintuple-gated FE with a four-stacked electrode lens. The fabrication process uses an etch-back technique. In our method, gate hole opening is a self-aligned process; therefore, the axes of electrode holes are well aligned without precise lithography. Both the quadruple-gated FE and quintuple-gated FE can focus the electron beam. However, lens function for the quintuple-gated FE is stronger than that of the quadruple-gated FE, and a beam crossover is formed for the quintuple-gated FE.

The multi-gated FE is a promising device for a micro-column for a scanning electron microscope and electron beam lithography.

### References

- [1] Y. Yamaoka, S. Kanemaru, and J. Itoh, *Jpn. J. Appl. Phys.* 35, pp.6626, 1996.
- [2] Y. Neo, T. Soda, M. Takeda, M. Nagao, T. Yoshida, C. Yasumuro, S. Kanemaru, T. Sakai, K. Hagiwara, N. Saito, T. Aoki, and H. Mimura, *Appl. Phys. Express* 1, pp.053001, 2008.
- [3] T. Soda, M. Nagao, C. Yasumuro, S. Kanemaru, T. Sakai, N. Saito, Y. Neo, T. Aoki, and H. Mimura, *Jpn. J. Appl. Phys.* 47, pp.5252, 2008.

# Multi-aperture High-speed CMOS Imager

Futa Mochiduki, Keiichiro Kagawa, Min-Woong Seo,  
 Keita Yasutomi, and Shoji Kawahito  
 Research Institute of Electronics, Shizuoka University  
 3-5-1 Johoku, Naka-ku, Hamamatsu, Shizuoka 432-8011,  
 Japan  
 kagawa@idl.rie.shizuoka.ac.jp

**Abstract**— To achieve ultra-high-speed image sensing faster than 1-giga frames per second, a multi-aperture high-speed imager is proposed. In this paper, the architecture of the imager and a design of digital circuits are presented. Basic operations of the digital circuits are verified by a fast SPICE simulator, NanoSim by Synopsys. Arbitrary shutter pattern of 128 bits and the number of repetition can be reprogrammed. A shutter pattern generation at 100 MHz is successfully verified.

**Keywords**—High-speed camera, CMOS imager, multi-aperture camera

## I. Introduction

High-speed imagers that can capture images at more than hundreds of frames per second (fps) are effective to analyze high-speed phenomena. High-speed continuous capturing has been achieved by high-speed column-parallel analog-to-digital converters (ADCs)[1]. Burst readout with on-chip frame memory enables much higher frame rate, although continuous capturing is not possible; Only the limited number of frames about 100 frames can be captured at once. 1M fps has been achieved by an in-pixel multi-stage charge transfer structure based on the charge-coupled device (CCD) [2], and 20M fps has been realized with a column analog voltage memory structure[3]. The CCD type has a tradeoff between the charge transfer efficiency and the transfer speed. The speed of the column analog memory type is determined by the parasitic resistance of the column readout line and the sample-hold capacitance. In this paper, we propose a burst-readout-type ultra-high-speed imager based on a multi-aperture imaging system whose frame rate is limited only by the saturation speed of electron in silicon, which is about 100 $\mu$ m/ns. Architecture of the imager and design and simulation results of the digital circuits are described.

## II. Multi-aperture Ultra-high-speed Camera

A part of this work was supported by JSPS KAKENHI Grant Number 24686046. This work is also supported by VLSI Design and Education Center(VDEC), The University of Tokyo with the collaboration with Cadence Corporation, Synopsys Corporation, and Mentor Graphics Corporation.

### A. 2.1 Multi-aperture Camera

Multi-aperture camera[4,5] is composed of multiple elemental cameras as shown in Figure 1. Each camera has an imaging lens and an imager, which is called an aperture or a

sub-aperture. Cameras of this kind are used for multi-viewpoint imaging or three-dimensional imaging. However, we are focusing on its potential of ultra-high-speed imaging as suggested in reference [6].

### B. Principle

Figure 2 depicts a procedure of ultra-high-speed imaging with the multi-aperture camera system. In this scheme, a special imager that can implement electronic shutter with an arbitrary temporal binary pattern, and a storage diode is used as a memory. Simplified pixel structure is depicted in Figure 3. The storage diode is a temporary storage to which photocarriers (electrons in this case) can be completely transferred without any noise[7]. The electron transfer is controlled by transfer gates. As shown in Figure 3, the electrons for the shutter OFF state are abandoned to the drain by turning G2 ON. Those for the ON state are transferred to and accumulated in the storage diode. Each aperture captures a complete optical copy of a scene with a specific shutter pattern. Note that the shutter patterns are independent each other. Therefore, temporally resolved images can be reproduced by solving the inverse problem. The temporal resolution is determined by the maximum effective frequency of the shutter pattern.

The virtual maximum frame rate of this scheme is determined only by the electron transfer speed from the photodiode to the storage diode, which is limited by the speed of electron in silicon, typically about 100 $\mu$ m/ns. Another advantage of the proposed method is better signal-to-noise ratio (SNR). Because the signals are temporally multiplexed and accumulated in the storage diode, the number of electrons

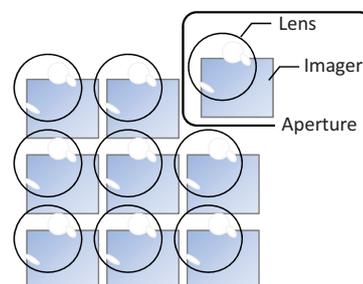


Figure 1: Multi-aperture camera.

per pixel is larger than that for the resultant single frame period. The constraint for smoothness in the reproduction processing will contribute to high-quality image reproduction from noisy measured data. Therefore, it is expected that higher

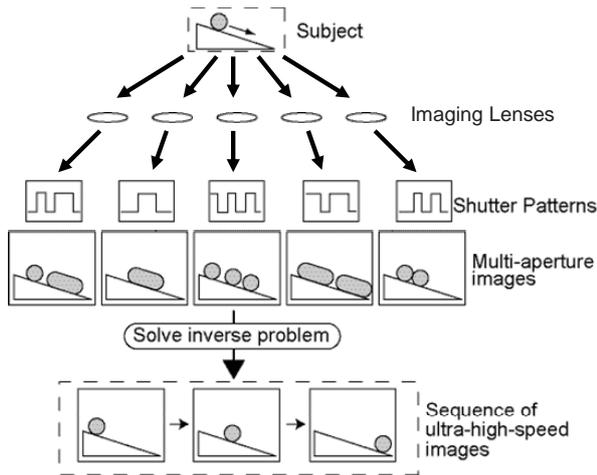


Figure 2: Procedure of image acquisition with the proposed multi-aperture high-speed imager.

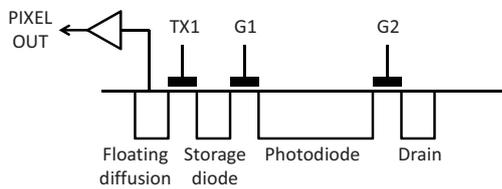


Figure 3: Simplified pixel structure.

SNR of pixel values in our scheme will enable reproduction of a sequence of high resolution ultra-high-speed images.

### C. Sensor Architecture

The sensor architecture of the proposed multi-aperture ultra-high-speed imager is shown in Figure 4. The sub-apertures are integrated on the same chip. To read out images, our imager is equipped with image readout circuits such as vertical and horizontal scanners, column-parallel analog amplifiers (shown as analog double sampling in Figure 4), analog-to-digital converters, digital double sampling, and an output block. A serial peripheral interface is used for setting the imager's parameters, and a reference block supplies reference voltages and currents to analog circuits. The specific parts to our imager are a clock controller, an addressing module, and sub-apertures. In ordinary imagers, photosensing area is a homogeneous array of pixels. On the other hand, sub-aperture is a small imager composed of sub-aperture driver and a pixel array, and the whole sensor is an array of small imagers. The sub-aperture driver generates arbitrary electronic shutter pattern, and controls electron transfer and drain of the pixels in the same sub-aperture.

## III. Digital Circuit Design

### A. Block Diagram

Figure 5 shows more detailed block diagram of digital circuit. Each sub-aperture driver can be reprogrammed from

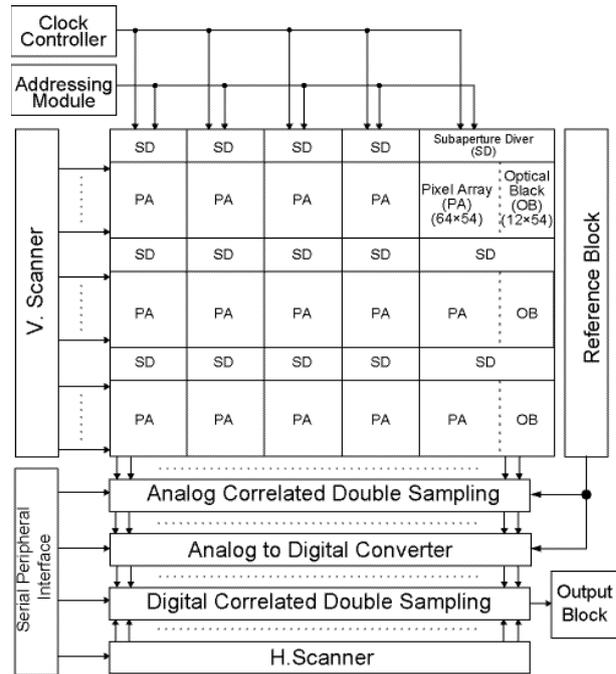


Figure 4: Sensor block diagram.

the outside through serial interface. SDI and SCK mean an input 1-bit datum and a writing clock, respectively. The sub-aperture has two operation modes: shutter pattern setting and pattern generation. In the pattern generation mode, the shutter pattern set in the setting mode is put out 1 to multiple times as programmed. Because the pattern memory is implemented by cyclic shift registers, both of setting and generation are executed by a clock signal. However, the clock signals for setting and generation have to be prepared separately, namely, PAT\_SCK and CLK, respectively. These signals are selected at the clock controller by the signal CK\_SELECT. Then, the clock signal is conveyed to each row of sub-apertures through the clock tree. The sub-aperture to be programmed is selected by the addressing module. The address is specified by ADDR\_IN<7:1>.

### B. Sub-aperture Pattern Generator

The block diagram of sub-aperture is shown in Figure 6. The sub-aperture driver is mainly composed of clock reverse circuit, two kinds of cyclic memories, counter, and a pixel driver. The sub-aperture to be programmed is specified by SUB\_SELECT that is asserted by the addressing module. The clock reverse circuit inverts the clock signal by PAT\_SDI\_CKREV, which is memorized by a 1-bit memory in the sub-aperture, to realize a half clock phase delays. CYC\_MEMORY, which is programmed by CLOCK and PAT\_SDI, stores a 128-bit-long electronic shutter pattern. PAT\_MEMORY programmed by CLOCK and PAT\_SDI\_STF is also 128-bit-long, which shows the head of

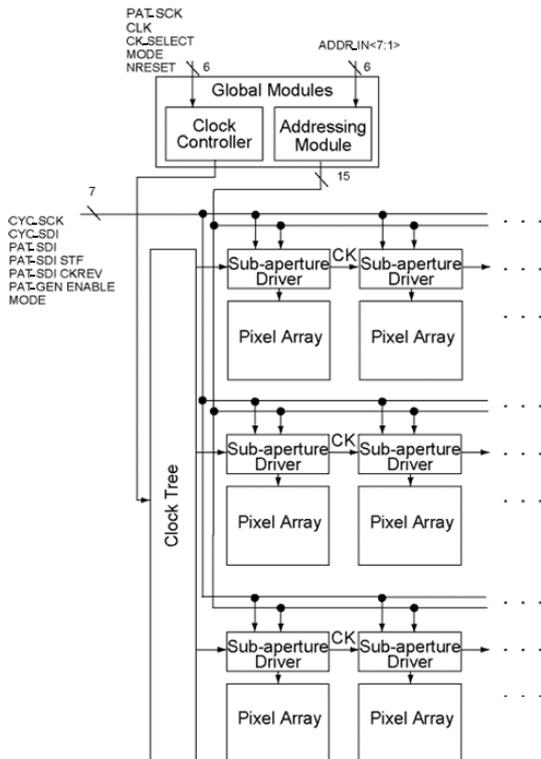


Figure 5: Clock distribution.

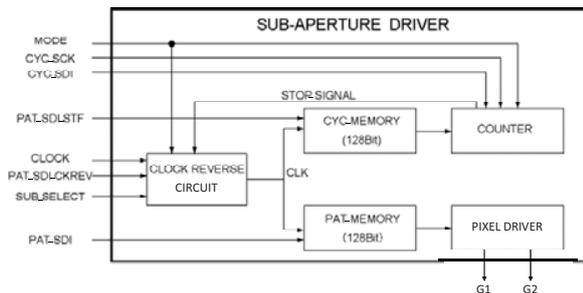


Figure 6: Sub-aperture driver.

the pattern. Namely, only one of the 128 bits is high, and the others are low. The head bit is counted by the counter to generate patterns 1 to multiple times. The number of repetition is set by `CYC_SCK` and `CYC_SDI`. `MODE` determines the operation mode of the sub-aperture: pattern setting mode and pattern generation mode. In the setting mode, `MODE` is set to low. In generating shutter pulses, `MODE` is set to high. Then, pattern generation starts when `PAT_GEN_ENABLE` turns from low to high. When the pattern generation ends, `STOP_SIGNAL` turns from low to high. Finally, whole multi-aperture image is read out.

#### iv. Simulation

The digital part of the ultra-high-speed multi-aperture imager has been designed in the standard 0.11- $\mu\text{m}$  CMOS

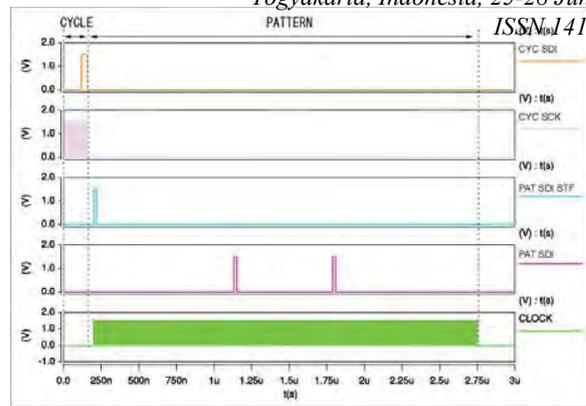


Figure 7: Simulation result of setting phase.

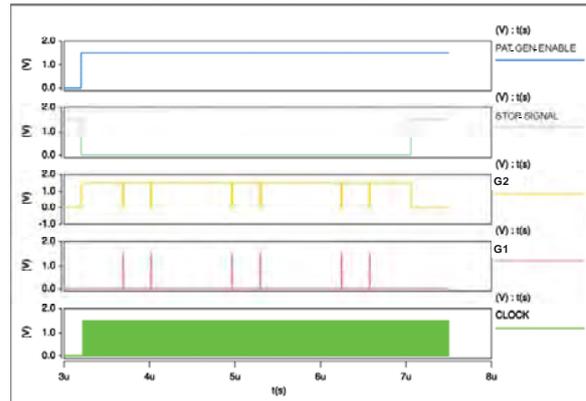


Figure 8: Simulation result of shutter pattern generation.

technology, which is suitable for faster than 1-GHz operation, and its basic operations were verified by a fast SPICE simulator, NanoSim by Synopsys.

Figure 7 shows a simulation result for pattern setting to one aperture. At first, the number of repetition, three in this case, was written. Then, the electronic shutter pattern and the head of the pattern were written. In this example, the pattern includes two pulses.

Figure 8 shows a simulation result for pattern generation. By turning `PAT_GEN_ENABLE` from low to high, it began to generate the pixel driving signals, `G1` and `G2`. The frequency was 100 MHz. After the pattern was put out three times, signal generation was stopped, and `STOP_SIGNAL` turned from low to high to trigger the image readout. From the simulation results, operations of the digital circuit were successfully verified.

#### v. Conclusion

To achieve ultra-high-speed image sensing more than 1-giga frames per second, a multi-aperture high-speed imager is proposed. The architecture of the imager and a design of digital circuits are presented. Basic operations of the digital circuits have been verified by a fast SPICE simulator, NanoSim by Synopsys. Setting a shutter pattern and shutter pattern generation at 100 MHz have been successfully verified.

### References

- [1] M. Furuta, Y. Nishikawa, T. Inoue, S. Kawahito, "A high-speed, high-sensitivity digital CMOS image sensor with a global shutter and 12-bit column-parallel cyclic A/D converter," *IEEE J. Solid-State Circuits* 42, pp. 766-774 (2007).
- [2] G. Etoh, D. Nguyen, S. Dao, C. Vo, M. Tanaka, K. Takehara, T. Okinaka, H. Kujik, W. Klaassens, J. Bosier, M. Lesser, D. Ouellette, H. Maruyama, T. Hayashida, and T. Arai, "A 16Mfps 165kpixels backside-illuminated CCD," *ISSCC Tech. Dig. Papers*, pp. 406-408 (2011).
- [3] Y. Tochigi, K. Hanzawa, Y. Kato, R. Kuroda, H. Mutoh, R. Hirose, H. Tominaga, K. Takubo, Y. Kondo, and S. Sugawa, "A global-shutter CMOS image sensor with readout speed of 1Tpixels/s burst and 780Mpixels/s continuous," *ISSCC Tech. Dig. Papers*, pp. 382-384 (2012).
- [4] J. Tanida, T. Kumagai, K. Yamada, S. Miyatake, K. Ishida, T. Morimoto, N. Kondou, D. Miyazaki, and Y. Ichioka: "Thin observation module by bound optics (TOMBO), concept and experimental verification", *Appl. Opt.* 40, pp. 1806-1819 (2001).
- [5] P. Green, W. Sun, W. Matusik, F. Durand, "Multi-aperture photography," *ACM Trans. Graphics* 26 (2007).
- [6] M. Shankar, N. Pitsianis, and D. Brady, "Compressive video sensors using multichannel imagers," *Appl. Opt.* 49, pp. B9-B17 (2010).
- [7] K. Yasutomi, S. Itoh, S. Kawahito, "A two-stage charge transfer active pixel CMOS image sensor with low-noise global shuttering and a dual-shuttering mode," *IEEE Trans. Electron Devices* 58, 740-747 (2011).

# Variation of Seebeck Coefficient in Ultrathin Si Layer by Tuning Its Fermi Energy

Faiz Salleh, Yuhei Suzuki, Kazutoshi Miwa, Hiroya Ikeda  
 Research Institute of Electronics  
 Shizuoka University  
 Hamamatsu, Japan

Faiz Salleh  
 Research Fellow of the Japan Society for the Promotion of  
 Science  
 Tokyo, Japan  
 faiz@rie.shizuoka.ac.jp

**Abstract**— We have varied the Seebeck coefficient of n-type ultrathin Si-on-insulator (SOI) layer by tuning the Fermi energy. The Fermi energy was tuned by doping P atoms into the SOI layer and by injecting carriers by applying an external bias to the SOI surface with respect to the p-Si substrate. It was found that the Seebeck coefficient decreases with increasing the impurity concentration, with a peak around  $1 \times 10^{20} \text{ cm}^{-3}$ . From the calculated density-of-states (DOS), it is considered that the peak in Seebeck coefficient is likely to be due to the formation of impurity band near the conduction-band edge, which will demolish the sharp features in low-dimensional DOS. On the other hand, the Seebeck coefficient is found to increase with increasing the external bias which is in agreement with the variation of carrier concentration in the SOI layer under external bias and it is found that the Fermi energy can be controlled without the influences of impurity band.

**Keywords**—Thermoelectric material; thermopile infrared photodetector; Seebeck coefficient; Si on insulator; nanostructure

## I. Introduction

Thermoelectric (TE) devices have attracted much attention owing to their wide application in daily life, not only as a power generator but also as a sensor. However, the low conversion efficiency of such devices currently limits their commercial use. In sensor applications, nanostructured TE materials are important for a highly-sensitive thermopile infrared photodetector, in which the thermocouple (a pair of n- and p-type TE materials) array gives us a thermoelectromotive force (TEMF) corresponding to the temperature difference caused by infrared absorption in the absorber film. The detector sensitivity  $R$  is defined as  $R=nS\eta/G$ , where  $n$  is the number of thermocouples in the thermopile,  $S$  the Seebeck coefficient,  $\eta$  the infrared absorbance, and  $G$  the thermal conductance of the TE material. The enhancement of detector sensitivity is expected by using nanostructure that will increase the number of semiconductor thermocouples and decrease the thermal conductivity due to phonon boundary-scattering [1,2].

Moreover, the Seebeck coefficient is theoretically expected to be enhanced significantly due to quantum confinement

coefficient is proportional to the energy derivative of logarithmic density-of-states (DOS) at the Fermi energy  $E_F$  [3], therefore the  $E_F$  needs to be tuned in the vicinity of the conduction-band edge  $E_C$  in n-type low-dimensional semiconductor materials in order to observe the enhancement. In the present paper, we show the variation of Seebeck coefficient in n-type ultrathin Si layers fabricated on Si-on-insulator (SOI) substrates with tuned  $E_F$  by impurity doping and external bias, with a view to clarifying the suitable control of the  $E_F$ .

## II. Experimental

The sample was fabricated by using SOI wafers consisted of a top Si layer (SOI layer), a buried oxide (BOX) layer and a p-type Si substrate. The BOX layer was 400 nm thick and the p-type Si substrate had an impurity concentration of  $\sim 10^{15} \text{ cm}^{-3}$ . In this paper, the sample for controlling the Fermi energy by impurity doping is referred as “doped SOI sample” and control by external bias is referred as “biased SOI sample,” and detail of fabrication is described elsewhere [4,6,9]. For the doped SOI sample, the SOI wafer was cut to a size of  $10 \times 10 \text{ mm}^2$  and the SOI layer was thinned to a thickness of 6 to 100 nm. P atoms were doped into the SOI layer to form an n-type SOI layer and the impurity concentration ranged from  $1 \times 10^{18}$  to  $2 \times 10^{20} \text{ cm}^{-3}$ . On the other hand, for the biased SOI sample, the SOI layer was thinned to a thickness of 78 nm. It was also doped with P atoms with a concentration of  $\sim 1 \times 10^{18} \text{ cm}^{-3}$ . The SOI layer was patterned to a size of  $7 \times 1 \text{ mm}^2$ . Then, Al electrodes were deposited and patterned to a size of  $0.5 \times 0.5 \text{ mm}^2$  on the surface of the SOI layer, and another Al electrode was deposited over the entire bottom surface of the p-type Si substrate. Finally, the sample was annealed to form ohmic contacts at the Al/Si interface.

The Seebeck coefficient was measured using the same method that was briefly described in our previous studies [4,9]. A temperature difference was given to the sample in a plane parallel to the sample surface. The time evolution of the TEMF was measured simultaneously with the temperature at the high- and low-temperature regions. For the biased SOI sample, during the measurement, a constant external bias was applied to the SOI layer through the patterned Al electrode with respect to the earthed p-Si substrate bottom. The Seebeck coefficient was determined using  $S = -(V_H - V_L)/(T_H - T_L) = -\text{TEMF}/\Delta T$ . Fig. 1 shows the determined Seebeck coefficient as a function of average temperature. From this figure the

This work was financially supported by a Grant-in-Aid for Scientific Research (No. 19560701 and 21360336), a Grant-in-Aid for Challenging Exploratory Research (No. 24651168) and a Grant-in-Aid for JSPS Fellows (No. 23-6002) from the Japan Society for the Promotion of Science. effect of electrons. According to the theory, the Seebeck

Seebeck coefficient is seen to be nearly constant in the measured temperature range. Therefore, the average Seebeck

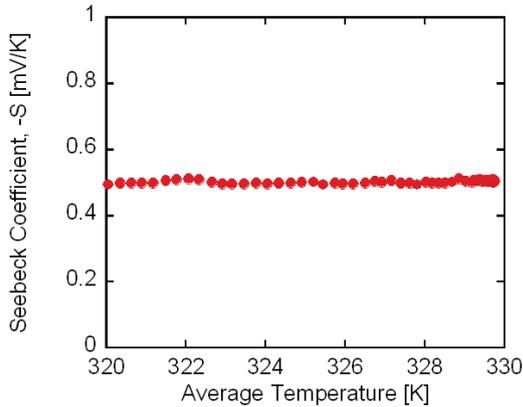


Fig. 1. Seebeck coefficient as a function of average temperature.

coefficient was evaluated from the gradient in the relationship between measured TEMF and temperature difference.

### III. Seebeck Coefficient Of Phosphorus-Doped Soi Layers

The average Seebeck coefficient of doped SOI sample is shown in Fig. 2 as a function of impurity concentration. The numbers adjacent to the filled circles indicate the SOI layer thickness and the solid line represents the theoretical calculation of Seebeck coefficient based on the dispersion relation in simple bulk Si [10]. From Fig. 2 the average Seebeck coefficient decreases with increasing the impurity concentration below  $2 \times 10^{19} \text{ cm}^{-3}$  (indicated by broken line in Fig. 2), as usually observed in n-type semiconductor materials [11,12]. However, experimental results quantitatively differ with the theoretical results. This is likely to be due to the influence of phonon drag and it is known to become weak at high impurity concentration [13]. Therefore, when the impurity concentration is above  $1 \times 10^{19} \text{ cm}^{-3}$ , the experimental values become close to the theoretical values.

On the other hand, the average Seebeck coefficient is found to exhibit unusual behavior by increasing the impurity concentration above  $2 \times 10^{19} \text{ cm}^{-3}$  which is likely to be due to the influences of heavy impurity doping since it is considered that the SOI thickness above 6 nm does not contribute to the enhancement in the Seebeck coefficient [4-8]. Fig. 3 shows the DOS calculated by considering three principle influences of heavy impurity doping; formation of impurity band [14,15], ionization-energy shift of an impurity atom [16,17] and band tailing at the  $E_C$  [16-19], for impurity concentration of  $1 \times 10^{18} \text{ cm}^{-3}$ ,  $1 \times 10^{19} \text{ cm}^{-3}$  and  $1 \times 10^{20} \text{ cm}^{-3}$ , where the original  $E_C$  is set to zero [6-8]. The positions of  $E_F$  evaluated from the charge-neutrality condition are indicated in the figure by arrows. It is found that the DOS of impurity band for  $1 \times 10^{18} \text{ cm}^{-3}$  starts to form around  $-45 \text{ meV}$  and is not connected to the conduction band. In addition, the  $E_F$  is found to be located

in the band gap and far from the conduction band, which shows that the doped SOI sample still has the characteristics

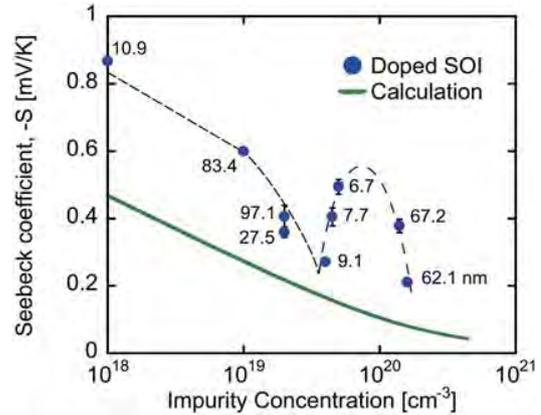


Fig. 2. Seebeck coefficient as a function of impurity concentration. The solid line represents the calculated value and broken line is an eye-guide.

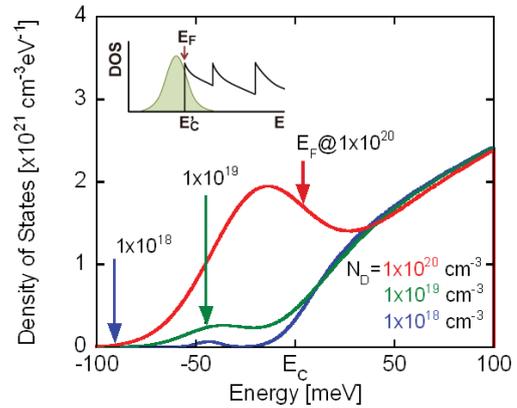


Fig. 3. Calculated DOS for bulk Si with P concentration of  $1 \times 10^{18} \text{ cm}^{-3}$ ,  $1 \times 10^{19} \text{ cm}^{-3}$  and  $1 \times 10^{20} \text{ cm}^{-3}$  where  $E_C$  is set to zero. The inset shows a schematic of DOS distribution in an impurity band and a one-dimensional conduction band. The arrows indicate the Fermi energies.

of a semiconductor. Thus, it is considered that the Seebeck coefficient of lightly-doped SOI sample should behave like the characteristics of normal n-type semiconductor.

However, in the case of DOS for impurity concentration of  $1 \times 10^{19} \text{ cm}^{-3}$  and  $1 \times 10^{20} \text{ cm}^{-3}$ , the impurity band becomes broad and connects with the conduction band. Moreover, the  $E_F$  stays in the continuous band. This band arrangement should exhibit metallic properties, which is likely contributes to the peak in the Seebeck coefficient in heavy doping region [4-8]. As mentioned in "INTRODUCTION," in order to observe the enhancement of Seebeck coefficient by nanostructuring, the  $E_F$  needs to be tuned in the vicinity of  $E_C$ . However, from Fig. 3, it can be seen that even if the  $E_F$  could be tuned by varying the impurity concentration, the impurity band that forms near the  $E_C$  will demolish the sharp features in low-dimensional DOS, as illustrated in the inset of this figure. This suggests that controlling the  $E_F$  by impurity doping is not suitable to obtain the benefits of nanostructured materials.

#### IV. Soi Seebeck Coefficient Controlled By External Bias

In order to tune the  $E_F$  without the influence of an impurity band, the Seebeck coefficient was varied by applying an external bias to the biased SOI sample. Some studies have modulated the Seebeck coefficient of organic materials, Si, and compound semiconductors with a field-effect transistor structure by varying the gate bias [20-23]. On the other hand, we have varied the Seebeck coefficient of biased SOI sample by applying a voltage through an Al electrode deposited on the SOI surface without using a field-effect transistor structure. Fig. 4 shows the average Seebeck coefficient as a function of applied external bias. The average Seebeck coefficients are observed to increase with increasing the external bias. When the SOI sample surface is positively biased, the energy difference  $E_C - E_F$  near the n-SOI/BOX interface increases as schematically depicted in the inset of Fig. 4. In other words, by applying a positive bias the carrier concentration in SOI layer is reduced that makes the Seebeck coefficient to increase, which is in agreement with characteristics of P-doped SOI layer shown in Fig. 2 for impurity concentration below  $2 \times 10^{19} \text{ cm}^{-3}$ .

We used a technology computer-aided design simulator (Synopsys Co. Ltd.) to estimate the carrier distribution in the SOI layer under external bias. The simulated SOI sample had a width of  $195 \mu\text{m}$  (horizontal direction) and a thickness of  $5.462 \mu\text{m}$  (vertical direction). We confirmed that the sample dimension do not affect the carrier distribution. Fig. 5 shows a contour plot of the simulated carrier concentration for biased SOI sample subjected to (a) 0 V and (b) +30 V. This contour plot depicts the cross section of the SOI sample; vertical and horizontal axes respectively represent the depth (thickness) and width of the sample. From Fig. 5, it is found that the electron density in the SOI layer gradually decreases with distance from the surface and that when the SOI surface is positively biased it drops abruptly near the n-SOI/BOX interface. This result is consistent with the band diagram depicted in the inset of Fig. 4. In addition, Fig. 5 shows that the electron density is constant in the horizontal direction. Therefore, the carrier concentration in SOI layers can be varied by external bias, which demonstrates that it may be possible to control the  $E_F$  without the influence of impurity band.

As mentioned above, it is essential to adjust the  $E_F$  in the vicinity of  $E_C$ , the fact that the external bias induces band bending in the SOI may reduce the enhancement of the Seebeck coefficient by smoothing the sharp features in the low-dimensional DOS. However, from the general expression of Seebeck coefficient for the electronic contribution [24], the Seebeck coefficient can be regarded as the integral of its local components, and the sharp features is expected to be preserved at the  $E_C$ . Consequently, nanostructured materials are expected to have enhanced Seebeck coefficient under a given external bias.

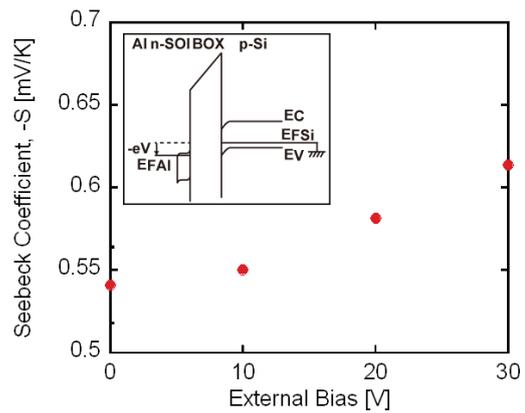


Fig. 4. Seebeck coefficient of biased SOI sample as a function of applied external bias. The inset shows a band diagram of Al/n-SOI/BOX/p-Si under a positive bias with respect to the ohmic contact between p-Si/Al.

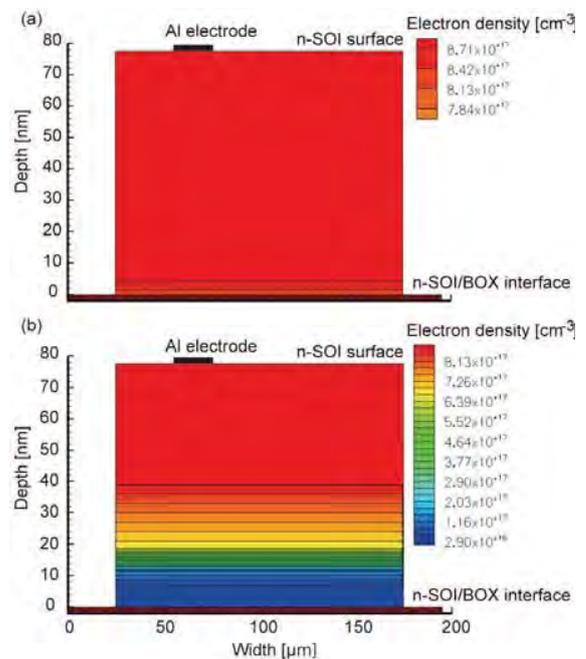


Fig. 5. Contour plot of simulated carrier concentration of n-type biased SOI sample subjected to external bias (a) 0 V and (b) +30V. The vertical and horizontal axes respectively represent the depth and width of the sample.

#### V. Conclusion

We measured the variation of Seebeck coefficient of ultrathin n-type SOI layer by controlling the carrier concentration by doping P atoms into the SOI layer. The Seebeck coefficient is found to decrease with increasing the impurity concentration, with a peak around  $1 \times 10^{20} \text{ cm}^{-3}$ . The enhancement of Seebeck coefficient in heavy doping region is considered to be likely due to influences of formation of impurity band near  $E_C$ . From the calculated DOS including the

influences of impurity doping, it was found that the influences is expected to demolish the sharp features in low-dimensional DOS which resulting a difficulties in achieving the benefit of nanostructure. Therefore, we measured the variation of Seebeck coefficient by applying an external bias for tuning the  $E_F$  without the influence of impurity band. The Seebeck coefficient increases as the external bias becomes increasingly positive, which is qualitatively consistent with the characteristics of P-doped SOI layers by considering the variation of simulated carriers in the SOI layers. This demonstrates that the  $E_F$  can be controlled to enhance the Seebeck coefficient by nanostructures without forming impurity bands by heavy doping.

### Acknowledgment

This work was financially supported by a Grant-in-Aid for Scientific Research (No. 19560701 and 21360336), a Grant-in-Aid for Challenging Exploratory Research (No. 24651168) and a Grant-in-Aid for JSPS Fellows (No. 23-6002) from the Japan Society for the Promotion of Science.

### References

- [1] A. I. Hochbaum, R. Chen, R. D. Delgado, W. Liang, E. C. Garnett, M. Najarian, A. Majumdar, and P. Yang, "Enhanced thermoelectric performance of rough silicon nanowires," *Nature*, vol. 451, pp. 163-167, Jan. 2008.
- [2] A. I. Boukai, Y. Bunimovich, J. T. Kheli, J. -K. Yu, W. A. Goddard III, and J. R. Heath, "Silicon nanowires as efficient thermoelectric materials," *Nature*, vol. 451, pp. 168-171, Jan. 2008.
- [3] N. F. Mott, and E. A. Davis, *Electronic Processes in Non-Crystalline Materials*, Clarendon Press, Oxford, 1979, pp. 52.
- [4] F. Salleh, K. Asai, A. Ishida, and H. Ikeda, "Seebeck coefficient of ultrathin silicon-on-insulator layers," *Appl. Phys. Express*, vol. 2, pp. 071203-1-3, July 2009.
- [5] F. Salleh, K. Asai, A. Ishida, and H. Ikeda, "Impurity concentration dependence of Seebeck coefficient in silicon-on-insulator layers," *J. Autom. Mobile Rob. & Intell. Syst.*, vol. 3, no. 4, pp. 134-136, 2009.
- [6] H. Ikeda and F. Salleh, "Influence of heavy doping on Seebeck coefficient in silicon-on-insulator," *Appl. Phys. Lett.*, vol. 96, pp. 012106-1-3, Jan. 2010.
- [7] F. Salleh and H. Ikeda, "Influence of impurity band on Seebeck coefficient in heavily-doped Si," *Adv. Mater. Res.*, vol. 222, pp. 197-200, April 2011.
- [8] F. Salleh and H. Ikeda, "Seebeck coefficient of heavily P-doped Si calculated from an alteration in electronic density of states," *J. Electron. Mater.*, vol. 40, pp. 903-906, May 2011.
- [9] F. Salleh, K. Miwa, and H. Ikeda, "Variation of SOI Seebeck coefficient by applying an external bias," *J. Adv. Res. Phys.*, vol. 3, no. 2, pp. 021207-1-4, 2012.
- [10] A. Ishida, D. Cao, S. Morioka, Y. Inoue, and T. Kita, "Seebeck efficient in IV-VI semiconductor films and quantum wells," *J. Electron. Mater.*, vol. 38, pp. 940-943, July 2009.
- [11] T. H. Geballe and G. W. Hull, "Seebeck effect in silicon," *Phys. Rev.*, vol. 98, pp. 940-947, May 1955.
- [12] L. Weber and E. Gmelin, "Transport properties of silicon," *Appl. Phys. A*, vol. 53, pp. 136-140, Aug. 1991.
- [13] G. D. Mahan, "Good thermoelectrics," *Solid State Phys.*, vol. 51, pp. 81-157, 1997.
- [14] W. Baltensperger, "On conduction in impurity bands," *Philos. Mag.*, vol. 44, pp. 1355-1363, July 1953.
- [15] T. P. Brody, "Nature of the valley current in tunnel diodes," *J. Appl. Phys.*, vol. 33, pp. 100-111, July 1962.
- [16] T. F. Lee and T. C. McGill, "Variation of impurity-to-band activation energies with impurity density," *J. Appl. Phys.*, vol. 46, pp. 373-380, 1975.
- [17] D. S. Lee and J. G. Fossum, "Energy-band distortion in highly doped silicon," *IEEE Trans. Electron Devices*, vol. 30, pp. 626-634, June 1983.
- [18] E. O. Kane, "Thomas-Fermi approach to impure semiconductor band structure," *Phys. Rev.*, vol. 131, pp. 79-88, July 1963.
- [19] T. N. Morgan, "Broadening of impurity bands in heavily doped semiconductors," *Phys. Rev.*, vol. 139, pp. A343-A348, July 1965.
- [20] K. P. Pernstich, B. Rössner, and B. Batlogg, "Field-effect-modulated Seebeck coefficient in organic semiconductors," *Nat. Mater.*, vol. 7, pp. 321-325, Feb. 2008.
- [21] A. Yoshikawa, K. Uchida, K. Koumoto, T. Kato, Y. Ikuhara, and H. Ohta, "Electric-field modulation of thermopower for the  $\text{KTaO}_3$  field-effect transistors," *Appl. Phys. Express*, vol. 2, pp. 121103-1-3, Dec. 2009.
- [22] W. Liang, A. I. Hochbaum, M. Fardy, O. Rabin, M. Zhang, and P. Yang, "Field-effect modulation of Seebeck coefficient in single PbSe Nanowires," *Nano Lett.*, vol. 9, pp. 1689-1693, Mar. 2009.
- [23] H. J. Ryu, Z. Aksamija, D. M. Paskiewicz, S. A. Scott, M. G. Lagally, I. Knezevic, and M. A. Eriksson, "Quantitative determination of contributions to the thermoelectric power factor in Si nanostructures," *Phys. Rev Lett.*, vol. 105, pp. 256601-1-4, Dec. 2010.
- [24] H. Fritzsche, "A general expression for the thermoelectric power," *Solid State Commun.*, vol. 9, pp. 1813-1815, Nov. 1971.

# The Application of Spectrophotometry Method for Measuring Iron Content of Groundwater after Merapi Mountain Eruption

Bernadeta Wuri Harini  
 Electrical Engineering  
 Sanata Dharma University  
 Yogyakarta, Indonesia  
 wuribernard@usd.ac.id

Sri Agustini Sulandari  
 Physic Education  
 Sanata Dharma University  
 Yogyakarta, Indonesia  
 agustfis@usd.ac.id

**Abstract**— The eruption of Merapi Mountain in Yogyakarta in November 2010 spewed a lot of material to the surface of the earth. These conditions could affect the chemical content in ground water, such as iron content. Therefore, in this research will be made an iron content measuring instrument that is used to measure iron content in ground water of Turi, Klangkapan, Kali Kuning and Umbul Pajangan after the eruption of Merapi Mountain.

The measuring iron content in the groundwater in this research is using spectrophotometric method. Because iron is measured at wavelengths between 495-570 nm, so this system will work by using a green laser light source. The results of the data processing will be displayed on the LCD (Liquid Cell Display) in mg/l.

The iron content instrument can measure the iron content 1 – 5 mg/l as well. The iron content instrument still needs improvement because it can not measure iron content below 1 mg/l in accordance with the results should be. The iron content of four springs are increasing with the rate between 19.17 – 305.7%. However, the iron content in the water in the four areas is safe for consumption because it is on the allowed threshold by the Ministry of Health (less than 0.3 mg/l).

**Keywords**—groundwater, Merapi Mountain, eruption, iron content, green laser

## I. Introduction

Ground water is a strategic resource, because it involves the basic necessities lives of many people in various community activities. In November 2010 had occurred eruption of Merapi Mountain in Yogyakarta which spewed a lot of material to the surface of the earth. These conditions could affect the chemical content in ground water, such as iron content. The maximum allowed by the Ministry of Health No.. 416/MENKES/PER/IX/1990 for Fe content in the water not more than 0.3 mg/l [1].

The measuring iron content in the groundwater in this research is using spectrophotometric method. This method is considered a fairly simple method. The analysis is done relatively quickly, and the samples were analyzed in small quantities. Today, the spectrophotometers on the market are very expensive and only certain people that could use a spectrophotometer, so many people are less able to take advantage of these tools. Therefore, we intend to make the iron content in the water measuring instrument more simple,

inexpensive, and easy to use with the spectrophotometric method. Some researcher has been utilizing a spectrophotometer for testing content of iron in the water. One of the existing research conducted by Nia Faricha, in a research entitled "*Pembuatan Alat Ukur Kadar Besi dalam Air dengan Metode Absorpsi Spektrofotometri*". This research used polychromatic light source i.e. a halogen lamp and a light sensor i.e. LDR (Light Dependent Resistor). The results are displayed in units of percent. [2]. Another researcher is Ram Murat Singh et al that developed instrument for measuring iron content in water [3]. The instrument uses RGB-LED (Red Green Blue - Light Dependent Resistor) as light source and LDR receiver. The method of conversion Fe to the red complex solution is done by adding the solution with KSCN.

In this research, an iron content in water measuring instrument will be designed using laser light source. Because the iron is measured at wavelengths between 495-570 nm, so this system will work by using a green laser light. The instrument of iron content that is made will be used to measure iron content in ground water of Turi, Klangkapan, Kali Kuning and Umbul Pajangan to assess changes in the content of iron in groundwater after the eruption of Merapi Mountain. These four areas are located at the edge of Mount Merapi. The results of the data processing will be displayed on the LCD (Liquid Cell Display) in mg/l unit. The iron content measurement tool is equipped with a battery that can be recharged so that it can be brought to a place where there is no power source.

## II. MATERIALS AND METHODS

The stages of this research are as follows:

1. Taking samples of ground water in Turi, Klangkapan, Kali Kuning and Umbul Pajangan
2. Manufacturing iron content instrument

The principle of the measurement of the sample shown in Figure 1. Light with intensity  $I_0$  passes through the sample containing molecules along  $b$ , some light will be absorbed by the molecule. This resulted in the intensity drops to  $I$ . Both the value of the light intensity ( $I_0$  and  $I$ ) were measured by photodetector. Light with intensity  $I_0$ , after passing through the absorber with concentration  $c$ ,

along  $b$ , the intensity will drop to  $I$  follow the relationship

$$\log(I_0 / I) = \epsilon b c \quad (1)$$

where  $\epsilon$  is the molar absorptivity [4],[ 5]

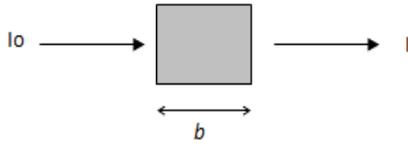


Figure 1 Absorption of light by the sample

Molar absorptivity is a constant that depends on the type of molecule and the wavelength. Equation 1 can be expressed in the form

$$\log(I_0 / I) = A \quad (2)$$

where  $A$ : absorbance, then equation 1 becomes

$$A = \epsilon b c \quad (3)$$

Where  $\epsilon$  and  $b$  is constant and  $A$  is measured, the iron level  $c$  can be obtained. The block diagram of this instrument is shown at Figure 2. The circuit of laser source and photodiode are shown at Figure 3. The flowchart of the measurement process is shown at Figure 4.

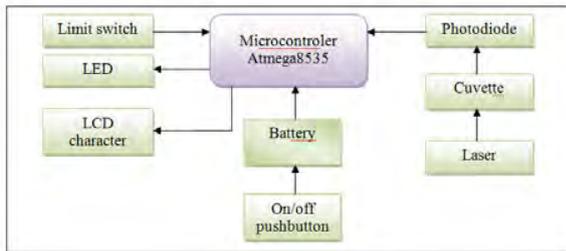
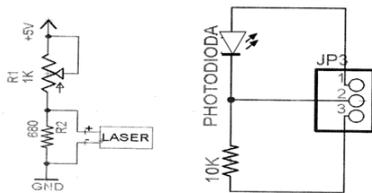


Figure 2. Block diagram



a. Laser source circuit      b. Photodiode circuit  
 Figure 3. The circuit of laser source and photodiode

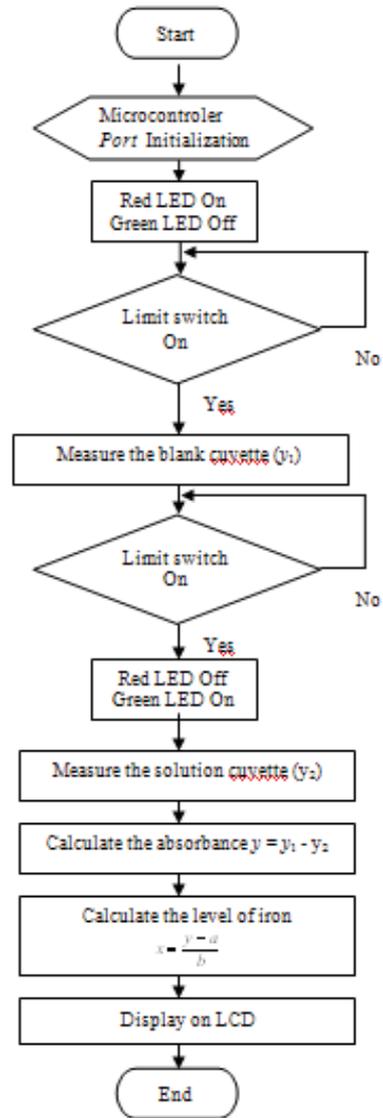


Figure 4. Flowchart of the measurement process

### 3. Preparation of Fe standard curve

- a. 1 ml of standard solution of standard Fe 100 ppm pipetted and put in a 100 ml flask. one drop of 0.2 M Na-acetate, 5 ml solution hidroksilaminklorida 10%, and 5 ml of 0.25% o-phenantrolin added into the flask. Then the solution in the flask is diluted to mark boundaries.
- b. In the same way, the solution to the volume of iron solution 0, 2, 3, and 4 ml were made. The number of drops of a solution of Na-acetate adjusted to the volume pipetted iron, then, 5 ml solution of o-phenantrolin 0.25%, 5 ml solution

hidroksilaminklorida added to the flask and the mixture was diluted to mark boundaries.

4. Measurement of Fe standart series:

- measure the blank cuvette ( $y_1$ ) and iron solution cuvette ( $y_2$ ) for sixth solution above at a wavelength of maximum absorbance
- calculate the absorbance for sixth solution above with formula

$$y = y_1 - y_2 \quad (4)$$

- draw the graph of the absorbance for sixth solution above to obtain a linear equation of Fe standart curve:

$$y = bx + a \quad (5)$$

where  $y$  = absorbance

$x$  = iron content

$b, a$  = constant

5. Calibration of the Fe standart curve measurement between the instrument and standart spectrophotometer

6. Preparation of the sample solution

25 ml water sample is pipetted into a 100 ml measuring flask. One drop of 0.2 M Na-acetate, 5 ml of 10% hidroksilaminklorida solution and 5 ml of 0.25% o-phenantrolin added to the flask and then the solution was diluted to mark boundaries.

7. Measurement of iron content:

- measure the blank cuvette ( $y_1$ ) and iron solution cuvette ( $y_2$ )
- calculate the absorbance ( $y = y_1 - y_2$ )
- calculate the content of iron:  $x = \frac{y - a}{b}$  with  $a$  and  $b$  are obtained from linear equation of Fe standart curve

### III. RESULT AND DISCUSSION

Figure 2 shows the iron content instrument that is made up. This figure shows the outside and inside of the iron content instrument. Table 1 shows the results of the voltage measurement of fifth Fe standart solution according to equation 4, which is further illustrated in Figure 3. The figure shows that the standart solution has 0.989 linearity level. The standart equation is

$$y = 0.003x + 0.002 \quad (6)$$

Table 2 shows the absorbance measurement using standart spectrophotometer, which is further illustrated in Figure 4. The figure shows that the standart solution has 0.994 linearity level. The standart equation is

$$y = 0.1889x - 0.0169 \quad (7)$$

From the two graphs above it is clear that the linearity of the iron content instrument is smaller than the standart spectrophotometer. It means that the iron content instrument still needs improvement.

Table 3 shows the content of Fe in mg/l in groundwater of four region after Merapi Mountain eruption using iron content instrument (in accordance with the equation 6) and standart spectrophotometer (in accordance with the equation 7). Table 4 shows the content of Fe in mg/l at before and after Merapi Mountain eruption that is tested at Balai Besar Teknik Kesehatan Lingkungan dan Pemberantasan Penyakit Menular (BBTKL PPM) Yogyakarta. If Table 3 compared with Table 4, it can be seen that the measured Fe content in groundwater using a standart spectrophotometer is similar to BBTKL PPM measurement result. It means that the method of preparation of the solution is correct. However, the iron content instrument can not measure iron content in accordance with the results should be. This is because the iron content in the water sample is too small. The iron content instruments can not detect iron content that is too small. For further improvement, the sensitivity of iron content instrument will be upgraded so that it can measure the small iron content as well. From table 4, we can know that the iron content after the eruption of Mount Merapi is higher than before the eruption. The greatest change occurred in the springs in the area Kali Kuning, i.e. 305.7%. However, the content of iron in the four springs is still below the threshold required by the Ministry of Health, which is less than 0.3 mg / l, so it is safe for consumption.

Table 1. Absorbance measurement of the iron content instrument.

Solution	Voltage (V)	Absorbance
0 mg/l	4.81	-
1 mg/l	4.805	0.005
2 mg/l	4.801	0.009
3 mg/l	4.797	0.013
4 mg/l	4.795	0.015
5 mg/l	4.791	0.019



Figure 2. Iron content instrument

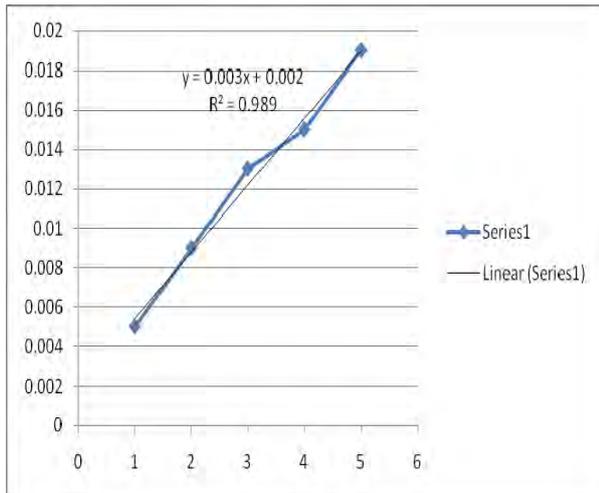


Figure 3. Series solution measurement result of the iron content instrument.

Table 2. Absorbance measurement using standart spectrophotometer

Solution	Absorbance
1 mg/l	0.186
2 mg/l	0.362
3 mg/l	0.535
4 mg/l	0.709
5 mg/l	0.957

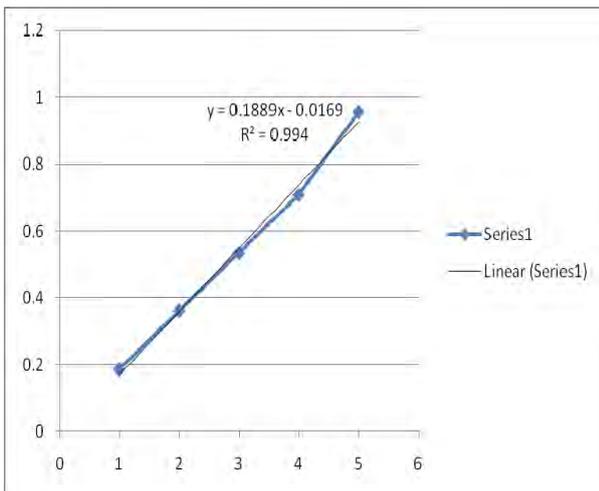


Figure 4. Series solution measurement result of standart spectrophotometer.

Table 3. Fe content of groundwater measurement using the iron content instrument and Standart spectrophotometer

Region	Absorbance Measurement		Fe content (mg/l)	
	Using the iron content instrument	Using Standart spectro-photometer	Using the iron content instrument	Calculating from absorbance using standart spectro-photometer
Klangkapan	0.001	-0.011	-0.333	0.031
Turi	0.001	-0.013	-0.333	0.020
Kali Kuning	0.001	-0.007	-0.333	0.052
Umbul Pajangan	0.001	-0.012	-0.333	0.026

Table 4. Fe content of groundwater measurement (tested at Balai Besar Teknik Kesehatan Lingkungan dan Pemberantasan Penyakit Menular Yogyakarta)

Region	Fe content (mg/l)		Increase (%)
	Before eruption	After eruption	
Klangkapan	0.0193	0.0230	19.17
Turi	0.0193	0.0230	19.17
Kali Kuning	0.0193	0.0783	305.70
Umbul Pajangan	0.0193	0.0230	19.17

#### IV. CONCLUSION

From the explanation above, it can be concluded below:

- The iron content instrument can measure the iron content 1 – 5 mg/l as well
- The iron content instrument still needs improvement because it can not measure iron content below 1 mg/l in accordance with the results should be
- The iron content of four springs are increasing with the rate between 19.17 – 305.7%. However, the iron content in the water in the four areas (Turi, Klangkapan, Kali Kuning and Umbul Pajangan) is safe for consumption because it is on the allowed threshold by the Ministry of Health (less than 0.3 mg/l).

#### Acknowledgment

Thanks to Karolus Catur Setyo Noviyanto who helped this research.

### References

- [1]. <http://dinkes-sulsei.go.id/new/images/pdf/Peraturan/kmk%20syarat%20dan%20pengawasan%20kualitas%20air%20minum%20907-2002.pdf>, was accessed on Dec 4<sup>th</sup>, 2012.
- [2]. <http://lib.uin-malang.ac.id/thesis/fullchapter/03540019-nia-faricha.pdf>, was accessed on Nov 1<sup>st</sup>, 2012, unpublished
- [3]. Singh, R.M., Mustafa, R., Ahemad, R., "Development of Microcontroler Based Instrument for Measuring Iron Content in Water", International Journal of Engineering and Innovative Technology (IJEIT), Volume 2, Issue 4, October 2012
- [4]. Skoog, D.A., Leary, J.L. 1992. Principles of Instrumental Analysis. Fort Worth: Saunders College Publishing.
- [5]. Harris, D.C. 1999. Quantitative Chemical Analysis. New York: W.H. Freeman and Company.

# Parallel Computing of WaveCluster Algorithm for Face Recognition Application

Erina Letivina Anggraini  
 Informatics Department  
 Faculty of Information Technology, ITS  
 Surabaya, Indonesia  
 erina.letivina@gmail.com

Nanik Suciati, Wahyu Suadi  
 Informatics Department  
 Faculty of Information Technology, ITS  
 Surabaya, Indonesia  
 nanik@its-sby.edu, wahyu@its-sby.edu

**Abstract**—There have been widely applied many research related to face recognition system. The system is commonly used for video surveillance, human and computer interaction, robot navigation, and etc. Along with the utilization of the system, it leads to the need for a faster system response, such as robot navigation or application for public safety. A number of classification algorithms have been applied to face recognition system, but it still has a problem in terms of computing time. In this system, computing time of the classification or feature extraction is an important thing for further concern.

Classification algorithm that is suitable for very large databases and efficient in time complexity is WaveCluster. WaveCluster based on wavelet transform able to analyze function at different resolution. To enhance system ability as a real-time system, WaveCluster will be present to be parallel process and implemented on GPU using CUDA.

CUDA is a parallel computing architecture that can manage high-performance parallel computing on GPU with large memory bandwidth. The parallelization of WaveCluster algorithm on GPU using CUDA is expected to speed-up the process computing time compared to serial process on CPU. In addition, the system is intended to improve level of accuracy in recognition process of facial images

**Keywords**—face recognition, wavecluster algorithm, parallel computing, GPU, CUDA

## I. Introduction

Face recognition system is one of topics that have been widely studied. This is because of the system is widely used in public safety application, financial security, human computer interaction and robot navigation, etc.

Some researches related to face recognition system have optimized in terms of feature extraction and classification methods. Classification approaches said to be good, if it can classified in a variety of shapes, efficient, sensitive to noise and data input sequence. WaveCluster is classification approaches based on wavelet transform that meet all the criteria mentioned. By using the wavelet transform, a variety of shapes can be identified and classified at different levels of accuracy effectively. In addition, WaveCluster is very efficient in terms of time complexity [1].

However, computational time of wavelet transform in multilevel data decomposition and reconstruction will reduce performance, especially for large size image [2]. Time

complexity of the wavelet transform is  $O(N^2)$ , where  $N$  is image size. The time needed for the computation will be increased with image size [3]. It certainly would not be appropriate when it applies to a system that requires fast computation time and quick response.

Computer Unified Device Architecture (CUDA) is a parallel computing architecture developed by Nvidia. CUDA is software for managing large data parallel computing with high performance on GPU (Graphics Processing Unit) hardware. Each GPU with CUDA-enabled can serve as a data parallel computing devices with large amount of memory on-board [4].

Previous research [5] implements WaveCluster algorithm using GPU with CUDA. There are two sub-algorithms WaveCluster approach implemented with CUDA, the extraction of low-frequency components of signal are obtained by using wavelet transform and connected component labeling. 2D dataset and high-resolution dataset are used for testing. The result concluded that the extraction of low-frequency components using GPU (NVIDIA GTX 465) can speed up the computing process with 107 times faster on the implementation on CPU (Intel Core2Duo 2.4 GHz) and connected component labeling to 6 times faster.

Parallelization of WaveCluster algorithm for face recognition system on GPU with CUDA is expected to accelerate the computing process of image extraction and classification so that it can respond faster and can be utilized for robot navigation or video surveillance in public areas.

## II. WaveCluster Algorithm

Given a set of spatial objects  $o_i$ ,  $1 \leq i \leq N$ , the goal of the algorithm is to detect clusters and assign labels to the objects based on the cluster that they belong to. The main idea in WaveCluster is to transform the original feature space by applying wavelet transform and then find the dense regions in the new space. It yields sets of clusters at different resolutions and scales, which can be chosen based on users needs. The main steps of WaveCluster are shown in Fig. 1 [1].

Algorithm: Input: Multidimensional data objects feature vectors Output: clustered objects 1. Quantize feature space, and then assign
---

- objects to the units.

  2. Apply wavelet transform on the feature space.
  3. Find the connected components (clusters) in the subbands of transformed feature space, at different levels.
  4. Assign label to the units.
  5. Make the lookup table.
  6. Map the objects to the clusters.

Fig. 1. WaveCluster algorithm

### A. Quantization

The first step of WaveCluster algorithm is to quantize the feature space, where each dimension  $i$  in the  $d$ -dimensional feature space will be divided into  $m_i$  intervals. If we assume that  $m_i$  is equal to  $m$  for all the dimensions, there would be  $m^d$  units in the feature space. Then the objects will be assigned to these units based on their feature values. Let  $F_k = (f_1, f_2, \dots, f_d)$  be the feature vector of the object  $o_k$  in the original feature space. Let  $M_j = (v_1, v_2, \dots, v_d)$  denote a unit in the original feature space where  $v_i, 1 \leq v_i \leq m_i, 1 \leq i \leq d$ , is the location of the unit on the axis  $X_i$  of the feature space. Let  $s_i$  be the size of each unit in the axis  $X_i$ . An object  $o_k$  with the feature vector  $F_k = (f_1, f_2, \dots, f_d)$  will be assigned to the unit  $M_j = (v_1, v_2, \dots, v_d)$  if

$$\forall i \quad (v_i - 1) s_i \leq f_i < v_i s_i, \quad 1 \leq i \leq d \quad (1)$$

The number (or size) of these units is an important issue that affects the performance of clustering. Because of multi-resolution property of wavelet transform, it considers different unit size at different scales of transform [1].

### B. Wavelet Transform

In the second step, discrete wavelet transform will be applied on the quantized feature space. Applying wavelet transform on the units  $M_j$  results in a new feature space and hence new units  $T_k$ . Given the set of units  $T_k$ , WaveCluster detects the connected components in the transformed feature space. Each connected component is a set of units  $T_k$  and is considered as a cluster. Corresponding to each resolution  $r$  of wavelet transform, there would be a set of clusters  $C_r$ , where usually at the coarser resolutions, number of clusters is less. The subbands  $LL$  show the clusters at different scales [1].

### C. Label and Make Look Up Table

Each cluster  $c, c \in C_r$ , will have a cluster number  $c_n$ . In the fourth step of algorithm, WaveCluster labels units in the feature space that are included in a cluster, with its cluster number. That is,

$$\forall c \forall T_k, T_k \in c \Rightarrow l_{T_k} = c_n, c \in C_r, \quad (2)$$

where  $l_{T_k}$  is the label of the unit  $T_k$ . The clusters that are found are in the transformed feature space and are based on wavelet coefficients. Thus, they cannot be directly used to define the clusters in the original feature space. WaveCluster makes a lookup table  $LT$  to map the units in the transformed feature space to the units in the original feature space. Each entry in

the table specifies the relationship between one unit in the transformed feature space and the corresponding unit(s) of the original feature space. So the label of each unit in the original feature space can be easily determined. Finally, WaveCluster assigns the label of each unit in the feature space to all the objects whose feature vector is in that unit, and thus the clusters are determined. Formally,

$$\forall c \forall M_j, \forall o_i \in M_j, l_{o_i} = c_n, c \in C_r, 1 \leq i \leq N, \quad (3)$$

where  $l_{o_i}$  is the cluster label of object  $o_i$  [1].

## III. CUDA

Compute Unified Device Architecture (CUDA) is parallel computing architecture included with new parallel programming model and set of formatting instruction to Graphical Processing Unit (GPU). Parallel computing on GPU is used to solve a number of complex computational problems more efficiently than computing on CPU. A compiled CUDA program can be executed on some processor cores. A multithreaded program is partitioned in a number of thread blocks are executed independently of each other, so that GPU with more processor cores will automatically execute the program with much less time than GPU with less processors cores.

CUDA programming model is an extension to the C language. There are three main parts of CUDA programming model, namely kernel, threads, memory. Kernel is a program code to be executed in parallel on GPU. When kernel function is called, then a number of programs to be executed  $N$  times in parallel on  $N$  number CUDA threads. Thread is a mechanism used to execute a program code. Threads in execution are grouped in blocks and grids. Block is a collection of threads executed together, while the grid is a collection of blocks. There are limits on the number of threads in a block. In particular GPU, a block can contain up to 1024 thread. A thread block can be executed independently in parallel or sequentially. A number of threads in a block can coordinate data sharing and synchronization via shared memory execution time for memory access.

CUDA programming model assumes that the thread is executed on a device that serves as a coprocessor for a host running the C program, CPU as a host and GPU as a device. Host and device uses its own memory space in DRAM is referred to as host memory and device memory. So that a program will be set up memory space available for kernel includes device memory allocation and deallocation, and data transfer between host memory and device memory. When a program calling the function kernel, then the kernel will be executed on GPU in parallel, in addition program code will be executed sequentially on CPU.

GPU has been designed with large memory bandwidth than CPU so it can have a high-throughput computing. Available memory bandwidth cannot achieve good performance if all the data are globally accessible memory. Some types of memory on GPU have different behavior and performance which can be influential in improving memory performance. Global memory is memory space that has access

slowest among the other type of GPU memory. Therefore, more data that is accessed from global memory will reduce the computational performance of implementation program result.

#### IV. Proposed Method

This research will proposed an implementation method for parallel computing of WaveCluster algorithm that shows in Fig. 2 and 3. The input is color image and then going through the process to get grayscale intensity of 2D vector. Furthermore, the image recognition needs two main methods, namely feature extraction and classification.

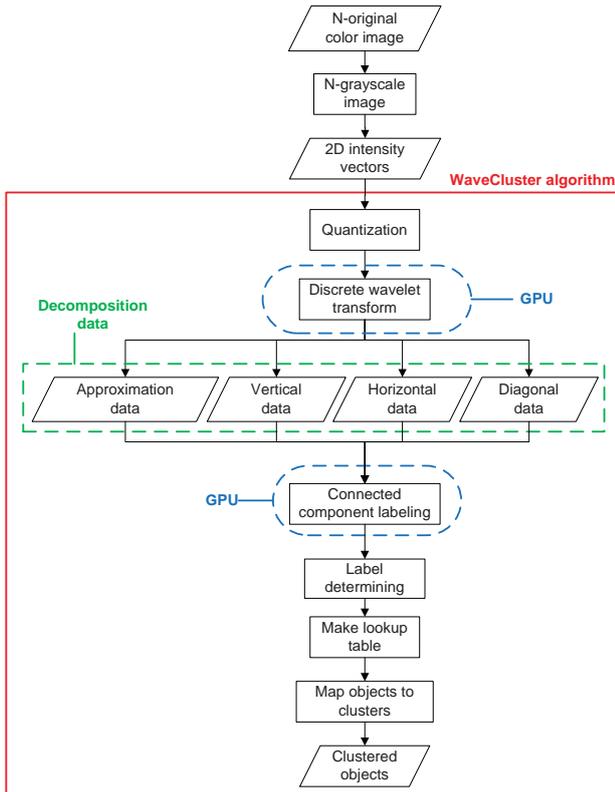


Fig. 2. Parallel computing flow of clustering process with WaveCluster algorithm for face recognition system

WaveCluster algorithm already includes the feature extraction and classification. For feature extraction of face images are used Haar wavelet transform at every level transformation produces four decomposition data, i.e. approximation data, horizontal data, vertical data, and diagonal data. All of decomposition data will be used as input to the classification process with multi-pass connected component labeling algorithm. This is done to analyze the classification results obtained from some combination of decomposition data.

#### v. Future Work

Parallelization for facial image recognition system will be made on WaveCluster algorithm, namely discrete wavelet transform and connected component labeling. Furthermore, the research will be carried out measurements of the computing time of decomposition data on WaveCluster algorithm on GPU and compared with result obtain in previous research [5].

Implementation will be done on the entire process of face recognition system ranging from feature extraction and classification with WaveCluster algorithm and face recognition process with suitability connected component labeling algorithm. Then it will be measured overall computing time implementation is a combination of CPU and GPU computing. From the results of these measurements will be compared with the implementation of the computational process occurs on CPU.

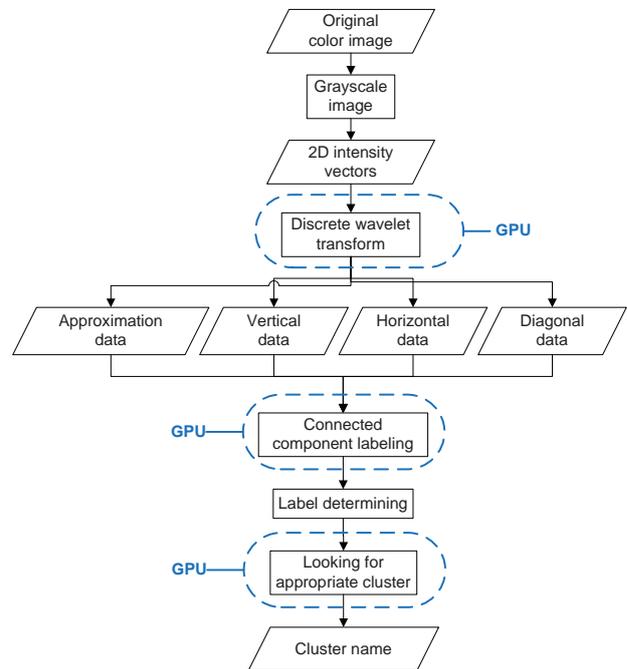


Fig. 3. Parallel computing flow of find cluster name with WaveCluster algorithm for face recognition system

#### References

- [1] G. Sheikholeslami, S. Chatterjee, and A. Zhang, "WaveCluster: A Multi-Resolution Clustering Approach for Very Large Spatial Databases", Proceedings of 24<sup>th</sup> International Conference on Very Large Databases, pp. 428-439, 1998.
- [2] Yang Su and Zhijie Xu, "Parallel Implementation of Wavelet-Based Image Denoising on Programmable PC-Grade Graphics Hardware", Signal Processing, vol. 90, issue 8, Elsevier, pp. 2396-2411, 2010.
- [3] J. Adjari, "Parallel Implementation of 2D Haar and Daubechies D4 Transform in Mers Architecture", IJIIP 1(2), pp. 55-64, 2010.
- [4] T. R. Halfhill, Parallel Processing with CUDA, Microprocessor Report Online, 2008.

- [5] A. A. Yildirim and C. Özdoğan, "Parallel Wavelet-Based Clustering Algorithm on GPUs using CUDA", *Procedia Computer Science* 3, pp. 396-400, 2011.
- [6] C. Garcia, G. Zikos and G. Tziritas, "Wavelet Packet Analysis for Face Recognition", *Image and Vision Computing* 18, Elsevier, pp.289-297, 2000.
- [7] R. C. Gonzales, R. E. Woods and S. L. Eddins, *Digital Image Processing using Matlab 2<sup>nd</sup> Edition*, Prentice Hall, 2002.
- [8] Jun-Ying Gan and Mengfei Liu, "Face Recognition using Wavelet Packet Decomposition and Hopfield Neural Network", *Proceedings of the 2009 International Conference on Wavelet Analysis and Pattern Recognition*, pp. 335-339, 2009.
- [9] S.Z. Ueng, M. Lathara, S. S. BaghSorkhi, and W. W. Hwu, "CUDA-lite: Reducing GPU Programming Complexity", *Language and Compilers for Parallel Computing*, Springer, vol 5335, pp. 1-15, 2008.
- [10] NVIDIA CUDA 4.0 Programming Guide, NVIDIA Toolkit 4.0, <http://developer.nvidia.com/cuda-downloads>
- [11] G. Eason, B. Noble, and I.N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," *Phil. Trans. Roy. Soc. London*, vol. A247, pp. 529-551, April 1955. (*references*)
- [12] J. Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68-73.
- [13] I.S. Jacobs and C.P. Bean, "Fine particles, thin films and exchange anisotropy," in *Magnetism*, vol. III, G.T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271-350.
- [14] K. Elissa, "Title of paper if known," unpublished.
- [15] R. Nicole, "Title of paper with only first word capitalized," *J. Name Stand. Abbrev.*, in press.
- [16] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," *IEEE Transl. J. Magn. Japan*, vol. 2, pp. 740-741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
- [17] M. Young, *The Technical Writer's Handbook*. Mill Valley, CA: University Science, 1989.

# Design Simulator Detection Fuel Tank on Condition Genset Use SMS Through Microcontroller ATmega 8535

Stevan Ralianto

Electrical Department  
 Christian University of Indonesia  
 East Jakarta, Indonesia  
 simondewanto@gmail.com

Nicholas T.P. Sirait, Yohannes Dewanto

Electrical Department  
 Christian University of Indonesia  
 East Jakarta, Indonesia  
 simondewanto@gmail.com

**Abstract**— In this paper we discuss about the initial stages of the study to design a system to detect the volume of fuel in the generator base stations on remote islands precisely at the Bidadari islands on Kepulauan Seribu. As this study designed a simulator that implements change fuel level and transmits the parameter changes to the BTS technician supervisor. In making this simulator, sensors are used to detect changes in elevation are a couple of LED and LDR. Meanwhile, the expected response is a call technicians to fill the fuel tank, in order to call the technician to use mobile phones, and the content of calls is a short message services (SMS) that has been in the program. For sending SMS, we was used FASTER M1306B MODEM. From the test results the design of the simulator system, we can say the system works, and send short messages in a timely manner to the technicians, and we have been proposed this to INDOSAT company.

**Keywords:** Fuel scheduling, simulator, wireless communication.

## I. INTRODUCTION

The company or plant requires a backup power supply for voltage supply equipment using Power Generator Set (GENSET). Performance GENSET one factor influenced by the use of fuel oil (BBM) which should always be monitored or monitored so that no vacuum fuel. Short Message Service (SMS) is a facility to send and receive a short text message via wireless devices, i.e. mobile communication device. One of the advantages of SMS is cost. Besides SMS is a store and forward method so that the benefits are when the mobile phone recipient can't be reached, meaning inactive or outside the service area, recipients can still receive the SMS when the mobile phone is already active. SMS provides a mechanism to send short messages to and from a place using wireless media using a Short Messaging Service Center (SMSC), which acts as a system for maintaining and re-transmit short messages. Wireless networks provide a mechanism to find the destination station and send short messages between the SMSC to the wireless station. SMS users rarely (never) get a busy signal, when the voice network is busy, unless it is an SMS Center is being very busy. By considering the issues

fueling generators and excess SMS to deliver short messages with mobile phone media, we are interested in studying how the short message can be up to in 'real time' for the condition when the tank is empty. For that we are interested in doing research on the issue, and create a form of solution.

## II. BASIC THEORY

### A. Microcontroller AVR ATmega8535

Microcontroller is a semiconductor technology in which there is a combination of millions of transistors and packaged in a single chip IC. In the memory of the microcontroller has two program memory (ROM) is used to store programs and versatile memory (RAM) is used to store temporary data include registers that are used according to the program have been made. AVR Microcontroller (Atmel and Vegard's RISC processor) has a 8 bit RISC architecture, all instructions are packed in 16-bit code (16-bits word) and most of the instructions executed in one clock cycle.

In architecture and the instructions used, can be said to be almost the same. Therefore, one used Atmel AVR products, namely ATmega8535. In addition to readily available and cheaper, ATmega8535 microcontroller also has complete facilities. For the type of AVR there are 3 types of ATtiny, classic AVR, ATmega. They differ only in facilities and I/O are available as well as other facilities such as ADC, EEPROM, and so forth. One example is ATmega8535. It has a RISC technology with speeds up to 16 MHz makes ATmega8535 faster when compared with MCS51 variants. With complete facilities such as the ATmega8535 microcontroller makes a powerful see figure 1.

### B. Liquid Level Detection

#### a. LED

LEDs are electronic components that are made from semiconductor diode that can disperse light. LED is a product of the other findings after diode. The structure is also similar to the diodes, but later discovered that electrons that hit the connection PN. To obtain light emission in semiconductors,

doping use is gallium, arsenic and phosphida. Different types of doping produce different colors of light.

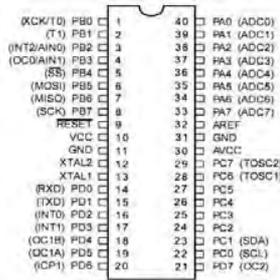
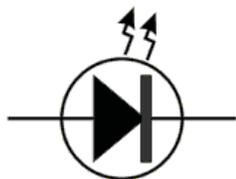


Figure 1. Konfigurasi Pin Mikrokontroler ATmega8535

LEDs have a current or voltage limits are differentiated by color. For example, red = 1.8 Volt, Orange = 2 Volt, Yellow = 2.1 Volt, Green = 2.2 Volt. The standard is 20 mA LED forward voltage and works ranged between 1.4 Volt - 3 Volt. Therefore, the use of LEDs is usually connected in series with a resistance (R) see figure 2a and 2b.



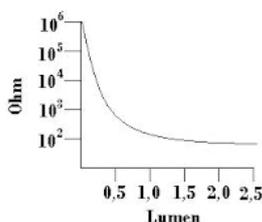
Figure 2.a LED



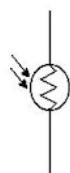
b LED electric symbol

b. LDR (Light Dependent Resistor)

LDR is a resistor resistance value varies whose Because the intensity of the light is absorbed. LDR is also a resistor having a negative temperature coefficient, the resistance value is affected by light intensity. LDR is composed of Cadmium Sulfide (CDS) was generated from ceramic powders. In general, CDS also called conductive photo equipment, as long as the conductivity or resistance of CDS varies with the intensity of the light. If the intensity of the light received high then high barriers would also result in an exit voltage will also be high and vice versa where the mechanism of the process of change light into electricity Occurs. CDS does not have the same sensitivity at each wavelength from ultraviolet to infrared.



( a )



( b )

Figure 3. a . LDR characteristics, b. LDR symbol

C. MODEM

Modem is short for modulator-demodulator. Modulate is the process of translating the data from digital to analog so it can be transmitted. Demodulate the contrary, the process of translating from analog to digital. Modulator is the part that converts the signal information into the signal (carrier) and ready to be delivered, while the demodulator is the part that separates the information signal (which contain data or messages) of the signal (carrier) received that information can be received well.

Modem is a two-way communication tool. Any remote communication devices generally use two-way section called "modem", but the term generally known as the modem hardware is often used for communication on the computer. Data from the computer in the form of a digital signal if it will be given to the modem, to be converted into analog signals. Analog signals can be transmitted through multiple media such as telephone and radio telecommunications.

III. DESIGN SYSTEM

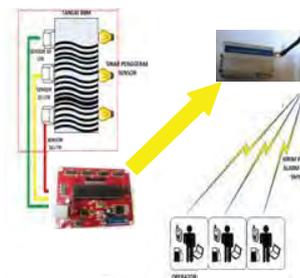


Figure 4. System Design

A. Schematic Sensor Level

Fuel level controller, schematically designed according to Figure 5. below:

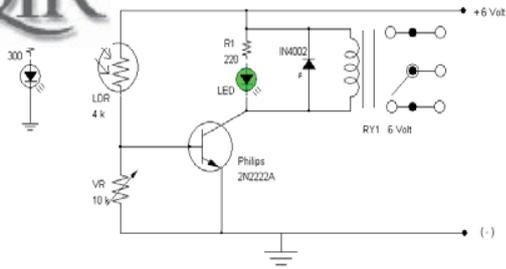


Figure 5. Sensor Circuit Design

Description of figure 5: The circuit is connected to the 5 Volt power supply, if the LDR in exposed conditions, resistance value of LDR will be 500 kilo Ohm so the current can't flow, but if the LDR is exposed to light, in the LDR resistance value will drop to 4 pounds ohm so that current can flow through LDR, toward the base of the transistor 2N2222A, and LED colors used are as in table 1.

Table 1. LED indication on the height of the liquid simulator

No.	LED color	LED Voltage	LED Current
1.	Green	1,5 Volt	20 mA
2.	Yellow	1,5 Volt	
3.	Red	1,5 Volt	

**B. Microcontroller ATmega 8535**

In designing this simulator, controllers used are microcontroller ATmega 8535, as for the pins that was used as in Table 2.

Table 2. Pins Used In Microcontroller ATMEGA 8535

No	pin	function	used for
1.	Pin D. 2	INPUT	Red Lamp
2.	Pin D. 3	INPUT	Yellow Lamp
3.	Pin D. 4	INPUT	Green Lamp
4.	Pin D. 0	OUTPUT	MODEM Fastrack M1306B
5.	Pin D. 1	OUTPUT	MODEM Fastrack M1306B

The algorithm is programmed on the microcontroller are:

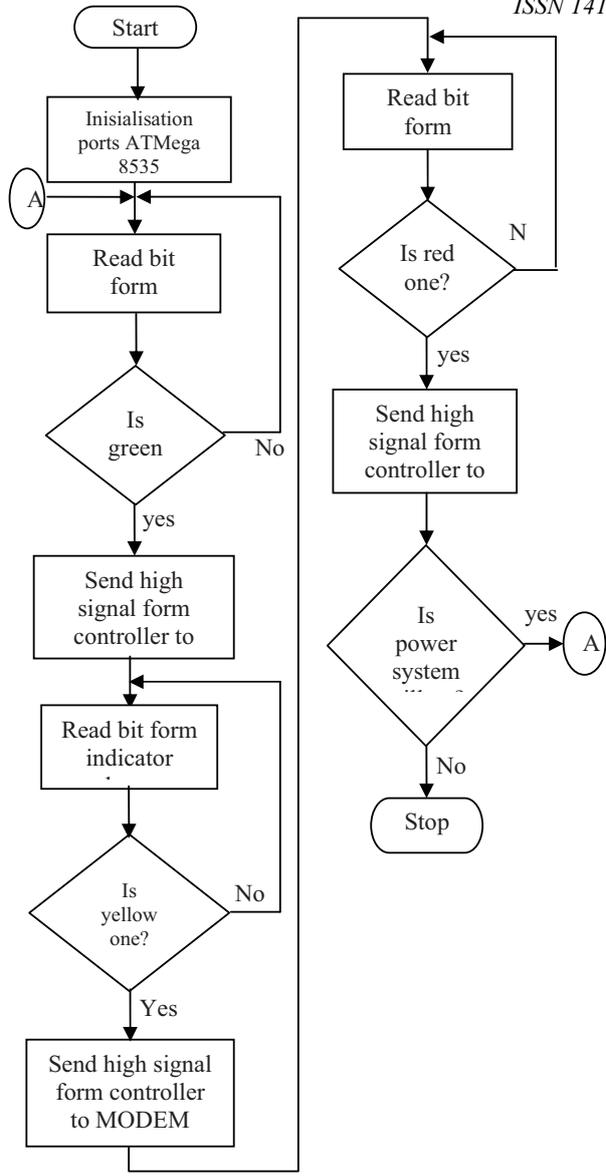


Figure 6. Flowchart Minimum System

**C. MODEM Fastrack M1306B**

FASTRACK Modem M1306B working at the dual frequencies in the 900/1800 Mhz which means that according to the existing mobile frequencies in the Indonesian market, so it fits with the desired characteristics and functions in this paper, namely the media sending data from microcontroller ATmega 8535, i.e. the form of a short message, and then the data is sent to the mobile responsibility tank GENSET. As for the connectivity of the microcontroller ATmega 8535 to 1360 MODEM FASTRACK M 1306b are as in Figure



Figure 7. Fastrack M 1306 Modem

#### IV. SYSTEM TEST AND ANALYSIS

##### A. Sensor Calibration

The results of tests performed by reducing the fluid content that is on the tank, gives the difference between mounting the sensor on the tank with fuel level when testing is done when conditions was detected LDR, as attached in Table 3.

Table 3. Sensor calibration tables for the height of liquid in tank

No	Color	Sensor position (cm)	measurable position (cm)	acuration (%)
1.	Red	9	8,5	94.4
2.	Yellow	20	19,3	96.5
3.	Green	33	32.5	94.6

##### B. Compare between Fuel Level and Volume in the Tank

Table 4. Presentation of the fuel level in the fuel tank volume

No	Color	Tank High Position	Area Tank	Volume
1.	Red	9 cm	531 cm <sup>2</sup>	4,7 liter
2.	Yellow	20,5 cm	531 cm <sup>2</sup>	10,8 liter
3.	Green	34,5 cm	531 cm <sup>2</sup>	12,1 liter

Fuel level sensor can be applied to the alarm system of a company / industry, one of the fuel level sensor application made on cellular systems in BTS in small islands like kepulauan seribu.

##### C. SIM Card

Table 5. Testing sending a message to the MODEM with 4 SIM card in UKI Electrical Laboratory

NO	SIM CARD	TIME
1.	IM3	16 Second
2.	AS	13 Second
3.	3	15 Second
4.	XL	14 Second

#### V. CONCLUSION

There are differences between the measurements of the height sensor installed with fuel level when tested on the boundary conditions, the difference in fuel level LED-level upper limit of 0.5 cm higher than the sensor mounting position, to limit fuel center height difference at the level of 0.7 LED cm lower than the mounting position of the sensor, while the lower limit of the difference in fuel level LED level of 0.5 cm lower than the sensor mounting position.

The use of LED and LDR sensor pair for the fuel level is connected to the generator tank fuel sensor makes it safe to be installed in the generator and fuel system that is inside the tank.

Four times of testing SIM Card, for GSM modems and mobile phones, the time of short messages to each destination on average 14.5 sec. It is still included in the rapid delivery of SMS on GSM.

#### REFERENCES

- [1]. Arifanto, Deni, "Kumpulan Rangkaian Elektronika Sederhana", Edisi Pertama, Kawan Pustaka, 2011.
- [2]. Zaenal, "Dioda", Edisi Pertama, Jakarta Concourse, 2009.
- [3]. Arifin, Irwan, "Elektronika 1", Edisi Pertama, Yogyakarta, 2004.
- [4]. Wasito, Suharjo, "Vademekum Elektronika", Edisi Pertama, Gramedia Pustaka Umum, 2001
- [5]. Texas Instruments Incorporated, "The TTL data Book For Engineers", Second Edition, Texas, 1976
- [6]. Budiharto Budi, Firmansyah Sigit, "Elektronika Digital Dan Mikroprosesor", CV Andi Offset, Yogyakarta, 2010
- [7]. Daniel, W. Hart, "Introduction To Power Electronics", Edisi Pertama, New York Prentice Hall International, Inc, 1997
- [8] <http://www.kpsec.freeuk.com/index.htm>, tanggal 10 mei 2012.

# Prognosis of Bearing Damage Performance to Industrial System Using Nonlinear AutoRegressive with eXogenous (NARX)

Gunawan Budi Santoso<sup>1</sup>  
 Master of Information System  
 Diponegoro University  
 Semarang 50241, Indonesia  
 gunawan\_budi@student.undip.ac.id

Toni Prahasto<sup>2</sup>  
 Master of Information System  
 Diponegoro University  
 Semarang 50241, Indonesia  
 toni\_prahasto@yahoo.com

Achmad Widodo<sup>3</sup>  
 Department of Mechanical Engineering  
 Diponegoro University  
 Semarang 50275, Indonesia  
 awid@undip.ac.id

**Abstract**—Monitoring the engine's performance carried out with the aim of the business process can run smoothly without any process stalled because if the business process stops only a few seconds, the industry will experience a loss. In this research, monitoring of industrial systems using an intelligent system that will do the prognosis of damage to the components contained in the industrial machine is the bearing performance. The method used is the nonlinear autoregressive with exogenous (NARX), based on the linear ARX model, which is commonly used in time-series modeling. This model uses a recurrent dynamic network, with feedback connections and enclosing several layers of tissues. The results of this research remaining useful life (RUL) in machine tools industry. It means the fatal damage in a machine can be avoidable. It is also part of maintenance on industrial machinery, in order to become more efficient in costing and replacement of equipment to be effective.

**Keywords**—bearing damage performance; NARX; recurrent dynamic network; time-series modeling

## I. INTRODUCTION (Heading 1)

Industrial system has rapidly developed. Therefore, to support a success in processing business, industrial system has already computerized. One of the components which operated by a computer is the monitoring of machine usage in industrial system. The purpose of machine performance monitoring is to keep the business process work endless smoothly. There will be a big loss if the business process stops, even only for a second.

In this research, industrial system monitoring used intelligent system that will prognosticate the component damage in the industrial machine, which called by bearing. Bearing is one of the important components in the majority of rotating machine. Because of the damage, bearing is one of the problems in the rotating machine, so it needs the monitoring. Later on, a Feature Extracting Data is used to monitor the

vibration condition. Some of the features are the mean, root mean square (RMS), skewness, kurtosis, and beta kurtosis. The purpose of this monitoring is to detect degradation in the engine. Thus proactive and corrective maintenance can be performed before the worse degradation or failure occurs [9].

Prognosis is a prediction of machine damage at a particular time. Consequently, machine fatal damage can be avoided. It is also a part of industrial machinery maintenance, in order to make expenses and equipment replacement more efficient and effective [18].

NARX model is a method based on the linear ARX model, which commonly used in time-series modeling. Prediction with NARX method is more accurate and consistent [19].

The method used in this research is a nonlinear autoregressive method with exogenous (NARX). This method used for bearing damage prognosis.

## II. FEATURE EXTRACTION AND NARX METHOD

### A. Feature Extraction

Feature extraction is a way to process the data to produce a feature data. In this study, there are 5 features used for prognosis. Those features are the mean, root mean square (RMS), skewness, kurtosis and beta kurtosis. Feature mean is an average or mean value of arrays. Feature root mean square (RMS) is a measure root mean square (RMS) value of the signal. Feature skewness is a measure of the asymmetry of the data around the sample mean.

Kurtosis is the the degree of kurtosis of rolling bearing vibration signal. The equation for kurtosis feature is:

$$K = E(\chi - \mu)^4 / \sigma^4 \quad (1)$$

where  $\kappa$  is the kurtosis,  $E$  is the expected value,  $x$  is the data,  $\mu$  is the average and  $\sigma$  is the standard deviation.

While beta kurtosis is the fourth moment of the beta function. The equation for the beta kurtosis feature is:

$$BK = M_4 / (\sigma^2)^2 \quad (2)$$

where  $BK$  is the beta kurtosis,  $M$  is the moment, and  $\sigma$  is the standard deviation.

### B. Nonlinear Autoregressive with exogenous (NARX)

Method of Method of Nonlinear Autoregressive with exogenous (NARX) is a general model that suitable to represent the dynamics of nonlinear systems. This model uses a repetitive dynamic network, with feedback connections and attaching multiple networks. The equation used in NARX models are:

$$y(t) = f[y(t-1) \dots y(t-ny), x(t-1) \dots x(t-nx)] + e(t) \quad (3)$$

where  $y(t)$  is the output signal at time  $t$ ,  $f$  is a nonlinear function,  $x$  is the external input,  $n$  is the order process, and  $e(t)$  is the error signal (error). Fig. 1, shows the layer of NARX, which two-layer feed forward networks are used for approximation.

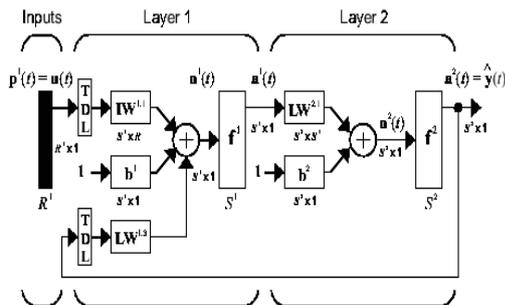


Fig. 1. Layer of NARX

Configuration training is required before demonstrate the training of the NARX network. The output of the NARX network needs to be determined to estimate the output in some nonlinear dynamic system. Fig. 2, shows how to can be accomplished by trying a model of Series-Parallel Architecture for training an NARX.

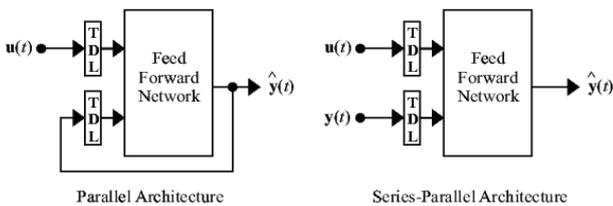


Fig. 2. Series-Parallel Architecture for training an NARX

### III. RESEARCH OBJECTS AND DATA

Research Objects and data used in this study are data on the bearing vibration measurement. These data (from NASA's

Data) are produced by the NSF I / UCR Center for Intelligent Maintenance Systems and supported by Rexnord Corp. in Milwaukee, WI. The data consists of individual files that generated from recorded vibration signals at specific intervals. In addition, each of these file consists of 20,480 points with a sampling rate set at 20 kHz. In this research used 2nd test of NASA's data.

Later, extraction features process these data to produce 5 features, namely mean, root mean square (RMS), skewness, kurtosis and beta kurtosis. The results of extraction feature in the form of the total\_features data with matrix size at 984 x 5. Hence, there are 5 features with each feature consists of 984 data. The fifth feature is used as a dataset 1 to dataset 5. Feature mean as dataset 1. Feature RMS become dataset 2. Feature skewness into dataset 3. Feature kurtosis as dataset 4. And feature beta kurtosis used as dataset 5.

### IV. RESULT AND DISCUSSION

#### A. Data Set 1

Data set 1 using the mean feature. The amount of data on the mean features is 984. The next step performed training data. The data used for the training process is 884 data, that is (1:884,1). Later from first dataset, the prognosis was processed for 100 NARX points of data with NARX method. 100 data of Data Testing Set, in the matrix is (885:984,1). Fig. 3, shows the plot mean feature and prognosis results using mean feature.

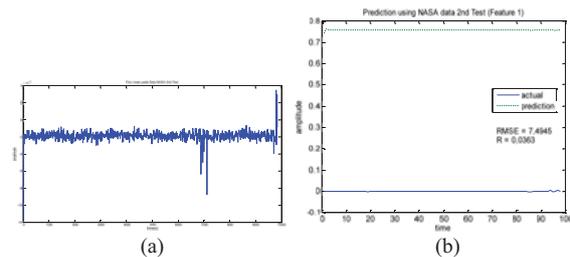


Fig. 3. (a) mean feature. (b) prognosis results using the mean feature

#### B. Data Set 2

Data set 2 using root mean square (RMS) feature. The amount of data on the RMS features is 984. The next step performed training data. The data used for the training process is 884 data, that is (1:884,2). Later from second dataset, the prognosis was processed for 100 NARX points of data with NARX method. 100 data of Data Testing Set, in the matrix is (885:984,2). Fig. 4, shows the plot RMS feature and prognosis results using RMS feature.

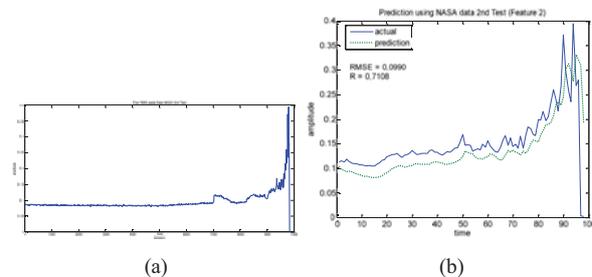


Fig. 4. (a) RMS feature. (b) prognosis results using RMS feature

C. Data Set 3

Data set 3 using skewness feature. The amount of data on the skewness feature is 984. The next step performed training data. The data used for the training process is 884 data, that is (1:884,3). Later from 3rd dataset, the prognosis was processed for 100 NARX points of data with NARX method. 100 data of Data Testing Set, in the matrix is (885:984,3). Fig. 5, shows the plot skewness feature and prognosis results using skewness feature.

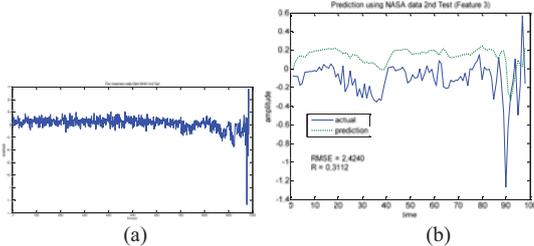


Fig. 5. (a) skewness feature. (b) prognosis results using skewness feature

D. Data Set 4

Data set 4 using kurtosis feature. The amount of data on the kurtosis features is 984. The next step performed training data. The data used for the training process is 884 data, that is (1:884,4). Later from 4th dataset, the prognosis was processed for 100 NARX points of data with NARX method. 100 data of Data Testing Set, in the matrix is (885:984,4). Fig. 6, shows the plot kurtosis feature and prognosis results using kurtosis feature.

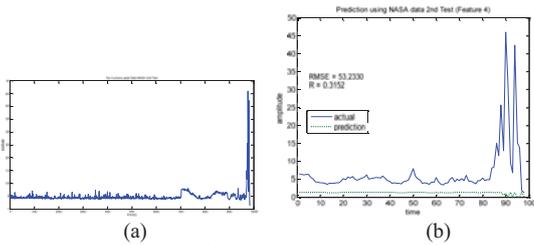


Fig. 6. (a) kurtosis feature. (b) prognosis results using kurtosis feature

E. Data Set 5

Dataset 5 using beta kurtosis feature. The amount of data on the beta kurtosis features is 984. The next step performed training data. The data used for the training process is 884 data, that is (1:884,5). Later from 5th dataset, the prognosis was processed for 100 NARX points of data with NARX method. 100 data of Data Testing Set, in the matrix is (885:984,5). Fig. 7, shows the plot beta kurtosis feature and prognosis results using beta kurtosis feature.

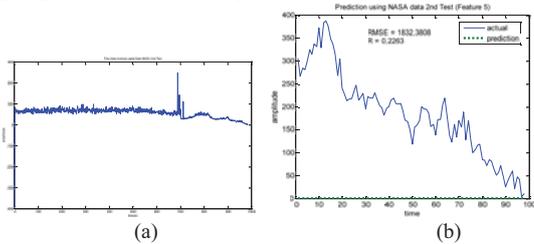


Fig. 7. (a) beta kurtosis feature. (b) prognosis results using beta kurtosis feature

F. Step Ahead Prediction

From the results of the above prediction, a good predictor is RMS feature, because this feature has root mean square error (RMSE) = 0,099 and coefficient correlation (R) = 0,7108. Then the dataset is done step ahead prediction.

- One Step Ahead

For the prediction one step ahead using 10 data, that is (885:894,2). Fig. 8, shows the result plot predicted one step ahead in the features RMS.

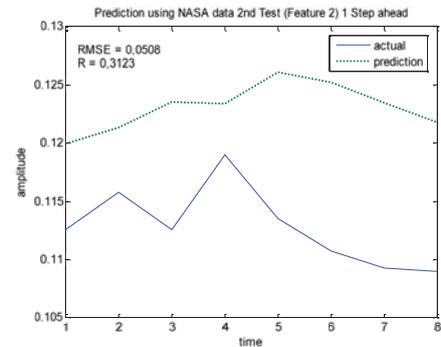


Fig. 8. Prediction one step ahead in the features RMS

- Two Step

For the prediction two step ahead using 20 data, that is (885:904,2). Fig. 9, shows the result plot predicted one step ahead in the features RMS.

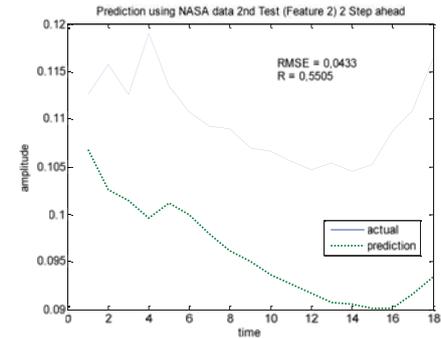


Fig. 9. Prediction two step ahead in the features RMS

- Three Step Ahead

For the prediction three step ahead using 30 data, that is (885:914,2). Fig. 10, shows the result plot predicted one step ahead in the features RMS.

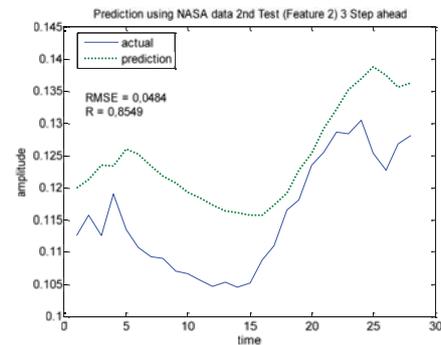


Fig. 10. Prediction three step ahead in the features RMS

## V. CONCLUSION

### A. Remaining Useful Life

Remaining Useful Life calculated using prediction step ahead, that is the amount of data on a step ahead multiplied by the file recording interval. NASA data sets have file recording interval every 10 minutes, so that the data points in the data can be interpreted NASA represents 10 minutes. So when do the predictions One Step Ahead, which 10 points of data in the future, it means that it has been doing predictions for the next 100 minutes. And when do the Two Step Ahead predictions, 20 points of data in the future, it means that it has been doing predictions for the next 200 minutes. Then, if the prediction Three Step Ahead, 30 points of data, means doing the next 300 minutes. Step ahead prediction calculation is :

$$\text{Step Ahead prediction} = \text{amount of data} \times \text{file recording interval} \quad (4)$$

Table 1, shows the table of step ahead prediction.

TABLE 1. STEP AHEAD PREDICTION

Step ahead	Amount of data (points data)	File recording interval (minutes)	Step Ahead prediction (minutes)
One	10	10	100
Two	20	20	200
Three	30	30	300

So if a roller bearing 10 data will be broken in the future, the company still has 100 minutes to replace it. So it can help the company to replace equipment before the equipment suffered fatal damage.

From these five experimental data, starting from the dataset 1 to dataset 5, then the most likely prognosis outcome testing set is RMS feature. Thus, RMS feature can be used as a dataset to predict step ahead for bearing damage prognosis using NARX.

The final results of prognosis aimed to determine the bearing remaining useful life. By knowing the bearing remaining useful life on a piece of equipment in the industrial system, this can help the company to replace equipment before the equipment suffered fatal damage. Therefore, the company can save costs and business processes can be carried out effectively and efficiently.

## REFERENCES

- [1] Bartlett, M. S., Movellan, J. R., & Sejnowski, T. J., Face recognition by independent components analysis. *IEEE Transactions on Neural Networks*, 13(6), 1450–1464, 2002.
- [2] Gebraeel, N., Sensory-updated residual life distribution for components with exponential degradation pattern. *IEEE Transactions on Automation Science and Engineering*, 3(4), 382–393, 2006.
- [3] Harmeling, S., Ziehe, A., Kawanabe, M., Blankertz, B., & Muller, K., Nonlinear blind source separation using kernel feature spaces. In *Proceedings of the international workshop on independent component analysis and blind signal separation (ICA2001)* (pp. 102–107), 2001.
- [4] Haykin, S., *Neural network* (2nd ed.). New Jersey, Upper Saddle River: Prentice-Hall, 1999.
- [5] Heng, A., Zhang, S., Andy, C. C. T., & Mathew, J., Rotating machinery prognostics: State of the art, challenges and opportunities. *Mechanical System and Signal Processing*, 23(3), 724–739, 2009.
- [6] Lee J., Qiu, H., Yu, G., Lin, J., and Rexnord Technical Services, Bearing Data Set , IMS, University of Cincinnati. NASA Ames Prognostics Data Repository, <<http://ti.arc.nasa.gov/project/prognostic-data-repository>>, NASA Ames, Moffett Field, CA, 2007.
- [7] Liu, C., & Wechsler, H., Independent component analysis of Gabor features for face recognition. *IEEE Transactions on Neural Networks*, 14(4), 919–928, 2003.
- [8] Medjaher, K., Camci, F., and Zerhouni, N., Feature Extraction and Evaluation for Health Assessment and Failure Prognostics. In *Proceedings of First European Conference of Prognostics and Health Management Society, PHM-E'12*, Dresden, Germany, 2012.
- [9] Niu, X., Zhu, L., Ding, H., New Statistical Moments For The Detection Of Defects In Rolling Element Bearings, *Int J Adv Manuf Technol* 26, 1268–1274, 2005.
- [10] Vachtsevanos, G., Lewis, Frank, L., Roemer, M., Hess, A., and Wu, B., *Intelligent Fault Diagnosis and Prognosis for Engineering System*. John Wiley & Sons, Inc., New Jersey, 2006.
- [11] Vapnik, V. (1995). *The nature of statistical learning theory*. New York: Springer-Verlag, 1995.
- [12] Wang, W.Q., Ismail, F., and Golnaraghi, M.F., Assessment Of Gear Damage Monitoring Techniques Using Vibration Measurements, *Mechanical Systems and Signal Processing* 15(5), 905-922, 2001.
- [13] Wang, W.Q., Golnaraghi, M.F., and Ismail, F., Prognosis Of Machine Health Condition Using Neuro-Fuzzy Systems, *Mechanical Systems and Signal Processing* 18, 813–831, 2004.
- [14] Wang, W., An Adaptive Predictor for Dynamic System Forecasting, *Mechanical System and Signal Processing* 21, 809-823, 2007.
- [15] Wang, Y. F., & Kootsookos, P. J., Modelling of low shaft speed bearing faults for condition monitoring. *Mechanical System and Signal Processing*, 12(3), 415–426, 1998.
- [16] Widodo, A., and Yang, B. S., Support vector machine in machine condition monitoring and fault diagnosis. *Mechanical Systems and Signal Processing*, 21(6), 2560–2574, (2007a).
- [17] Widodo, A., and Yang, B. S., Application of nonlinear feature extraction and support vector machines for fault diagnosis of induction motors. *Expert System with Application*, 33(1), 241–250, 2007b.
- [18] Yam, R.C.M., Tse, P.W., Li L., and Tu, P., Intelligent Predictive Decision Support System for Condition-Based Maintenance, *Int J Adv Manuf Tech* 17, 383–391, 2001.
- [19] Zemouri, R., Gouriveau, R., Zerhouni, N., Defining and Applying Prediction Performance Metrics On A Recurrent NARX Time Series Model, *Neurocomputing* 73, 2506–2521, 2010.

# Power Element Management System via Radio Microwave at PT Smartfren Telecom Palembang

Parulian<sup>a</sup>, Yuslan Basir<sup>b</sup>,

Sariati, Hazairin Samaulah<sup>c</sup>

Faculty of Electrical Engineering, Universitas Tridinanti,  
 Palembang 30129

Faculty of Electrical Engineering, Universitas Tridinanti,  
 Palembang 30129

<sup>a</sup> [parulian\\_n70@yahoo.com](mailto:parulian_n70@yahoo.com), <sup>b</sup> [yuslanbasir@yahoo.co.id](mailto:yuslanbasir@yahoo.co.id),

<sup>c</sup> [hazairinsamalah@ymail.com](mailto:hazairinsamalah@ymail.com)

**Abstract** Power supply is one of the most important thing in mobile telecommunications system. Power quality determine the reliability of telecom equipment, therefore electrical interferences should known as soon as possible to avoid power supply interruption and affecting to the operation of telecommunication system. To keep the power system in any location of base stations could be real time monitor, they invented a remote power monitoring system. It control, monitor and manage all units of rectifier on remote area via microwave radio. As we know there are any weakness of microwave radio, one of them is fading on air due to weather conditions changes. Like a radio communication system in general, it's affects to the reliability of power monitoring system. In this paper, the authors will discuss and analyze the root cause of failure to get information from rectifier in remote area with a case study in a particular location which has been specified by the author.

**Keywords :**

*Path Calculation, RSL, Losses, Gain, Fade Margin*

## 1. INTRODUCTION

Power Element Management System is a centralized power system monitoring which applicable on many industries. The main purpose of PEMs is to ensure the reliability and availability of power supply in any base stations. After check one of the most frequently failure of get electrical information from rectifier in a remote area, the authors investigated an HOP of radio microwave on site Mariana direction to Mato merah site. On this HOP we finding so many failure of radio microwave system which impact of the reliability of power monitoring decrease.

### 2.1. PATH CALCULATION

A calculation of output power levels to ensure the reception power level are greater than or equal to the threshold power level ( $RSL > R_{th}$ ), several parameters that affect to link budget such as Tx Power, EiRP, RSL, FSL, etc. This calculation is to maintain the balancing of gains and losses in order to achieve an ideal parameter link budget.

#### 2.1.1. Tx Power

A radio transmitter usually has an output power which measured by the equations (2.1) and (2.2) with each values as below :

$\text{dBm}$  : Relative power to one (1) milliwatt  
 $W$  : Linear power as Watts

A transmit radio transmit power is not through reinforcement or losses in transmission media. Calculated by the following equations.

#### 2.1.2. Effective Isotropic Radiated Power

An amount that states transmit power of a transmitter that has been through the reinforcement and damping on the transmission line can be calculated by the formula in Equation (2.3) where :

$P_{Tx}$  : Transmit power (dBm)  
 $G_{Tx}$  : Transmitter antenna gain (dB)  
 $L_{Tx}$  : Losses transmitter (dB)

#### 2.1.3. Receive Sensitivity

All radios have a minimum point, where if the signal received is lower than the minimal point of the data sent can not be received well. Minimal point radio sensitivity in dBm or W is known as Threshold. Defined as the limit of tolerance acceptance that can still be tolerated, rec.594 CCIR standards and technical specifications on the level-77dBm.

#### 2.1.4. Receive Signal Level

Receive Signal Level is the level of receptivity in the receiver whose value must be greater than the sensitivity of the receiver ( $RSL \geq R_{th}$ ). The sensitivity of receiver is used as a threshold size (refer to figure 1). RSL value can be calculated by equation (2.4):

Where the values are as below :

$EIRP$  : Effective Isotropic Radiated Power (dBm)  
 $L_{fs}$  : Propagation loss (dB)  
 $G_{Rx}$  : Rx antenna gain (dB)  
 $L_{Rx}$  : Line losses (dB)

Or with equation (2.5) where :

$P_{Tx}$  : Tx output power (dBm)  
 $P_{Tx Loss}$  : Cable loss + Connector loss / insertion loss + Adaptor (dB)  
 $G_{ant1}$  : Antenna Tx Gain (dBi)  
 $L_{fs}$  : Free space loss (dB)  
 $G_{ant2}$  : Antenna Rx Gain (dBi)  
 $Rx loss$  : Rx losses (dB)

#### 2.1.5. Free Space Loss

Free space loss is the wave propagation losses in the air between two isotropic antennas due to the energy spread in the equation (2.6).

where  $D$  = Path distances (km) and  $f$  = Frequency (GHz)

3. TABLES AND FIGURES

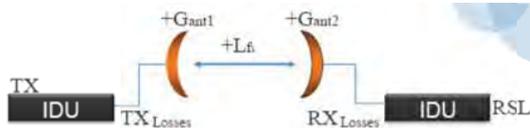


Figure 1: Gain & Losses on Microwave Radio System

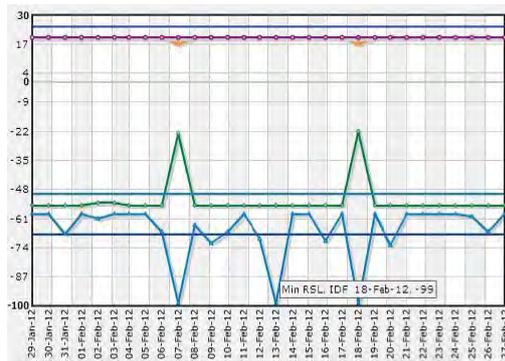


Figure 2: RSL monitoring

Date & Time	Severity	Module	State	Description
25-Feb-12 18:23:06	▲	IDU	Cleared	IDU extreme temperature conditions
25-Feb-12 12:59:06	▲	IDU	Raised	IDU extreme temperature conditions
19-Feb-12 19:50:38	▲	IDU		Configuration upload failed
19-Feb-12 19:47:29	▲	IDU		Configuration creation succeeded
19-Feb-12 05:11:45	▲	IDU		Configuration upload failed
19-Feb-12 05:08:35	▲	IDU		Configuration creation succeeded
18-Feb-12 00:24:38	▲	IDU		Remote communication failure
18-Feb-12 00:24:35	▲	IDU	Raised	Remote communication failure
18-Feb-12 00:24:28	▲	IDU	Cleared	Remote communication failure
18-Feb-12 00:24:28	▲	IDU	Raised	Remote communication failure
18-Feb-12 00:24:27	▲	IDU	Cleared	Remote communication failure
18-Feb-12 00:24:27	▲	IDU	Raised	Remote communication failure
18-Feb-12 00:24:24	▲	IDU	Cleared	Remote communication failure
18-Feb-12 00:24:24	▲	IDU	Raised	Remote communication failure
18-Feb-12 00:24:21	▲	IDU	Cleared	Remote communication failure
18-Feb-12 00:24:21	▲	IDU	Raised	Remote communication failure
18-Feb-12 00:24:18	▲	IDU	Cleared	Remote communication failure
18-Feb-12 00:24:18	▲	IDU	Raised	Remote communication failure
18-Feb-12 00:24:16	▲	IDU	Cleared	Radio signal degrade
18-Feb-12 00:24:16	▲	IDU	Cleared	Remote communication failure

Figure 3.2 Log alarm Radio Link

Table 1: Site survey Data

No	Description	Mariana	Mato Merah
1	Latitude	02° 58 18.08 S	02° 57 21.17 S
2	Longitude	104° 52 07.64 E	104° 50 05.46 E
3	Configuration	1+0	1+0
4	Distance ( KM )	4.16	4.16
5	Tower Height	SST 72	SST 70
6	Elevation (Amsl)	9.85	6.17
7	Ant Height ( Mtr)	38	40
8	Antenna Diameter (Mtr)	0.3	0.3
9	Antenna Gain (dBi)	30	30
10	Feeder Length (mtr)	48	50
11	Feeder Type	Belden 9914/RG8	Belden 9914/RG8
12	Feeder Loss (dB/100ft)	5.5	5.5
13	Connector Model / Type	Amphenol RF / NM RG-8U	Amphenol RF / NM RG-8U
14	Tx Freq ( GHz )	13.143	12.877
15	Rx Freq ( GHz )	12.877	13.143
16	Tx Power ( dBm )	22	22
17	RSL Actual ( dBm )	-65	-67
18	RSL Min (dBm)	-99	-99
19	Rx Threshold (dBm)	-75.5	-75.5
20	Insertion Loss (dB)	0.15	0.15

Table 2: Gains both location

No	Strengthening (Gain)	Mariana	Mato Merah
1	Antenna (dBi)	30	30
2	Tx Power (dBm / Watts)	22	22
3	EIRP	42.939	42.578
4	Strengthening both sides	82	82

Table 3: Link budget calculations

Link Budget		Values	
		Installed (0.3 m)	Planning (0.6m)
EIRP (dBm)	Mariana	42.939	47.939
	Mato Merah	42.578	47.678
RSL (dBm)	Mariana	-63.511	-53.11
	Mato Merah	-63.689	-53.68
FM (dBm)	Mariana	11.989	23.291
	Mato Merah	11.811	23.581
L <sub>fs</sub> (dB)	Mariana	127.206	125.436
	Mato Merah	127.028	125.824

#### 4. EQUATIONS

$$Power (dBm) = 10 \log \left[ \frac{Power (W)}{0.001W} \right] \dots\dots\dots [1]$$

$$EIRP = P_{Tx} + G_{Tx} - L_{Tx} \dots\dots\dots [2]$$

$$RSL = Tx - Tx_{loss} + G_{ant1} - L_{fs} + G_{ant2} - Rx_{loss} \dots\dots\dots [3]$$

$$L_{fs} = 92.45 + 20 \log (f \times D) \dots\dots\dots [4]$$

$$L_{tr} = L_{fs} + L_f + L_b + A_{eff} - G_{tot} \dots\dots\dots [5]$$

$$Cable_{loss} = L \times A_{loss} \dots\dots\dots [6]$$

$$L_{fs} = 92.45 + 20 \log (f \times D) \dots\dots\dots [7]$$

- [1] Alfin Hikmaturohman, ST on Dictates of Microwave radio Akademi Teknik Telekomunikasi Shandy Putra Purwokerto.
- [2] Link Budget Calculation, Marco Zennaro and Carlo Fonda the Abdus Salam International Centre for Theoretical Physics mzenarro@ictp.it the EIRP is the Equivalent Isotropically Radiated Power
- [3] White Paper of Tranzeo Wireless Technologies.inc on TR304-01
- [4-7] Ceragon Fiber Air Training Handbook

#### 5. DISCUSSION

##### Site Survey

In order to obtain accurate data on the condition of the field, the authors conducted site visits to collect data and information on the data obtained can be seen in (Table 3.1)

##### Cable Loss

Mariana site with length of cable = 48 m  
= 48 x 3.2810 = 157.48ft, The cable losses value is 8.661 dB

Mato merah site with length of cable = 50 m  
= 50m x 3.2810 = 164.050ft, The cable losses value is 9.022 dB

##### Connector Loss

For both station has 2 units of IF connectors , 1 connected to the RFU dan the other connected to the IDU, therefore the insertion loss at those sites as follow :

Mariana site = 2 x 0.15dB = 0.3 dB  
Mato Merah site = 2 x 0.15dB = 0.3 dB

##### Free space Loss

This losses is common in every wave that propagates in air, which is expressed by the LFS refer to the (eq.2.6):

$$L_{fs} \text{ Mariana, } f = 13.143 \text{ GHz}$$

$$= 92.45 + 20 \log (f \times D)$$

$$= 92.45 + 20 \log (13.143 \times 4.16)$$

$$= 127.206 \text{ dB}$$

$$L_{fs} \text{ Mato Merah, } f = 12.877 \text{ GHz}$$

$$= 92.45 + 20 \log (f \times D)$$

$$= 92.45 + 20 \log (12.877 \times 4.16)$$

$$= 127.028 \text{ dB}$$

##### Line Losses

The amount of losses on the transmission line which is calculated in both of location of the biggest losses obtained from free-space loss propagation. This is due to the use of frequency 13 GHz with a distance of 4.16 km. Here are the total transmission losses in both locations as follow :

##### EIRP

Number of additional power in the pentransmission depending on the type and specifications of antennas used. The EIRP values at the location Mariana and Mato merah are :

$$EIRP = P_{Tx} + G_{Tx} - L_{Tx}$$

$$EIRP_{\text{Mariana}} = 22 \text{ dBm} + 30 \text{ dBi} - 9.061 \text{ dB}$$

$$= 42.939 \text{ dBm}$$

$$EIRP_{\text{Mato merah}} = 22 \text{ dBm} + 30 \text{ dBi} - 9.422 \text{ dB}$$

$$= 42.578 \text{ dBm}$$

##### Gains (Refer to the table 3.2)

##### Receive Signal Level

The values of the received power at the receiver side, the good thing is RSL > RTH. RSL value at a receiver can be calculated by using the formula (eq 2.5) :

$$RSL_{\text{Mariana}} = 42.578 \text{ dBm} - 127.028 \text{ dB} + 30 \text{ dBi} - 9.061 \text{ dB} = -63.511 \text{ dBm}$$

$$RSL_{\text{Mato Merah}} = 42.939 \text{ dBm} - 127.206 \text{ dB} + 30 \text{ dBi} - 9.422 \text{ dB} = -63.689 \text{ dBm}$$

##### Fade Margin

For both location, we get the fade margins value as below :

$$FM_{\text{Mariana}} = -63.511 \text{ dBm} - (-75.5 \text{ dBm})$$

$$= 11.989 \text{ dBm}$$

$$FM_{\text{Mato Merah}} = -63.689 \text{ dBm} - (-75.5 \text{ dBm})$$

$$= 11.811 \text{ dBm}$$

Therefore, based on the calculation Fade Margin, it is known that the cause of frequently disruptions radio performance are caused by RSL degraded and fade margin values that has not reach the minimum values. To get it cleared from radio interference such as Fading, Multipaths, then the value should be increase to the over or equals than 15dB.

By the way, with assumes we gonna change the antenna diameters and gain with the values 0.6 (35dB) then change the frequency become 11GHz would be get the best result as follow :

$$EIRP_{\text{Mariana}} = 22 \text{ dBm} + 35 \text{ dBi} - 9.061 \text{ dB}$$

$$= 47.939 \text{ dBm (increase 5 dBm)}$$

$$EIRP_{\text{Mato merah}} = 22 \text{ dBm} + 35 \text{ dBi} - 9.422 \text{ dB}$$

$$= 47.678 \text{ dBm (increase 5.1 dBm)}$$

$$L_{fs} \text{ Mariana} = 92.45 + 20 \log (10.721 \times 4.16)$$

$$= 125.436 \text{ dB}$$

$$L_{fs} \text{ Matomerah} = 92.45 + 20 \log (11.211 \times 4.16)$$

$$= 125.824 \text{ dB}$$

$$RSL_{\text{Mariana}} = 47.678 \text{ dBm} - 125.824 \text{ dB} + 35 \text{ dBi} - 9.061 \text{ dB} = -52.209 \text{ dBm}$$

$$\text{(increase 11.302 dBm)}$$

$$RSL_{\text{Mato merah}} = 47.939 \text{ dBm} - 125.436 \text{ dB} + 35 \text{ dBi} - 9.422 \text{ dB} = -51.919 \text{ dBm}$$

$$\text{(increase 11.77 dBm)}$$

Therefore, the values of Fade Margin would be as follow :

$$\begin{aligned} \text{FM}_{\text{Mariana}} &= -52.209 \text{ dBm} - 75.5 \text{ dBm} \\ &= 23.291 \text{ dBm} \\ \text{FM}_{\text{Mato Merah}} &= -51.919 \text{ dBm} - 75.5 \text{ dBm} \\ &= 23.581 \text{ dBm} \end{aligned}$$

## 6. CONCLUSION

Fade Margin value Mariana to Mato merah not meet the standard, so it is fragile of interferences and impact to the reliability of power remote monitoring system at the location Mariana.

Mato merah to Mariana with 11GHz frequency applications rather than 13 GHz, the added value gained is reduced propagation losses of 2.5 dB free space.

By changing the antenna size with a bigger diameter 0.3 to 0.6 meters would get the result as an increasement of 10 dBm RSL and a power reserve of over than 23 dBm Fade margin.

## REFERENCES

- [1] Anonymous, "FibeAir® RFU-C, Versi 6.0" Ceragon, Juni 2009 [http://www.ceragon.com/na/products\\_category.asp?ID=10](http://www.ceragon.com/na/products_category.asp?ID=10), 18Mar2012
- [2] Anonymous, IP-10 G Basic Course (Installation,

Commissioning and System Configuration), Ceragon,

April 2011 <http://training.ceragon.com>, 11 April 2011

[3] Anonymous, SR-4200 Power Supply System Operation Manual, Dongah Elecomm Ltd, November 2010

[4] Hardiyanto, Modul Perkembangan Teknologi Komunikasi,

2009, [http://pksm.mercubuana.ac.id/new/elearning/files\\_modul/94021-6-973648939692.doc](http://pksm.mercubuana.ac.id/new/elearning/files_modul/94021-6-973648939692.doc), 23Nov2011

[5] Kurniawan, Adit, "Penentuan Kebutuhan Daya Pancar pada Sistem Telepon Radio Diam dengan Pengukuran Sampel Majalah Ilmiah Teknik Elektro

ITB" <http://ltrgm.ee.itb.ac.id/~adit/admin/modules/addjurnal/bahan/6.pdf>, 11Des2011

[6] L. Freeman, Roger, "Telecommunications Transmission Handbook", 1998.

Link Budget Calculation,

[http://wirelessu.org/uploads/units/2008/10/15/125/Link\\_Budget.pdf](http://wirelessu.org/uploads/units/2008/10/15/125/Link_Budget.pdf), 21Jan2012

[7] Anonymous, "Radio Link Budget"

<http://www.netcontrol.com/eng/services/radio-networking-help-tools/radio-link-budget/>, 21Feb2012

[8] Anonymous, "Wireless Link Budget Analysis"

[http://www.tranzeo.com/allowed/Tranzeo\\_Link\\_Budget\\_Whitpaper.pdf](http://www.tranzeo.com/allowed/Tranzeo_Link_Budget_Whitpaper.pdf), 18Mar2012

# Bandwidth Enhancement of Ultra-Wideband Microstrip Bandpass Filter Using Defected Ground Structure

Wisnu Aditomo

Radio Telecommunication and Microwave Laboratory  
School of Electrical Engineering and Informatics  
Institut Teknologi Bandung  
Bandung, Indonesia  
wisnu.aditomo@yahoo.com

Achmad Munir

Radio Telecommunication and Microwave Laboratory  
School of Electrical Engineering and Informatics  
Institut Teknologi Bandung  
Bandung, Indonesia  
munir@ieee.org

**Abstract**— In this paper, the bandwidth enhancement of ultra-wideband (UWB) microstrip bandpass filter (BPF) is proposed by utilizing defected ground structure (DGS). The initial UWB microstrip BPF which is designed to have the bandwidth response of 4GHz with the center frequency of 4GHz is deployed on FR4 Epoxy dielectric substrate with overall size and thickness of 11mm x 32mm and 0.8mm, respectively. To enhance the bandwidth response, an attempt is carried out by applying DGS on to the ground plane of initial filter. Here, the proposed DGS is constructed of 3 circular dumbbells. Some parametrical studies to the DGS such as changing the radius of dumbbells and the dimension of bridging-section of dumbbells are conducted intensively to obtain the optimum geometry of DGS with the desired bandwidth response. From the characterization result, it shows that the utilization of DGS on to the ground plane of filter has widened 3dB bandwidth response up to 5.36GHz ranges from 1.84GHz to 7.2GHz yielding an enhanced ultra-wideband response for various UWB applications. The minimum insertion loss and maximum return loss of microstrip BPF with proposed DGS in the passband area are 2.05dB and 6.73dB, respectively.

**Keywords**— Bandwidth enhancement, DGS, dumbbells, UWB microstrip BPF

## I. INTRODUCTION

During last decade, the development of technology for communication and information has been incredibly increasing. This development is principally to satisfy the demand for high speed communication which supports to transmit huge amounts of information [1]-[3]. Some investigation effort to fulfill the demand has also been conducted by improving the existing of device technology. However, the improvement sometimes arises some problems regarding the limited capability of related devices of communication and information technology, including antenna, signal amplifier, coupler, and filter [3]-[5]. From so many mentioned devices, the last device, i.e. filter, is one of the most important and essential parts for application in communication and information technology. As is already well-known, most of devices for communication and information technology could not perform well if they have no adequate quality in filtering system.

In accordance to the development of devices for communication and information technology, the demand of related devices, filters in particular, tends to have wide bandwidth response, compact in size, light in weight as well as adequate electrical characteristic performances. In order to accomplish the requirements above, ultra-wideband (UWB) technology has been one of the most promising solutions for wide range data communication application in future [6]. Several devices that support the UWB system have been theoretically and experimentally investigated including a number of UWB filters which have been developed using some techniques such as microstrip and uniplanar circuits [7]-[9]. However, even though most of devices supported UWB systems, especially filters, have claimed to have wide bandwidth response, another problem often arises regarding to the bandwidth capabilities of devices.

In connection to the attempts for obtaining the wide bandwidth response of filter, in this paper, the bandwidth enhancement of UWB microstrip bandpass filter (BPF) is conducted by changing and/or defecting the ground plane surface of filter called as defected ground structure (DGS). Here, the DGS is intentionally applied to have the BPF with enhanced performance for various UWB applications. The proposed DGS is constructed of 3 uniformly circular dumbbells which are positioned symmetrically between the ports on the ground plane of initial filter. Hence, the BPF itself is composed of dual open stubs and four sections of balanced coupled-lines for obtaining multimode filter responses [10]. The construction of filter and DGS which is deployed on FR4 Epoxy dielectric substrate is designed to have working bandwidth wider than 4GHz as the improvement effect from the original bandwidth response. In the design process, the performance of BPF with proposed DGS is investigated intensively to obtain the optimum design of overall structure. Some parametrical studies upon the DGS are investigated to obtain the optimum geometry of DGS with the desired bandwidth response by changing the radius of circular dumbbells as well as varying the dimension of bridging-section of circular dumbbells. Hence, the filter parameters including return loss, insertion loss, and bandwidth response will be used as key indicators in the evaluation of filter performance.

---

This work is partially supported by the Research Grant from ITB under the Program of Research and Innovation 2013.

## II. BRIEF OVERVIEW OF UWB MICROSTRIP BPF

### A. UWB Microstrip BPF without DGS

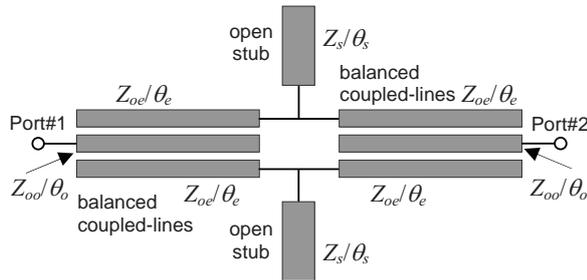


Fig. 1. Transmission line model of initial UWB microstrip BPF

By using the model in [10], the transmission line model of initial UWB microstrip bandpass filter (BPF) is illustrated in Fig. 1. The model is developed with balanced coupled-lines and dual open stubs perturbation to work with the center frequency of 4GHz. It is shown that the line impedance and electric length of every open stub perturbation are  $Z_s$  and  $\theta_s$  respectively. In addition, since the coupled-line is symmetrically structured yielding balanced coupled-line, therefore, the structure has a common line which is connected to the port. Every coupled-line provides the even-mode line impedance and the electric length of  $Z_{oe}$  and  $\theta_{oe}$ , respectively and also the odd-mode line impedance and the electric length of  $Z_{oo}$  and  $\theta_{oo}$ , respectively. Based on the transmission line model, the structure of UWB microstrip BPF is then implemented using microstrip technology on an FR4 Epoxy dielectric substrate with overall size and thickness of 11mm x 32mm and 0.8mm, respectively.

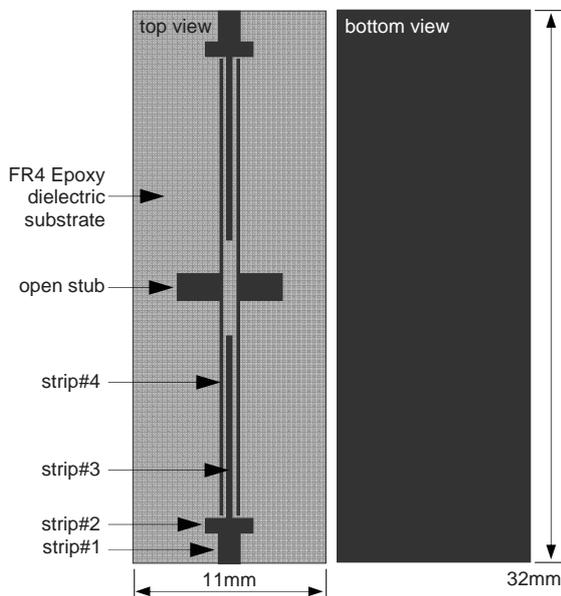


Fig. 2. Structure of initial UWB microstrip BPF.

Figure 2 shows the structure of initial UWB microstrip BPF composed of balanced microstrip coupled-lines with dual open stubs perturbation. Hence, Table 1 summarizes the detail geometry of each filter element, i.e. strips and stubs. The elements are made of metal copper on the top side of dielectric substrate as well as the ground plane on the bottom side. In order to have an accurate design, the losses of dielectric substrate and metal copper conductive for elements and ground plane are taken into account. The input/output signals for initial UWB microstrip BPF are obtained from SMA connectors.

TABLE I. GEOMETRY OF EACH ELEMENTS FOR INITIAL UWB MICROSTRIP BPF

Element	Width (mm)	Length (mm)
Strip#1	1.2	1.8
Strip#2	0.8	2.7
Strip#3	0.4	10.6
Strip#4	0.3	26.4
Open stub	1.5	2.7

### B. DGS-based UWB Microstrip BPF

By using the similar structure of filter elements as applied for the initial UWB microstrip BPF, the bandwidth enhancement to have the filter with improved performance is investigated by employing defected ground structure (DGS). Figure 3 illustrates the utilization of DGS over the ground plane. It shows that the proposed DGS is constructed of 3 uniformly circular dumbbells. The first and the third dumbbell are placed symmetrically each other from the center, while the second one is put at the center underneath open stubs perturbation. To obtain the optimum geometry of DGS, the investigation is carried out by changing the radius of circular dumbbells as well as varying the dimension of bridging-section of dumbbells.

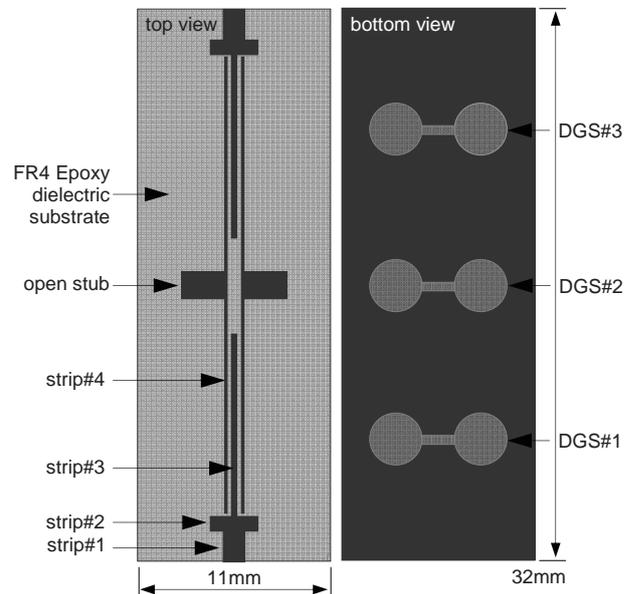


Fig. 3. Structure of DGS-based UWB microstrip BPF.

### III. CHARACTERIZATION RESULTS AND DISCUSSION

Figure 4 plots the characterization result of DGS-based UWB microstrip BPF with the radius of circular dumbbells varied from 1.3mm–1.5mm. The separation between DGS is set to be 7.8mm which is measured from the center of each circular dumbbell. The bridging-section length and width of each circular dumbbell is set to be uniform at 1.0mm and 0.5mm, respectively. From the result, it should be noted that the larger radius of dumbbell yields the better response of passband area at higher frequency bands (6.3–7.8GHz) but the worse response at middle frequency bands (4.6–6.3GHz). The result shows that the variation of circular dumbbell has no effect to the lower frequency bands. This can be understood that the characteristics of dumbbells as DGS affects to the decrease of overall inductance of filter.

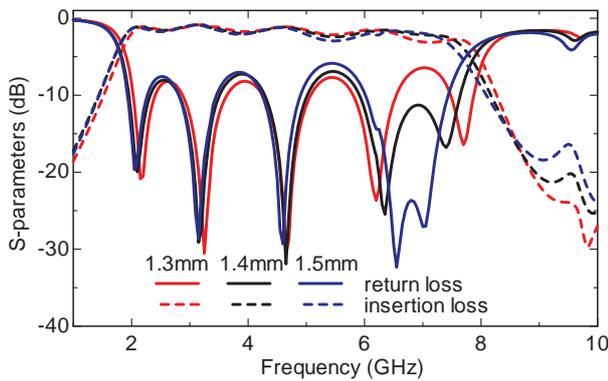


Fig. 4. Characterization result of DGS-based UWB microstrip BPF with the varied radius of circular dumbbells

Next, the characterization of DGS-based UWB microstrip BPF for the varied separation between DGS from 7.7mm–7.9mm and the different value of bridging-section width of circular dumbbell is conducted. The bridging-section width of circular dumbbell for DGS#1, DGS#2, and DGS#3 is 0.3mm, 0.5mm, and 0.3mm respectively, while the length for all is set to be constant at 1.25mm. The result of characterization is depicted in Fig. 5.

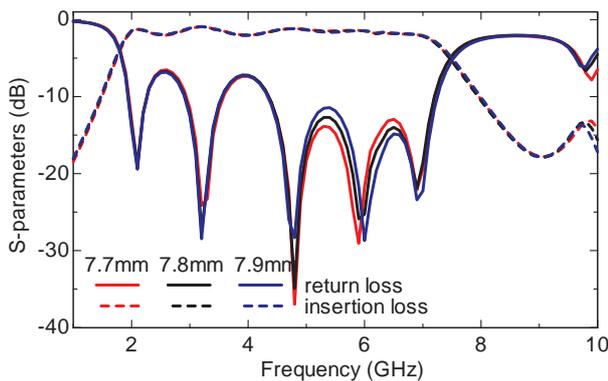


Fig. 5. Characterization result of DGS-based UWB microstrip BPF with the varied separation of DGS and non uniform bridging-section dimension.

From the figure, it shows that the variation of separation between DGS has the similar effect to the variation of radius of circular dumbbell. The similar effect also shows at the lower frequency response which is no discrepancy result. The characteristic response is better at higher frequency bands (6.1–6.9GHz) for the larger distance between DGS but worse for middle frequency bands (4.9–6.1GHz). However, in comparison of 2 results above, the effect of varied radius of circular dumbbell gives more significant change to the characteristics response than the varied distance of DGS. This is probably caused by the lower coupling between the DGS and the filter itself for the larger distance of DGS.

Finally, to demonstrate the enhancement bandwidth, the DGS-based UWB microstrip BPF is characterized with the radius of each circular dumbbell of 1.4mm, separation between DGS of 7.8mm, bridging-section length of 1.25m, and bridging-section width for DGS#1, DGS#2, and DGS#3 of 0.3mm, 0.5mm, and 0.3mm, respectively. The characterization result which is shown in Fig. 6 is plotted together with the characterization result of initial UWB microstrip BPF. It shows that the initial UWB microstrip BPF filter has 3dB bandwidth response up to 4GHz ranges from 2.15GHz to 6.15GHz. The minimum value of insertion loss in passband area is 1.47dB which occurs at 5.54GHz. On the other hand, the maximum value of return loss in passband area is 11.81dB at 2.98GHz. Whilst from the characterization results of proposed DGS-based UWB microstrip BPF, it has 3dB bandwidth response up to 5.36GHz ranges from 1.84GHz to 7.2GHz. In the passband area, the minimum insertion loss is 2.05dB which occurs at 4GHz and the maximum return loss is 6.73dB at 2.6GHz.

From the characterization results, it should be noted that the proposed DGS-based UWB microstrip BPF has the bandwidth response 1.36GHz wider than the initial filter, or in other term, the utilization of DGS can successfully enhance the bandwidth response up to 34% compared to the initial UWB microstrip BPF. The bandwidth enhancement occurs both at the lower and the higher frequency bounds of the DGS-based UWB microstrip BPF, where the lower frequency bound is shifted lower than the lower frequency bound of initial UWB microstrip BPF, as well as the higher frequency bound which is also shifted higher.

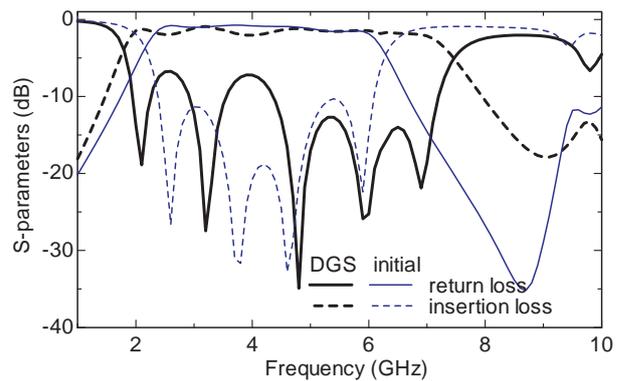


Fig. 6. Characterization result of proposed DGS-based UWB microstrip BPF in comparison with initial UWB microstrip BPF.

On the other hand, the initial UWB microstrip BPF has the lower value of maximum return loss and the higher value of minimum insertion loss compared to the DGS-based UWB microstrip BPF. This can be figured out the utilization of DGS to the initial UWB microstrip BPF has probably changed the characteristic filter type from the Butterworth response in initial filter to the Chebyshev in proposed filter. Due to the change of characteristic, the ripple is discovered in the passband area of proposed filter evokes the change of return loss and insertion loss values.

#### IV. CONCLUSIONS

The bandwidth enhancement of UWB microstrip BPF has been investigated by utilizing DGS on the ground plane surface. The used DGS was constructed of 3 uniformly circular dumbbells. From the characterization results, it has been shown that the variation of some DGS parameters has significant effect but not for all frequency responses at passband area. Hence, from the comparison of characterization results between the initial filter and the proposed DGS-based filter, it has been demonstrated that the utilization of DGS has successfully enhanced the bandwidth response up to 34% from the initial filter of 4GHz 3dB bandwidth response. It has also been shown that the utilization of DGS has probably changed the characteristic of filter, i.e. from Butterworth to Chebyshev, which is indicated by appearance of ripple in the passband area. Although some values of return loss and insertion loss of DGS-based UWB microstrip BPF is not better than the initial one, however, the proposed DGS-based filter has shown an improved and acceptable performance which can be applied for various UWB applications.

#### ACKNOWLEDGEMENT

The authors thank to Dr. M. Ridwan Effendi, School of Electrical Engineering and Informatics, Institut Teknologi Bandung (ITB) for the useful discussion and support.

#### REFERENCES

- [1] D.K. Misra, Radio frequency and microwave communication circuit, John Wiley, Sons Inc., Mar. 2001.
- [2] D.M. Pozar, Microwave engineering, Belmont, New York: John Wiley & Sons, 1998.
- [3] J. Vancl, V. Sokol, P. Cerny, Z. Skvo, "The UWB amplifier 3.1-10.6 GHz," in Proc. of the 14th Conf. on Microwave Techniques (COMITE), Prague, Apr. 2008.
- [4] A. Safarian, L. Zhou, and P. Heydari, P. "CMOS distributed active power combiners and splitters for multi-antenna UWB beamforming transceivers," IEEE Journal of Solid-State Circuits, vol. 42, issue 7, pp. 1481-1491, Jul. 2007.
- [5] K. Ma, K.C. B. Liang, R.M. Jayasuriya, and K.S. Yeo, "A wideband and high rejection multimode bandpass filter using stub perturbation," IEEE Microwave and Wireless Components Letters, vol. 19, no. 1, pp. 24-26, Jan. 2009.
- [6] M.G. Di Benedetto, T. Kaiser, A.F. Molish, I. Oppermann, C. Politano and D. Porcino, UWB communication system A Comprehensive Overview, EUARSIP Book Series on Signal Processing and Communications, New York: Hindawi Publishing Corporation, vol. 5, 2009.
- [7] A.K. Gorur and C.C. Karpuz, "Uniplanar compact wideband bandstop filter," IEEE Microwave Wireless Component Lett., vol. 13, pp. 114-116, Mar. 2003.
- [8] S. Prabhu and J.S. Mandeep, "Microstrip bandpass filter at S band using capacitive coupled resonator," Progress In Electromagnetics Research, PIER 76, pp. 223-228, 2007.
- [9] L. Zhu, S. Sun, and W. Menzel, "Ultra-wideband (UWB) bandpass filters using multiple-mode resonator," IEEE Microwave Wireless Components Lett., vol. 15, no. 11, pp. 796-798, Nov. 2005.
- [10] A. Munir and Y. Prasetyo, "Characterization of ultra wideband bandpass filter with balanced microstrip coupled-lines and dual open stubs perturbation," In Proc. of the 2<sup>nd</sup> Asia Pacific Conference on Antennas and Propagation (APCAP), Chiang Mai, Thailand, Aug. 2013. (to be presented)

# Incorporating Dynamic Constraint Matching into Vertex-based Graph Coloring Approach for University Course Timetabling Problem

Lely Hiryanto

Faculty of Information Technology  
 Tarumanagara University  
 Jakarta, Indonesia  
 lely@fti.untar.ac.id

**Abstract**—University Course Timetabling Problem (UCTP) belongs to Constraint Satisfaction Problems (CSPs), which are the set of objects whose state must satisfy a number of constraints. The constraints, in this case, are related to characteristics and regulations of a particular university. Certainly, these will vary from one university to the other. A number of approaches have provided feasible and optimal solutions for UCTP. However, their solutions are still based certain university's constraints. Our approach has given another way to occupy various constraints for various universities. Dynamic Constraint Matching (DCM) consists of constraints logical formulation, collision matrix generation, and validation using the collision matrix. Our experiment, using 93 subjects offered in Faculty of Information Technology Tarumanagara University, has shown that all constraints, taken from the characteristics and regulations of the Faculty, can be formulated successfully. When DCM were integrated with Vertex Graph Coloring (VGC) as one of the guaranteed optimal solutions for UCTP, the approach results a course schedule that does not contain any hard or soft constraints violations. The processing time can be said fast, which is less than 1 minutes.

**Keywords**—Dynamic Constraint Matching, Vertex-based Graph Coloring, University Course Timetabling Problem, Constraint Satisfaction Problem, Constraint Based Reasoning

## I. INTRODUCTION

UCTP is consisting of allocating a set of subjects within a given domain. UCTP model must accommodate characteristics and regulations of specific university. Certainly, these will vary from one university to the other. These characteristics and regulations define what we call later as constraints in generating a feasible and optimal course schedule.

Corne et.al [1] stated that constraints in UCTP can be classified into five categories:

1. Unary Constraints, involving one event, such as the constraint “event  $a$  must not take place on Tuesday”, or the constraint “event  $a$  must occur in timeslot  $b$ ”,
2. Binary (Event Clash) Constraints, concerning pairs of events, such as the constraint “event  $a$  must take place before event  $b$ , which must take place before  $c$ ”, etc,

3. Capacity Constraints, governed by room capacities, etc. For example, “all events should be assigned to a room which has a sufficient capacity”,
4. Event Spread Constraints, concerning requirements such as the “spreading-out” or “clumping together” of events within the timetable in order to ease student or lecturer workload, and to agree with university timetabling policy.
5. Agent Constraints, imposed in order to promote requirements or preferences of the people who will use the timetables, such as the constraint “lecturer  $x$  likes to teach event  $a$  on Mondays” or “lecturer  $y$  must have  $n$  free mornings per week”.

Constraints can be said to be hard constraints or soft constraints [2]. Hard constraints are those which must be satisfied in order to have a feasible schedule. For example, no lecturer may be scheduled to teach two subjects during the same timeslots. Soft constraints are request that should be fulfilled, if it is not fulfilled, the schedule is still considered feasible provided that all hard constraints have been satisfied. For example, a lecturer may request a particular timeslot free during the week.

There are two different points of view for UCTP [2]. One could assume that a particular set of courses will be offered during a term by particular lecturers, and first assign them times and rooms, and then allow students to register only for courses whose times do not conflict. The second approach would be to decide which courses would be offered, allow students to register for them, and then assign times and rooms to each course, so that the number of students who have course conflicts is minimized. Our research looks at the UCTP from the first point of view.

Based on our observation, characteristic of UCTP, in general, consists of a set of course subjects, a set of constraints and a two-dimensional scheduling domain (timeslots and rooms). Let consider a course subject as an object. Each object has a number of attributes, for example class, lecturer, time slot and room. A University might have other specific attributes which will vary from one university to the others. If we closely observe, a constraint basically defines a logical relationship between two different objects in terms of their attributes. One constraint may involve more than one logical relationship.

Thus, relations of AND and OR can be used to join those relationships. Using these basic ideas, we proposed Dynamic Constraint Matching (DCM) technique for dynamically defining constraints based on any characteristic and regulation of various universities.

Our proposed DCM, currently, focuses more on the Binary (Event Clash) Constraints. This particular constraint can be found in almost all UCTPs, and it presence allows parallels to be drawn with the well-known graph coloring problem [1]. For the Capacity Constraint, which is mainly on the room capacities, is also considered, but directly integrated in our subject-domain allocation step.

Optimization-based scheduling approaches that have lots of attention recently is the meta-heuristics approaches, such as graph coloring, simulated annealing, tabu search, genetic algorithms, and particle swarm optimization [3]. These approaches have been proven to give feasible results. However, if they were implemented alone, near-optimal solution cannot be obtained by them [4][5][6][7]. Some studies have shown that by incorporating constraint based reasoning, a near-optimal solution can be obtained [3].

A Hybrid Genetic Algorithm and Constraint Based Reasoning (GA-CBR) [8][9][10] and A hybrid Particle Swarm Optimization and Constraint Based Reasoning (PSO-CBR) [3] give feasible and near-optimal solution. DCM basically performs the same tasks that CBR do, but in more effective and flexible way. The success of PSO-CBR [3] is our main reference to incorporating DCM into Vertex-based Graph Coloring (VGC). We choose VGC because this technique is simple and guaranteed to provide feasible and optimal solution. However, since the scheduling domain is limited to a number of timeslots and a number of rooms with their own capacities, the solution of VGC still will have some constraint violations. Thus, incorporating the DCM will ensure less to no constraint violation with regard to domain limitation.

The rest of this paper is organized as follows. Section 2 describes more detail DCM. Section 3 discusses the incorporation of DCM into VGC. Section 4 reports and discusses our experimental results. Section 5 concludes in Section 5.

## II. DYNAMIC CONSTRAIN MATCHING (DCM)

DCM consists of three steps. The first step defines logical formulations of constraints. The second step matches the constraints with the attributes' value of two objects and generates a collision matrix. Finally, the third step is validation step that utilizes the collision matrix. This section describes the first two steps. The third step discussed in Section 3.

### A. Constraint Logical Formulation

UCTP, based on CSPs' model, is consisting of the following sets: [1][3]

1. A set of subjects,  $X = \{x_1, x_2, \dots, x_N\}$
2. A set of two-dimensional domain, consisting of timeslots and rooms,  $D = \{d_1, d_2, \dots, d_M\}$
3. A set of constraints,  $C = \{c_1, c_2, \dots, c_L\}$

Each subject,  $x_i$  for  $i = 1, 2, \dots, N$ , consists of a set of attributes or properties,  $A = \{a_1, a_2, \dots, a_K\}$ . In UCTP, these attributes of each subject could be room, timeslot, lecturers, subject's credits, room capacity, semester distribution, and others, depending on the characteristics and regulations of university operational curriculum.

UCTP domain,  $D$ , is viewed by timeslot and room dimensions. One timeslot is equal to one credit of a subject. For example, one credit is equal to one hour, then each timeslot is equal to one hour. So, if in one day, the course time schedule starts from 08.00 to 17.00, then in one day there are nine timeslots. In one week, with five days for face-to-face lectures, the total timeslots is 45 slots. Fig. 1 depicts the data structure of  $D$  in form of matrix. Each element in the matrix is called the position slot. In this case, each subject can take more than one slot. Two subjects are said to be parallel, if their position slots are overlapped. For Room  $r_i$  and Timeslot  $t_j$ , where  $i = 1, 2, \dots, R$  and  $j = 1, 2, \dots, T$ , the slot position index, can be defined using  $d_{(j-1)*R+i}$ .

	Room $r_1$	Room $r_2$	...	Room $r_R$
Timeslot $t_1$	$d_1$	$d_2$		$d_R$
Timeslot $t_2$	$d_{(R+1)}$	$d_{(R+2)}$		$d_{2R}$
.				
.				
Timeslot $t_T$	$d_{(T-1)*R+1}$	$d_{(T-1)*R+2}$		$d_{(T-1)*R+R}$

Fig. 1. UCTP Domain in a Form of a Matrix

Mathematically, a constraint can be defined as follows:

Definition 1: there exist one or more logical relations between subject  $x_i$  for  $i = 1, 2, \dots, N$  and subject  $x_j$  for  $j = 1, 2, \dots, N$  and  $i \neq j$  resulting true relationship, or

Definition 2: subject attribute for  $x_i$ ,  $i = 1, 2, \dots, N$  equal or not equal to certain value, or

Definition 3: combination of Definition 1 and Definition 2.

For example, a lecture cannot teach two subjects in the same time. This constraint is defined in the form of logical formulation as follow:

$$c_q = (x_i, a_k == x_j, a_k), \text{ where } 1 \leq q \leq L$$

Hence,  $a_k$  is assumed as lecture attribute, related to each different subject ( $i \neq j$ ). If  $c_q$  is true, then the relationship of  $x_i$  and  $x_j$  is marked with hard constraint violation value. This is done to prevent the  $x_i$  and  $x_j$  are being placed in the overlapped position slots.

### B. Constraint Matching and Generation of Collision Matrix

Assuming a set of subjects along with their attributes  $X = \{S_1, S_2, \dots, S_N\}$  and a set of related constraints  $C = \{c_1, c_2, \dots, c_L\}$ . If  $S_i$  is a subject  $x_k$  with its defined attributes, it is always possible for  $S_j$  to be a presentation of a subject  $x_k$  having different attributes with  $S_i$ . Collision Matrix consists of values ordered in rows and columns to describe the constraint violation (collision relation) value between  $S_i$  and  $S_j$ . If the value is equal to 0, it means that  $S_i$  and  $S_j$  can be placed in overlapped timeslots. If the value is equal to 1, it means that



possible. The minimum number of colors used is called chromatic number ( $\chi(G)$ ) [11]. There are many VGC algorithms can be used. In this paper, we use *Recursive Largest First* (RLF) algorithm [12] shown in Fig. 7.

A vertex in the graph represents a subject,  $S_i$ . After all vertices have been colored, each color, which will consists of a number of vertices with the same color, will be allocated to position slots in domain  $D$ , with same timeslots but different rooms. Initially, the allocation starts from  $t_1$ , continued until  $t_7$ , and each allocation considers room capacity. If the number of vertices in certain color exceeds the number of rooms, the vertices that cannot be allocated are collected in *unallocated particles* (*unP*). After all vertices have been placed to their positions in  $D$ , randomly, each vertex in *unP* is allocated to  $D$ . The allocation considers the constraints violations and room capacity.

Table I. Constraint Formulation of FTI Untar

Constraints	Logical Formulation	Type of Constraints
The same lecturer cannot teach in the same time	$(S[i].dosen.nik == S[j].dosen.nik)$	Hard Constraints
Single class of subject $S_i$ cannot be scheduled in the same time with other single or parallel class of subject $S_j$ , if $S_i$ and $S_j$ in the same semester distribution.	$(S[i].jenis.id_jenis == 1) \ \&\& \ (S[i].semester.id_sem == S[j].semester.id_sem) \ \&\& \ (S[i].prodi.id_prodi == S[j].prodi.id_prodi)$	Hard Constraints
	$(S[j].semester.id == 1) \ \&\& \ (S[i].semester.id_sem == S[j].semester.id_sem) \ \&\& \ (S[i].prodi.id_prodi == S[j].prodi.id_prodi)$	Hard Constraints
Parallel class of subject $S_i$ cannot be scheduled in the same time with other parallel class of subject $S_j$ , if $S_i$ and $S_j$ have the same class name and semester distribution.	$(S[i].jenis.id_jenis == 2) \ \&\& \ (S[i].semester.id_sem == S[j].semester.id_sem) \ \&\& \ (S[i].kelas.id_kelas == S[j].kelas.id_kelas) \ \&\& \ (S[i].prodi.id_prodi == S[j].prodi.id_prodi)$	Hard Constraints
Single class of subject $S_i$ is better not to be scheduled in the same time with other single or parallel class of subject $S_j$ , if semester distribution of $S_i$ and $S_j$ are different in exactly 1 semester, based on the even or odd period of academic semester.	$(S[i].jenis.id_jenis == 1) \ \&\& \ (S[i].semester.id_sem == 1) \ \&\& \ (S[j].semester.id_sem == 3) \ \&\& \ (S[i].prodi.id_prodi == S[j].prodi.id_prodi)$	Soft Constraints

### I. DISCUSSION

We developed an application to implement the approach. The application is developed using PHP and MySQL. Our experiment uses real data from Faculty of Information Technology Tarumanagara University (FTI Untar). There were 93 subjects offered in period of odd semester in academic year

2012/2013. To run the application to process the data, we used CPU Intel Centrino 1.83GHz Dual Core with 3MB RAM.

	TK12027	TK12026	TK12028	TK12030	TK12031
TK12027	-1	3	0	3	0
TK12026	3	-1	0	3	0
TK12028	0	0	-1	0	1
TK12030	3	3	0	-1	0
TK12031	0	0	1	0	-1

Fig. 8 Example of Collision Matrix of Several Subjects

The implementation of DCM for course scheduling problem in FTI Untar successfully accommodates all its constraints. TABLE I shows the formulation of hard constraints and one example of soft constraints for FTI Untar. Fig. 8 depicts the result portion of Constraint Matching in a form of Collision Matrix. We use logical expression evaluation function of PHP, `eval()`, to implement the Constraint Matching. Fig. 9 shows the screenshot of part of scheduling output resulted from VGC that utilizes the Collision Matrix.

We run VGC for 10 times, and the results show that no hard and soft constraints are violated. Time spend to output the schedule using VGC in average is less than 1 minute. Thus, our DCM incorporation to VGC can provide feasible and optimal solution with fast processing time.

### II. CONCLUSION

We have proposed Dynamic Constraint Matching (DCM) to occupy various constraints of UCTPs and integrate it with Vertex Graph Coloring (VGC) approach. Based our experiment, all constraints, taken from the characteristics and regulations of Faculty of Information Technology Tarumanagara University, can be formulated successfully by DCM. When the formulations were integrated with VGC, the approach results a course schedule that does not contain any hard or soft constraints violations. The processing time can be said fast, which is less than 1 minute. It can be concluded that our approach can provide feasible and optimal solution, with fast processing time.

Next research will take a look at several approaches to optimize the use of available rooms. Current solution although has given feasible and optimal solution in terms of constraints, it still has problem in room distribution. As can be seen from Fig. 9, certain positions of the same timeslots are allocated with just a number of subjects. Some approaches that we are going to consider are heuristic VGC, Particle Swarm Optimization, and Simulated Annealing.

### REFERENCES

- [1] Lewis, R., A Survey of Metaheuristic-based Techniques for University Timetabling Problems, *OR Spectrum* 30 (1), pp. 167-190, 2007.
- [2] Miner, S.K., Elmohamed S., Hon W.Y., Optimizing Timetabling Solution using Graph Coloring, In *Proceeding of NPAC REU program*, 1995.
- [3] Irene, S.F.Ho., Safaai, D., Siti, Z.M.H., Incorporating of Constraint-Based Reasoning Into Particle Swarm Optimization for University Timetabling Problem, *International Journal of Computer Science Letters*, Vol. 1, June, 2009.

- [4] S.C. Chu, Y.T. Chen, dan J.H. Ho, "Timetable Scheduling Using Particle Swarm Optimization", First International Conference on Innovative Computing, Information and Control - Volume III (ICICIC'06), 2006.
- [5] Danial Q.F., Amir N.A., M-Hossein M, Sarah S.R., Ehsan A., dan Javad M., "Finding Feasible Timetables with Particle Swarm Optimization", the 4<sup>th</sup> International Conference on Innovations in Information Technology, pp. 387-391, 2007.
- [6] Hendtlass T., "A Particle Swarm Algorithm for Complex Quantized Problem Spaces", IEEE Congres on Evolutionary Computation Sheraton Vancouver Wall Center Hotel, Volcouver, BC, Canada, July 16 - 21 2006, pp. 1015-1019.
- [7] Irene S.F., Safai D., dan Siti Zaiton M.H., "A Study on PSO-based University Course Timetabling Problem", IEEE 2009 International Conference on Advanced Computer Control (ICACC 2009), Singapore, pp. 648-651.
- [8] Hany T.A.A., "The Development of Reactive Constraint Agents for the Dynamic Timetabling Problem", Faculty of Computer Science & Information System, Unviersity of Technology Malaysia, Master Thesis, 2003.
- [9] Safaai D., Sigeru O., Hiroshi O., dan Puteh S., "Timetable Planning using Constraint-based Reasoning", Computer & Operation Research, 27, 2000, pp. 819 - 840.
- [10] Zalmyia Z., "Case-based Reasoning Approach for Reactive Timetabling", Faculty of Computer Science and Information System, University of Technology Malaysia, Master Thesis, 2001.
- [11] Welsh, D.J.A and Powell, M.B., An Upper Bound for the Chromatic Number of a Graph and It's Application to Timetabling Problems, Comp. Journal 10, 1967.
- [12] Leighton, F. T., A Graph Coloring Algorithm for Large Scheduling Problems, Journal of Research of the National Bureau of Standards, 84, pp. 489-505, 1979.

Waktu/Ruang	R701	R702	R703	R704	R705	R706	R801	R802	R803	R804	R805	R806
Monday (08.00-09.00)	TK12023(A)	SI23012(A)	TK44325(A)	TK44144(A)	SI24172(A)	SI15061(A)	TK33101(A)	TK33334(A)	TK44245(A)	TK44301(A)		
Monday (09.00-10.00)	TK12023(A)	SI23012(A)	TK44325(A)	TK44144(A)	SI24172(A)	SI15061(A)	TK33101(A)	TK33334(A)	TK44245(A)	TK44301(A)		
Monday (10.00-11.00)				TK44144(A)	SI24172(A)			TK33334(A)	TK44245(A)			
Monday (11.00-12.00)					SI24172(A)			TK33334(A)				
Monday (12.00-13.00)	TK44173(A)	SI14071(A)	TK12092(A)	SI23012(B)	TK13012(B)	TK23122(B)	TK44231(A)	SI12021(A)	SI14173(A)	TK12016(C)	TK34013(A)	TK12027(A)
Monday (13.00-14.00)	TK44173(A)	SI14071(A)	TK12092(A)	SI23012(B)	TK13012(B)	TK23122(B)	TK44231(A)	SI12021(A)	SI14173(A)	TK12016(C)	TK34013(A)	TK12027(A)
Monday (14.00-15.00)	TK44173(A)	SI14071(A)			TK13012(B)	TK23122(B)		TK33206(A)			TK34013(A)	
Monday (15.00-16.00)	TK23132(A)	SI15201(A)	TK12042(B)	SI15261(A)				TK33206(A)				
Monday (16.00-17.00)	TK23132(A)	SI15201(A)	TK12042(B)	SI15261(A)				TK33206(A)				
Tuesday (08.00-09.00)	TK44173(B)	SI12301(A)	TK23122(A)	TK44411(A)	TK12016(A)	TK12082(B)	TK12042(C)	SI15031(A)	TK34013(B)			
Tuesday (09.00-10.00)	TK44173(B)	SI12301(A)	TK23122(A)	TK44411(A)	TK12016(A)	TK12082(B)	TK12042(C)	SI15031(A)	TK34013(B)			
Tuesday (10.00-11.00)	TK44173(B)	SI12301(A)	TK23122(A)			TK12082(B)			TK34013(B)			
Tuesday (11.00-12.00)	TK33232(A)	SI23072(A)	TK33203(B)	TK44415(A)	TK12042(A)	TK12016(B)	SI14121(A)					
Tuesday (12.00-13.00)	TK33232(A)	SI23072(A)	TK33203(B)	TK44415(A)	TK12042(A)	TK12016(B)	SI14121(A)					
Tuesday (13.00-14.00)	TK33232(A)	SI23072(A)										
Tuesday (14.00-15.00)		SI23072(A)										TK13012(A)
Tuesday (15.00-16.00)	SI12031(A)											TK13012(A)
Tuesday (16.00-17.00)	SI12031(A)											TK13012(A)
Wednesday (08.00-09.00)	TK33292(A)	TK44132(B)	SI13036(A)	TK44321(A)	TK44382(A)							
Wednesday (09.00-10.00)	TK33292(A)	TK44132(B)	SI13036(A)	TK44321(A)	TK44382(A)							
Wednesday (10.00-11.00)	TK33292(A)	TK44132(B)	SI13036(A)		TK44382(A)							
Wednesday (11.00-12.00)	TK33292(B)	TK44132(A)	SI13011(A)	SI23074(A)	TK44333(A)	TK44327(A)						
Wednesday (12.00-13.00)	TK33292(B)	TK44132(A)	SI13011(A)	SI23074(A)	TK44333(A)	TK44327(A)						
Wednesday (13.00-14.00)	TK33292(B)	TK44132(A)	SI13011(A)									
Wednesday (14.00-15.00)	TK23143(A)	TK23143(B)	SI14171(A)	TK33153(A)	SI23081(A)	TK44251(A)						
Wednesday (15.00-16.00)	TK23143(A)	TK23143(B)	SI14171(A)	TK33153(A)	SI23081(A)	TK44251(A)						
Wednesday (16.00-17.00)	TK23143(A)	TK23143(B)	SI14171(A)									
Thursday (08.00-09.00)	TK44242(A)	TK44242(B)	SI24041(A)	SI23031(A)	TK33153(B)	TK44421(A)	TK43362(A)					
Thursday (09.00-10.00)	TK44242(A)	TK44242(B)	SI24041(A)	SI23031(A)	TK33153(B)	TK44421(A)	TK43362(A)					
Thursday (10.00-11.00)	TK44242(A)	TK44242(B)	SI24041(A)	SI23031(A)		TK44421(A)	TK43362(A)					
Thursday (11.00-12.00)	TK12044(A)	TK13114(B)	SI14082(A)	SI13034(A)	TK44431(A)	TK13012(C)						
Thursday (12.00-13.00)	TK12044(A)	TK13114(B)	SI14082(A)	SI13034(A)	TK44431(A)	TK13012(C)						
Thursday (13.00-14.00)			SI14082(A)			TK13012(C)						

Fig. 9. Screenshot of Part of Scheduling Output

# Handwritten Word Segmentation Using Kaiser Window

Linggo Sumarno

Faculty of Science and Technology  
Sanata Dharma University  
Yogyakarta, Indonesia  
E-mail : lingsum@usd.ac.id

**Abstract**—In the field of handwritten word recognition field, word segmentation into letters is an approach that could be used. Using this approach, word segmentation would be a complicated task, especially when dealing with a cursive handwritten word. A simple method in word segmentation called oversegmentation could be used. This paper discusses a simple method using Kaiser window. In general, the word segmentation process in this paper can be described as follow: Input - Preprocessing - Segmentation - Output. The input is an image of isolated handwritten word in binary format, while the output is images of letter segment. The main purpose of preprocessing is to correct slant and slope. This preprocessing is necessary since the segmentation method used is sensitive with slant and slope. The main purpose of segmentation is to divide a word into some letter segments. Based on a subjective test result, it was shown that the minimum parameters for the Kaiser window that can be used effectively for oversegmentation are 8 points in window's length and 10 in beta value. As its window's length is getting longer and its beta value is getting bigger, it can also be used effectively for oversegmentation. However, it must be noted that if the letter size is getting bigger, there will be more letter segments resulted.

**Keywords**— Handwritten word, segmentation, Kaiser window

## I. INTRODUCTION

In the field of handwritten word recognition, recognizing a word by means of letter-by-letter recognition is a way that can be carried out. If the word is written in handprinted style, the word recognition will be simple, since the segmentation of the letters is obvious. However, if it is written in cursive style, the word recognition will be difficult, since the segmentation of the letters is not obvious. This difficulty is in line with Sayre's Paradox [1]: a word cannot be segmented before being recognized and cannot be recognized before being segmented.

According Bunke [2], segmentation is a process by which a given word was segmented into smaller entities. Before that, in line with Bunke, Bozinovic and Srihiari [3] have proposed a simple segmentation approach using possible segmentation points, which results the number of entities that greater than the number of letters in a word image, that called oversegmentation.

A simple method in oversegmentation can be carried out by dividing a word image uniformly, as proposed by Senior [4]. However, it tends to produce too many segments.

Sumarno [5] has proposed a simple method in oversegmentation that divides a word image not uniformly, which based on vertical projection histogram, by using stationary wavelet. However, since the stationary wavelet can only process the input that has  $2^n$  in length, so, it is less practical. Sumarno *et al* [6] have proposed another variation of oversegmentation that divides a word image not uniformly, which based on vertical projection histogram, by using a Gaussian filter. By using this filter, the segmentation results were similar with the stationary wavelet, but it was more practical since it have no  $2^n$  limitation.

A Kaiser window [7] is a window that usually used in the design of FIR filters and spectrum analysis. If a Kaiser window is convoluted with a signal, so, the detail components of the signal will be reduced. On the other hand, a Kaiser window can be used as a low pass filter.

This paper proposes a new variation in handwritten word segmentation, which based on vertical projection histogram, by using Kaiser window. The segmentation method that will be discussed is the oversegmentation that divides a word image not uniformly.

## II. THEORY

### A. Segmentation

A simple strategy of segmentation is to use of explicit segmentation based on the dissection. In this strategy, a word image is divided into letter segments where the number of segments is equal to or greater than the number of letters in the image, without analyzing the class information or the shape of the letters. If the number of letter segments is greater than the number of letters in the word image, the segmentation is called oversegmentation. According Bunke [2], in oversegmentation there are some rules as follow.

- The image of a letter that occurs within a word may be broken into several segments.
- Merging two adjacent letters into the same segment must be avoided.
- Merging parts of two adjacent letters into the same segment must be avoided.

A strategy in explicit segmentation based on the dissection is to use vertical projection histogram of a word image. For example, Fig. 1(b) shows the shape of the histogram “hills” that represent the letter segments of the word image of Fig. 1(a). As a hypothesis, if the basic shape of the histogram hills can be made more obvious, the separation of letter segments can be made easier. The shape of the histogram hills in Fig. 1(b) still shows the rough shape (i.e. its basic shapes are less obvious), since there are details components shown. In order to make its basic shapes more obvious, a low pass filter is needed to remove the detail components. According Sumarno *et al* [6], a low pass filter for that purpose should have the following properties.

- It must be able to remove many detail components.
- It must be able to maintain histogram hills, which represent letter segments. On the other hand, it must have high localization property.

As shown in Fig. 1(c), the detail components have been removed by using a low pass filter. Fig. 1(d) shows the vertical lines that indicate the local minimum places. Finally, Fig. 1(e) shows the segmentation result where the segmentation places are based on the local minimum places.

### B. Kaiser Window

Kaiser window  $w(n)$  with the length  $N$  is defined by

$$w(n) = \begin{cases} \frac{I_0(\beta) \sqrt{1 - ((n - 0.5N)/(0.5N))^2}}{I_0(\beta)}, & 0 \leq n \leq N \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

where  $I_0(\cdot)$  is the zero-th order Modified Bessel function of the first kind, which can be computed using

$$I_0(x) = 1 + \sum_{k=1}^{\infty} \left[ \frac{(0.5x)^k}{k!} \right]^2 \quad (2)$$

### C. Convolution

As described above, the Kaiser window can be used as a low pass filter. Low pass filtering of the signal  $x(n)$  with a Kaiser window  $w(n)$  is the convolution process between  $x(n)$  with  $w(n)$ . Since the signal  $x(n)$  has finite length, there will be distortion at the edges of filtering results. In order to overcome that problem, Misiti *et al* [8] have proposed a method by lengthening the signal  $x(n)$  by means of signal repetition which called periodization. For example  $x(n) = \{x(1), x(2), \dots, x(M)\}$  is the signal to be convoluted with Kaiser window  $w(n) = \{w(1), w(2), \dots, w(N)\}$ , where  $N$  is an even number, and  $M > N$ , so the signal repetition by means of periodization will be

$$x_{per}(n) = \{x(M - n + 1), \dots, x(M), x(1), \dots, x(M), x(1), \dots, x(N - 1)\} \quad (3)$$

The convolution of lengthen signal  $x_{per}(n)$  with Kaiser window  $w(n)$  will give output signal

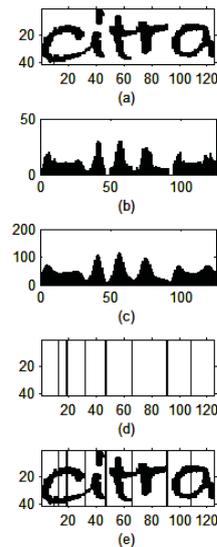


Fig. 1. An example of segmentation using vertical projection histogram; (a) Input image; (b) Vertical projection histogram; (c) Filtering result using Kaiser window 12 points with  $\beta$  value 10; (d) Vertical lines that indicate local minimum places; (e) Segmentation result. (Notes: Vertical and horizontal axes units are in pixels)

$$y(n) = x_{per}(n) * h(n) \quad (4)$$

or

$$y(n) = \sum_j x_{per}(j) h(n+1-j) \quad (5)$$

where the length of  $M+N-1$  is greater than the length of  $x(n)$ . In order that the output signal has the same length with the input signal, so, only the certain parts of the output signal are selected. For example, the output of the convolution above is  $y(n) = \{y(1), y(2), \dots, y(L)\}$ , where  $L=M+N-1$ , so, the selected certain parts of  $y(n)$  are

$$y_{keep}(n) = \{y(N+1), \dots, y(N+M)\} \quad (6)$$

## III. RESEARCH METHODOLOGY

### A. Materials and Equipments

Materials in this research were isolated handwritten word images in binary format. These materials came from the data acquisition sheets scanned at a resolution of 300 dpi. Data were taken from 10 writers from different ages and genders. They wrote the word “citra” as they usually write, i.e. handprinted, cursive, or mixed handprinted and cursive styles. Equipment in this research was a set of computer based on Intel processor Core2Duo E7500 (2,93GHz) and 2GB of RAM, which equipped with MATLAB software.

### B. System Development

By using materials and equipments above, a handwritten word segmentation system has been developed (see Fig. 2). In this system, the input is an image of isolated handwritten word in binary format, while the output is images of letter segment.

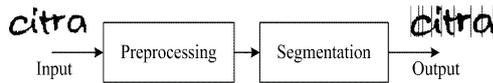


Fig. 2. A word segmentation system.

The main purpose of preprocessing is to correct slant and slope of the input image. This preprocessing is necessary since the segmentation process that uses vertical projection histogram is sensitive with slant and slope variation [6].

### C. Preprocessing

Preprocessing steps in Fig. 2 are shown in Fig. 3 [6]. The slope and slant corrections are carried out by using the linear transform for shearing. See Halmos [9] for the detail of the linear transform. The slope and slant corrections will make the image template become bigger than its image. (Note: for the word image input, the image and its template have the same size). To overcome this, a cutting according to bounding box was applied.

The slope and slant correction in Fig. 3 are carried out sequentially by simultaneous slant correction method, as proposed by Slavik & Govindaraju [10]. Fig. 4 [6] shows the slant correction steps for the slope and slant correction. By using this method, first, slope correction using the horizontal projection histogram carried out. Then, followed by slant correction using the vertical projection histogram. Determining of shearing coefficient  $k_s$  is carried out by searching a highest variance value in the vertical/horizontal projection histogram. See TABLE I.

### D. Segmentation

Segmentation steps are shown in Fig. 5 [6]. Low pass filtering is a convolution process between Kaiser window and vertical projection histogram, which has undergone periodization (see equations (3) to (6)). Letter segments cutting are a cutting of the input image in order to get letter segment images. The cutting places are based on the places of the local minimums in the vertical projection histogram that has undergone low pass filtering. An example of the segmentation steps is shown in Fig. 1.

## IV. RESULTS

### A. Segmentation results on various Kaiser window parameters

Segmentation results on various Kaiser window parameters, for an example of the word "citra", shown in Fig. 6 and 7. It can be shown in Fig. 6 and 7, for all Kaiser

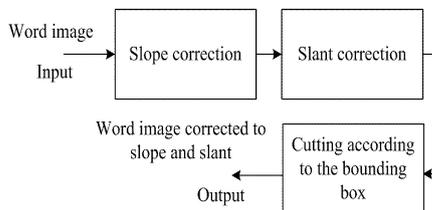


Fig. 3. Preprocessing steps.

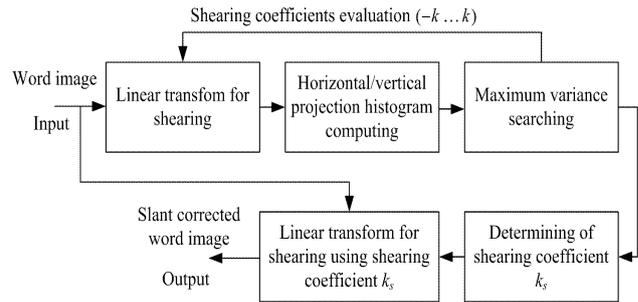


Fig. 4. Slant correction steps.

TABLE I. PARAMETERS FOR SLOPE AND SLANT CORRECTIONS.

Correction	Parameters
Slope	Shearing coefficient values for the evaluation of horizontal projection histogram at slope correction $\{-0.2, -0.15, \dots, 0.2\}$ . In this case it is assumed that the slope of horizontal projection histogram is in the range of $-0.2 \dots 0.2$ .
Slant	Shearing coefficient values for the evaluation of vertical projection histogram at slant correction $\{-0.4, -0.35, \dots, 0.4\}$ . In this case, it is assumed that the slope of vertical projection histogram is in the range of $-0.4 \dots 0.4$ .

windows with  $\beta$  value 0 and also with window's length 4 points, the segmentation results show parts of letter "c" and "i", or "i" and "t", or "r" and "a" are in the same segment. It means segmentation errors have been occurred, since they do not follow the oversegmentation rules [2].

As shown in Fig. 6 and 7, in order that oversegmentation can be effectively carried out, the minimum parameters of Kaiser window are 8 points in length and 10 in  $\beta$  value. As its window's length is getting longer and its  $\beta$  value is getting bigger, the oversegmentation can also be effectively carried out. In summary, the segmentation results from Fig. 6 and 7 can be seen in TABLE 2.

### B. Segmentation results on various writing styles and sizes

The segmentation results on various writing styles and sizes of 10 words of "citra" which uses a sample of 12 points Kaiser window with  $\beta$  value 10 shown in Fig. 8(a). As a note, the 10 words came from 10 writers who wrote as they usually write. For comparison, segmentations results for the same 10 words of "citra", which uses 16 points Gaussian filter with standard deviation 4 which proposed by Sumarno *et al* [6] are shown in Fig. 8(b). As shown in Fig. 8(a) and 8(b), no segmentation errors occurred since they follow the oversegmentation rules.

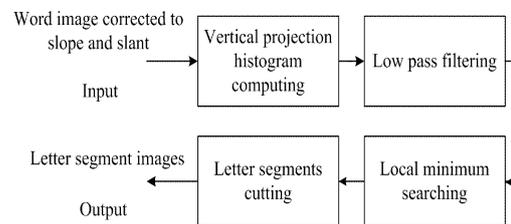


Fig. 5. Segmentation steps.



Fig. 6. Segmentation results on various parameters of Kaiser window; (a) – (f) Length: 4 points,  $\beta$  values: 0, 10, 20, 40, 80, and 160 respectively; (g) – (l) Length: 8 points,  $\beta$  values: 0, 10, 20, 40, 80, and 160 respectively; (m) – (r) Length: 12 points,  $\beta$  values: 0, 10, 20, 40, 80, and 160 respectively; (s) – (x) Length: 16 points,  $\beta$  values: 0, 10, 20, 40, 80, and 160 respectively. (Notes: Vertical and horizontal axes units are in pixels)

## V. DISCUSSIONS

As shown in Fig. 6 and 7 there are three tendencies that started from 8 points window's length. First, if  $\beta$  value is getting bigger, it will lower the occurrence of segmentation errors. As an example, from Fig. 7(s) – 7(x), if  $\beta$  value is getting bigger, the occurrence of segmentation error will be lower. This one indicates that the histogram hills localization is getting lower, since the number of detail components in the vertical projection histogram that removed also getting lower. Therefore, basic shapes of letter entities which represented by histogram hills become more unobvious (since too many component details), so that, the separation between letter entities become more obvious.

TABLE 2. SUMMARY OF THE SEGMENTATION RESULTS FROM FIG. 6 AND 7.

$\beta$	Window's length							
	4	8	12	16	20	24	28	32
0	x	x	x	x	x	x	x	x
10	x	√	√	x	x	x	x	x
20	x	√	√	√	x	x	x	x
40	x	√	√	√	√	√	x	x
80	x	√	√	√	√	√	√	√
160	x	√	√	√	√	√	√	√

Notes: a. "x" indicates there are segmentation errors.  
 b. "√" indicates there are no segmentation errors.

Second, if window's length is getting longer, it will raise the occurrence of segmentation errors. As an example, from Fig. 6(h), 6(n), 6(t), and 7(b), if window's length is getting longer, the occurrence of segmentation error will be raise. This one indicates that the histogram hills localization is getting higher, since the number of detail components in the vertical projection histogram that removed also getting higher. Therefore, basic shapes of letter entities which represented by histogram hills become more unobvious, so that, the separation between letter entities become more unobvious also.

Third, if window's length is getting longer and  $\beta$  value is getting bigger, there is no segmentation errors occurred. As an example, from Fig. 6(n), 6(u), 7(d), and 7(k), if window's length is getting longer and  $\beta$  value is getting bigger, there is no occurrence of segmentation errors. This one indicates that the histogram hills localization can be maintained (not too high nor too low), since the number of detail components in the vertical projection histogram that removed can also be maintained. Therefore, basic shapes of letter entities which represented by histogram hills can be maintained obvious, so that, the separation between letter entities can also be maintained obvious.



Fig. 7. The Segmentation results on various parameters of Kaiser window; (a) – (f) Length: 20 points,  $\beta$  values: 0, 10, 20, 40, 80, and 160 respectively; (g) – (l) Length: 24 points,  $\beta$  values: 0, 10, 20, 40, 80, and 160 respectively; (m) – (r) Length: 28 points,  $\beta$  values: 0, 10, 20, 40, 80, and 160 respectively; (s) – (x) Length: 32 points,  $\beta$  values: 0, 10, 20, 40, 80, and 160 respectively. (Notes: Vertical and horizontal axes units are in pixels)

A summary of the segmentation results in TABLE 2 are come from a subjective test results, since they only use one writing variety of the word "citra". In order to get a more objective test results, the segmentation needs to be tested on even more writing variety of the word "citra". However, if the segmentation results were observed visually, it would be impractical, since we have to observe it one by one. Therefore, in order to make it more practical, it is not done visually, but by observing the results of the recognition rate of the whole handwritten word recognition. It can be assumed that at the highest recognition rate, the number of segmentation errors is the lowest. Milewski [11] has shown an example of recognizing a word by means of character segment by character segment, which made use of a graph.

Fig. 8(a) and (b) show the segmentation results of the 12 points Kaiser window with  $\beta$  value 10 and the 16 points Gaussian filter with standard deviation 4 respectively. They can be used effectively to segment nine various writing styles and sizes of the word "citra", since there are no segmentation errors. However, Fig. 8(a5), (a8), and (a10) show one additional segment compared to Fig. 8(b5), (b8), and (b10) respectively, which indicates that 12 points Kaiser window with  $\beta$  value 10 a bit worse than 16 points Gaussian filter with standard deviation 4. This case shows that if it is compared with Kaiser window, the Gaussian filter is a bit more able to conserve "small hills" at vertical projection histogram, which represent character entities.

In general, Fig. 8 shows that if the letter size is getting bigger there will be more letter segments resulted. For example, at Fig. 8(a9), (a10), (b9), and (b10), a low pass filtering that made use of the 12 points Kaiser window with  $\beta$  value 10 and also the 16 points Gaussian filter with standard deviation 4 were not "strong" enough to smooth the "big hills" at projection histogram which represent character entities, so that, more letter segments are resulted. Therefore, in order to deal with the letter sizes it is suggested to introduce some size correction steps in the segmentation system.

## VI. CONCLUSION AND SUGGESTION

Based on what has been described above, it can be concluded the following.

- Based on the subjective test result, it was shown that the minimum parameters for the Kaiser window that can be used for oversegmentation effectively are 8 points in window's length and 10 in  $\beta$  value.
- For the Kaiser window, as the window's length is getting longer and its  $\beta$  value is getting bigger, it can also be used for oversegmentation effectively.
- If the letter size is getting bigger, there will be more letter segments resulted.

Here are some suggestions to further develop the segmentation system.

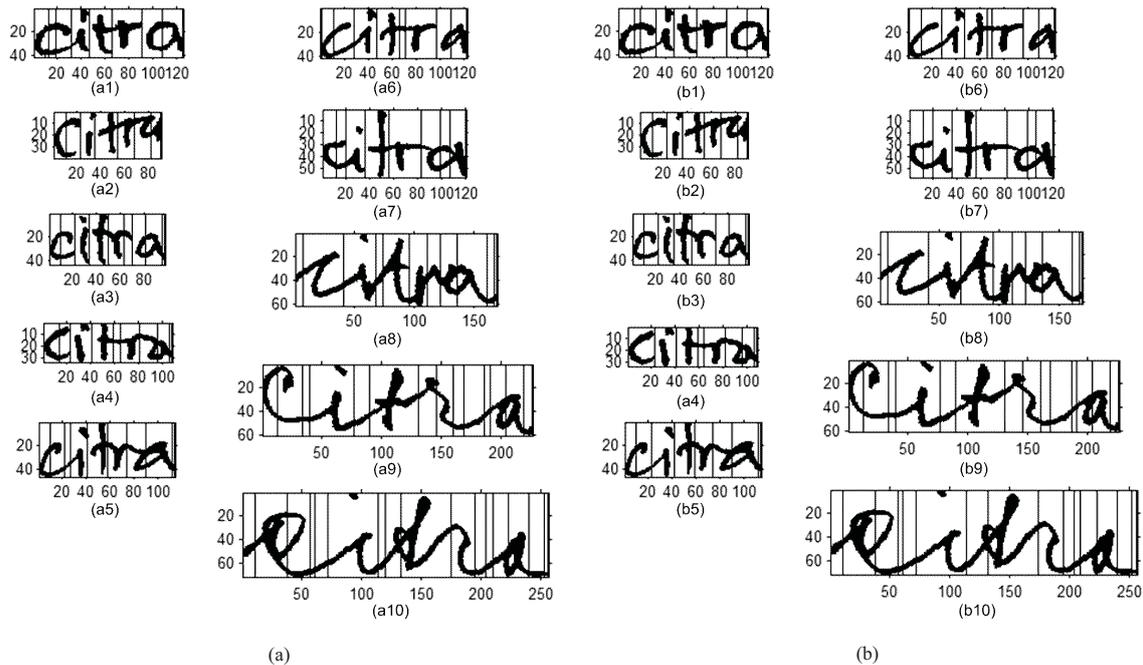


Fig. 8. Segmentation results for 10 writing styles and sizes of "citra"; (a) Using 12 points Kaiser window with  $\beta$  value 10; (b) Using 16 points Gaussian filter with standard deviation 4. (Notes: Vertical and horizontal axes units are in pixels)

- In order to obtain a more objective segmentation results, it is necessary to test more writing varieties and sizes of the word "citra" and for other words.
- In order to be more practical, it is suggested that the segmentation results are observed by observing the results of the recognition rate of the handwritten word recognition, which is the next process after the process of segmentation.
- In order to deal with the letter sizes it is suggested to introduce some size correction steps in the segmentation system.

#### REFERENCES

- [1] K. Sayre, "Machine Recognition of Handwritten Words: A Project Report", *Pattern Recognition*, vol. 5, no. 3, pp. 213-228, 1973.
- [2] H. Bunke, "Recognition of Cursive Roman Handwriting – Past, Present and Future", *Proceeding of 7<sup>th</sup> International Conference on Document Analysis and Recognition*, pp. 448-459, 2003.
- [3] R. M. Bozinovic and S.N. Srihari, "Off-Line Cursive Word Recognition", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 11, pp. 68 – 83, 1989
- [4] A. W. Senior, *Off-line Cursive Handwriting Recognition using Recurrent Neural Networks*, PhD Thesis, Cambridge: Cambridge University, 1994, unpublsh.
- [5] L. Sumarno, "Handwritten word segmentation using wavelet" (in Indonesian), *Compile*, vol. 1, no. 1, pp. 80-87, 2008.
- [6] L. Sumarno, A. Susanto, and J.E. Istiyanto, "Handwritten word segmentation using 1D Gaussian filter" (in Indonesian), *Sigma*, vol. 12, no. 2, pp. 179-189, 2009.
- [7] J. F. Kaiser, "Nonrecursive Digital Filter Design Using the Io-sinh Window Function", *Proceeding of IEEE Symposium of Circuits and Systems*, pp.20-23, 1974.
- [8] M. Misiti, Y. Misiti, G. Oppenheim, J.-M. Poggi, 2005, *Wavelet Toolbox: For Use with MATLAB, Version 3*, Massachusetts: The Mathworks Inc., 2005.
- [9] P. R. Halmos, *Finite-Dimensional Vector Spaces*. Springer-Verlag, 1993.
- [10] V. Slavik, and V. Govindaraju, "Equivalence of Different Methods for Slant and Skew Corrections in Word Recognition Applications", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 3, no. 3, pp. 323-326, 2001.
- [11] R. J. Milewski, *Automatic Recognition of Handwritten Medical Forms for Search Engines*, PhD Thesis, New York: University of New York, 2006, unpublsh.

# Green House Monitoring and Controlling Using Android Mobile Application

Aji Hanggoro  
 Electrical Engineering Department  
 University of Indonesia  
 Depok, Indonesia  
 aji.hanggoro@ui.ac.id

Mahesa Adhitya Putra  
 Electrical Engineering Department  
 University of Indonesia  
 Depok, Indonesia  
 mahesa.adhitya91@ui.ac.id

Rizki Reynaldo  
 Electrical Engineering Department  
 University of Indonesia  
 Depok, Indonesia  
 rizki.reynaldo@ui.ac.id

Riri Fitri Sari  
 Electrical Engineering Department  
 University of Indonesia  
 Depok, Indonesia  
 riri@ui.ac.id

**Abstract-** The existing system has the ability to yet lack the ability to control indoor humidity. Green House Monitoring and Controlling is a complete system designed to monitor and control the humidity inside a green house. This software uses an Android mobile phone, connected using Wifi to a central server which connects via serial communication to a microcontroller and humidity sensor. The result shows that the condition specified in sensor's datasheet and system in reality is appropriate. The achieved test result concludes that the system is working properly.

**Keyword:** green house, arduino uno, wireless network, embedded system, SHT 11 sensor

## I. INTRODUCTION

Green house farmers cannot precisely detect level of level of humidity inside the green house. They only know the condition inside the green house manually and by feel it by themselves. Ultimately, experiences play a bigger part on their daily operations. If the condition is too dry, they will give water to the plants or soil, but if it is too humid, they will open the rooftop of the green house, especially in the daylight.

In designing this device, there is limitation to problems, to see how far this system can do its tasks. This limitation according to the situation where this system will be used later. The limitation is the system can detect the humidity of air in the building. When the humidity sensor reach a certain threshold, the humidity sensor will send a signal to microcontroller which will then process the signal, to be sent into connected computer. Computer functions as a server which connects to the android platform.

There are 3 kinds of activity that are designed in the system. First, monitor the humidity level in

the green house. Secondly, if the green house is too dry, the water sprayer can be activated, to increase the humidity level. It also can deactivated water sprayer. Third, if the green house is too humid, the rooftop can be opened to lower the humidity level. The third function can be use to open or close the rooftop based on the needs.

## II. DESIGN OF GREEN HOUSE MONITORING AND CONTROLLING SYSTEM

This embedded system for monitoring and controlling the green house is based on measuring the humidity and temperature by sensor that located at different places. The monitoring and controlling is conducted through Android Smartphone.

### A. Hardware Description

Design of hardware for green house monitoring and controlling are used to control the environment condition of green house to get a good condition. The parameters are humidity and temperature in the greenhouse. The monitoring and controlling of greenhouse component consists of sensor for the humidity, Arduino UNO microcontroller, serial communication, wireless connection, LED module change for water sprayer, stepper motor, model of greenhouse, personal computer as server, and power supply unit. The output for the sensor become an input to microcontroller and sent to computer through serial communication. The task of the computer is to transfer the data through wireless communication to application software at Android Smartphone. The task of the Android Smartphone to control the microcontroller and the components, such as, LED module and stepper motor, sent to the computer.

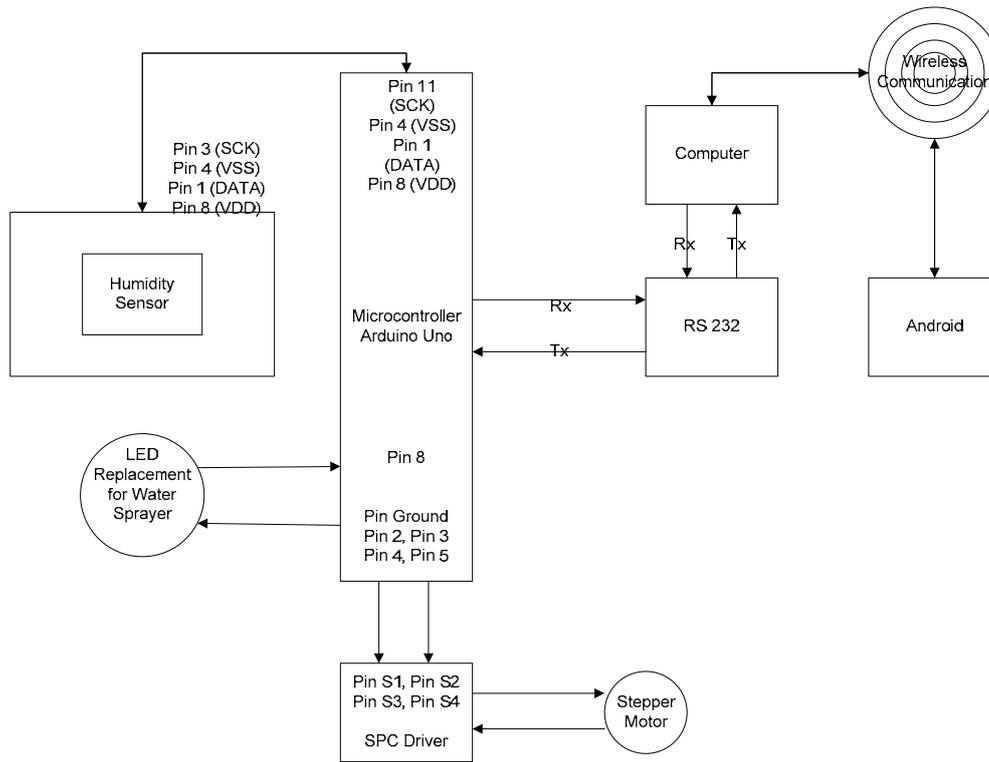


Figure 1. Schematic Diagram Showing The Green House Monitoring and Controlling System

The microcontroller will read the sensor periodically and updates the value of sensor to android. Figure 1 show the schematic diagram of greenhouse monitoring and controlling system.

### B. Software Description

The software is designed to process the humidity value, monitoring and controlling the green house. The software includes the various measurements of the sensor, analog to digital converters, send humidity value from sensor to microcontroller. Then continue to display the value in application at Android, control the microcontroller from the application in Android and update to user by sending the value of sensor for monitoring the green house. The microcontroller Arduino UNO is to convert analog to digital, send the value of sensor through serial communication to PC, control the stepper motor, water sprayer, and updating the user. The program is written in Arduino 1.0.1 IDE. The server used to process the value from the sensor, serial, and wireless communication by PHP serial programming and PHPmyadmin to transfer and receive the input for controlling and output for monitoring.

The hardware system is divided into 3 part. There are microcontroller arduino, a sensor, and IEEE wireless 802.11g. The microcontroller arduino used for monitoring and controlling the green house. It is used to read the measurement value of sensor, write an input to control the stepper motor and LED module, analog-digital converter and serial communication for the flow of value from sensor. First, microcontroller get the analog voltage signal from the sensor and convert it to digital signal. After microcontroller receive the digital signal, microcontroller send the value from sensor to the Android via computer through serial communication and wireless connection.

(PCINT14/RESET) PC6	1	28	PC5 (ADC5/SCL/PCINT13)
(PCINT16/RXD) PD0	2	27	PC4 (ADC4/SDA/PCINT12)
(PCINT17/TXD) PD1	3	26	PC3 (ADC3/PCINT11)
(PCINT18/INT0) PD2	4	25	PC2 (ADC2/PCINT10)
(PCINT19/OC2B/INT1) PD3	5	24	PC1 (ADC1/PCINT9)
(PCINT20/XCK/T0) PD4	6	23	PC0 (ADC0/PCINT8)
VCC	7	22	GND
GND	8	21	AREF
(PCINT6/XTAL1/TOSC1) PB6	9	20	AVCC
(PCINT7/XTAL2/TOSC2) PB7	10	19	PB5 (SCK/PCINT5)
(PCINT21/OC0B/T1) PD5	11	18	PB4 (MISO/PCINT4)
(PCINT22/OC0A/AIN0) PD6	12	17	PB3 (MOSI/OC2A/PCINT3)
(PCINT23/AIN1) PD7	13	16	PB2 (SS/OC1B/PCINT2)
(PCINT0/CLKO/ICP1) PB0	14	15	PB1 (OC1A/PCINT1)

### III. HARDWARE SYSTEM

#

#

Figure 2. Architecture of AT MEGA 328 for Microcontroller Arduino[1]

The reading program, the converter and also program to controlling is done in C Language for Arduino. The value from read the sensor, analog to digital converter, and for controlling is done in Microcontroller Arduino that use AT MEGA 328. Figure 2 shows the architecture of AT MEGA 328.

For sensor we use SHT 11 to measure humidity and temperature. This sensor is interfaced to the stamp over two I/O pins. Through a two-wire serial interface, both temperature and humidity can be read with excellent response time and accuracy. Figure 3 shows the module of SHT 11 sensor: [4]

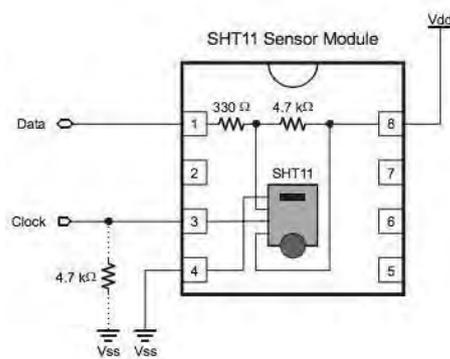


Figure 3. SHT 11 Sensor Module [2]

Each SHT 11 is individually calibrated in a precision humidity chamber from the manufacturer. The calibration coefficients are programmed into an OTP memory on the chip. These coefficients are used to internally calibrate the signals from the sensors. The 2 wire serial interface and internal voltage regulation allows for easy and fast system integration. SHT 11, for which datasheet applies-features a version 4 Silicon sensor chip. Besides the humidity and temperature sensors the chip contains an amplifier, A/D converter, OTP memory and a digital interface. Dimensions in mm (1mm = 0,39 inch). The type of sensor is SHT 11 and contacts are assigned as follows: 1:GND, 2:DATA, 3:SCK, 4:VDD.[5]

The features of SHT 11 sensor are:

- Temperature range: -40° Fahrenheit (-40° to +254,9°F (123,8°C)
- Temperature accuracy: +/- 0,5°C - 25°C
- Humidity Range: 0 to 100 %RH
- Low power consumption (typically 30W) [3]

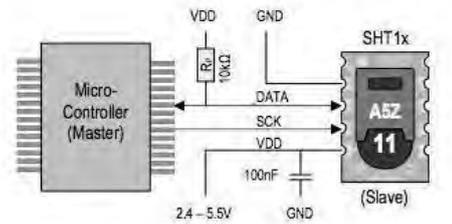


Figure 4. Schematic of SHT 11 Wire to Microcontroller [2]

Because the sensor built in resistors, the pins that should be connected,

- SHT-11 PIN 3 (SCK) -> Arduino PIN 11 (SCK)
- SHT-11 PIN 4 (VSS) -> Arduino's Ground
- SHT-11 PIN 1 (DATA) -> Arduino PIN 9 (data)
- SHT-11 PIN 8 (VDD) -> Arduino +5V

Arduino is process signal from this sensor, where the result will take in the right value. In this sensor, there is a LED to show whether the sensor is on or off.

For wireless transfer, we use IEEE 802.11g-2003 or 802.11g or Wireless G is an amendment to the IEEE 802.11 specification that extended throughput to up to 54 Mbit/s using the same 2.4 GHz band as 802.11b. This specification under the marketing name of Wi-Fi has been implemented all over the world. 802.11g is the third modulation standard for wireless LANs. It works in the 2.4 GHz band (like 802.11b) but operates at a maximum raw data rate of 54 Mbit/s, or about 19 Mbit/s net throughput (identical to 802.11a core, except for some additional legacy overhead for backward compatibility). 802.11g hardware is fully backwards compatible with the 802.11b hardware. Details of making b and g work well together occupied much of the lingering technical process. In an 802.11g network, however, the presence of a legacy 802.11b participant will significantly reduce the speed of the overall 802.11g network. Wireless G is used in our system as a communication path from Android to server and vice versa. [6]

#### IV. ANDROID APPLICATION SYSTEM

In developing the software, Eclipse Indigo. The method that used is created to make monitoring activity. It is called kosong.java with layout\_kosong.xml, controlling activity that called MainActivity.java with activity\_main.xml, main menu window that called MainMenu.java with layout\_mainmenu.xml, timer activity that needed to update data that received from database that called MyTimerTask.java.

Table 1. List of Class used in the System

Class Name	Methods	Description
kosong.java	DefaultHttpClient getThreadSafeClient()	Used to connecting & receiving data from android to PHP
	onBackPressed()	Used to disconnecting the update that received from PHP if we change to another window
MainActivity.java	setOnCheckedChangeListener(new CompoundButton.OnCheckedChangeListener())	Used to make what need to do with toggle button
	sendDataSpray()	Used to sending data water sprayer from android to PHP
	sendDataRooftop()	Used to sending data rooftop from android to PHP
MainMenu.java	setOnClickListener(new OnClickListener())	Used to change the window in main menu layout
MyTimerTask.java	MyTimerTask extends TimerTask {}	Used to handling timer that used for updating data that received from PHP

In the system, Kosong.java used to receiving data from PHP that has delay every three seconds. It will be shown in TextView on android window. MainActivity.java is the main class for controlling microcontroller. It send data from toggle button into database. Then it will get the string if the data get to database. If it doesn't get string, it will not receive any string because it is not connected to database that will send an echo into android. On MainMenu.java it is used to choose which window, whether it is monitoring or controlling. For MyTimerTask.java it is used to run the timer to control for updating data that received from PHP.

made through serial communication and computer as a server. The computer as a path for receive and transfer value from sensor for monitoring and input for controlling.

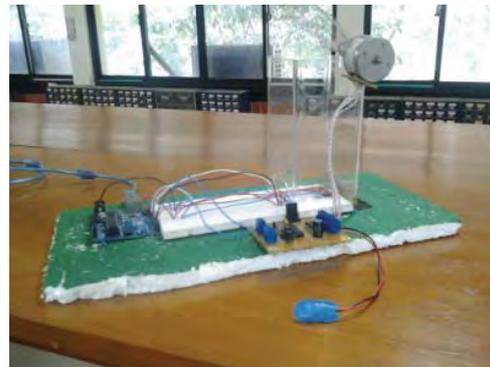


Figure 5. Actual Hardware Implementation

## V. IMPLEMENTATION OF GREENHOUSE MONITORING AND CONTROLLING SYSTEM

### A. Hardware Implementation

In the hardware implementation, it has wired components sensor to microcontroller arduino by jumper cable and use protoboard as a board for the components like stepper motor and LED module in the hardware. The 5V DC power is provided for microcontroller arduino UNO, stepper motor and also the sensor. Then, the connection between for microcontroller arduino, sensor circuit, stepper motor, water sprayer replace by LED module are

### B. Software Implementation

For software implementation, Figure 6 shows the flow of the software in monitoring and controlling the green house. C program for arduino to measure humidity, send the value to computer then to Android Smartphone through serial communication. Next receive input from Android Smartphone then control the stepper motor and LED module. PHP code use for communication path. Last, Modules for application in android are written in C program.

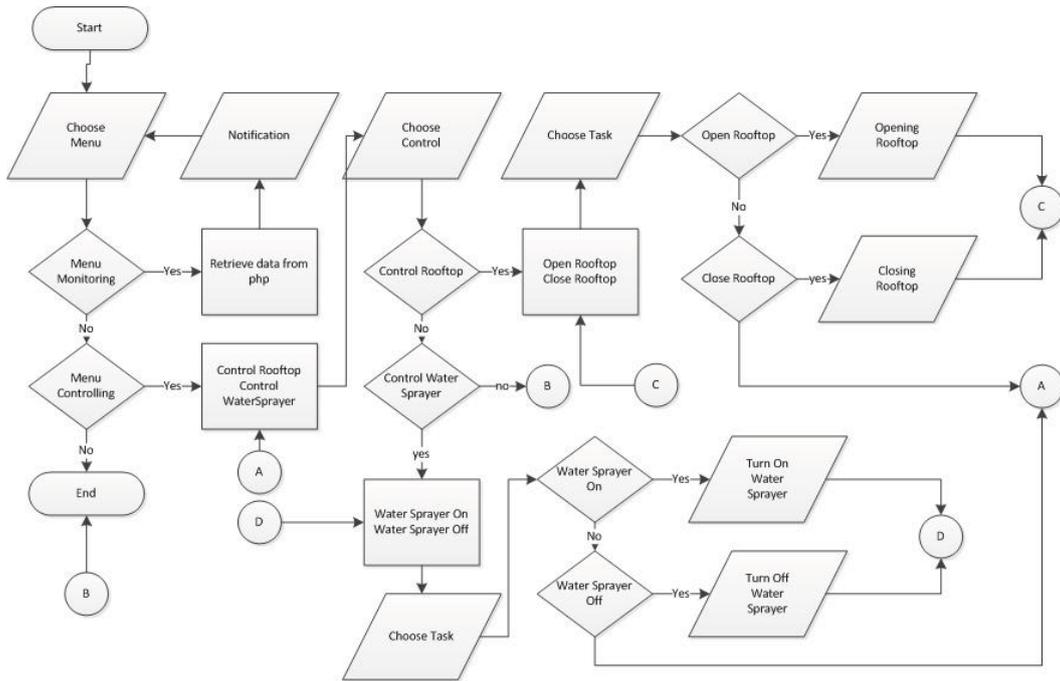


Figure 6. Software Flowchart Design

Figure 7 shown the picture of Main Menu in Android Mobile Phone.



Figure 7. Main Menu



Figure 8. Monitoring System

Figure 9 shown the picture of Controlling System in Android Mobile Phone.

Figure 8 shown the appearance of Monitoring System in the Smart Green House.

#

#



Figure 9. Controlling System

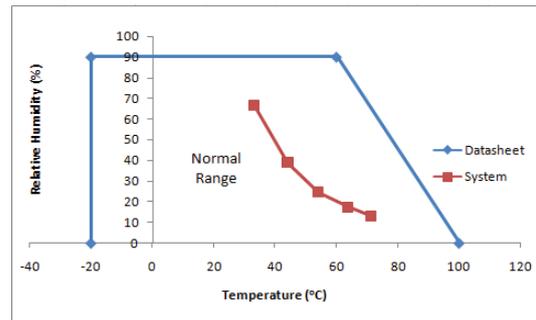


Figure 11. Comparison of Sensor Work Characteristic with Datasheet

In the test, the system is tested whether it is working properly or not. Table 2 shows that system is running properly.

### VI. ANALYSIS

Based on datasheet, sensor works stable within recommended normal range (see Figure 10). Long term exposures to conditions outside normal range, especially at humidity >80%RH. After return to normal range it will slowly return towards calibration state by itself. Prolonged exposure to extreme conditions may accelerate ageing. [5]

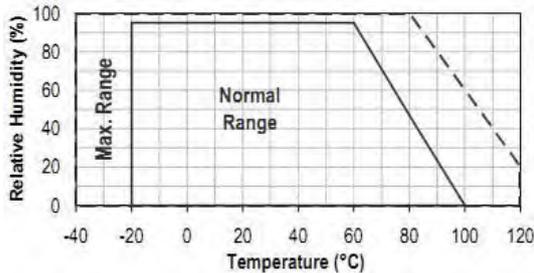


Figure 10. Operating Condition of SHT 11 Sensor [5]

In testing of work characteristic sensor, it used heat from GPU core of a computer through GPU ventilation to increase the temperature in environment. This test used a closed box to put the computer and sensor.

Figure 11 shows the graphic of sensor working characteristic in this system (shown in red) compared to ideal sensor characteristic (shown in blue), where the comparison between temperature and humidity is in normal range SHT 11 sensor. In the red line, the tests are from 30°C until 70°C. In conclusion, sensor works fine and fit with the value in datasheet. The system shows that the sensor works properly.

Table 2. Technology Acceptance Modeling

No	Parameter	Yes	No
1.	Android received humidity data from sensor	√	
2.	Android send data and received in PHP	√	
3.	Android send data for water sprayer to microcontroller and water sprayer's indicator is turned on	√	
4.	Android send data for motor stepper to microcontroller and motor stepper work	√	
5.	There is no error in the whole application	√	
6.	There is no error in the whole system	√	

### VII. CONCLUSION

The prototype of the system is successfully built and run in reality based on Technology Acceptance Modeling that shows in Table 2. The output for the given analog input values are visualized in android application system. The analog value given by the sensor changes it into a digital value.

The android software is already working properly and appropriate with the purpose in the beginning, that is to get humidity value from green house and give input to control components in green house. After development is finished, test for sensor's work is done and device is working properly.

#

#

The testing that has done shows that condition in datasheet of sensor and in system is appropriate. The test result shows in temperature 30°C to 70°C, humidity is still in normal range area. If temperature gets higher and more, relative humidity will be decrease and goes near to zero.

Looking into the Table 2 about Technology Acceptance Modeling, it can be conclude that the whole system, which are software and hardware is working fine.

#### REFERENCES

- [1] Arduino., "what is Arduino ?", Arduino Guide Introduction. Available [Accessed : 14 Oktober 2012]: <http://arduino.cc/en/Guide/Introduction>
- [2] Instructables., "Visualize Humidity with the SHT 11 Sensor". Available [Accessed: 20 December 2012]: <http://www.instructables.com/id/VISUALIZE-humidity-with-the-SHT11sensor/step2/Wire-the-sensor/>
- [3] Instructables., "Visualize Humidity with the SHT 11 Sensor". Available [Accessed: 20 December 2012]: <http://www.instructables.com/id/VISUALIZE-humidity-with-the-SHT11sensor/#step1>
- [4] Parallax., "Sensirion SHT11 Sensor Module". Available [Accessed: 22 December 2012]: <http://www.parallax.com/Portals/0/Downloads/docs/prod/acc/SensirionDocs.pdf>
- [5] Sensirion The Sensor Company., "Datasheet SHT 1x (SHT 10, SHT 11, SHT 15)". Available [Accessed: 23 December 2012]: <http://www.sensirion.com/cn/down/downimg/DatasheetSHT1x%20V5.pdf>
- [6] IEEE Standards, "Get IEEE 802®: Local and Metropolitan Area Network Standards". Available [Accessed: 22 Desember 2012]: <http://standards.ieee.org/getieee802/download/802.11g-2003.pdf>
- [7] Mittal, M., Tripathi, G., "Green House Monitor and Control Using Wireless System Network", VSRD-IJEECE, Vol. 2 (6), 2012, 337-345, 2012.
- [8] Ai, Q., Chen, C., "Green House Environment Monitor Technology Implementation Based on Android Mobile Platform", IEEE Conference Publications. Page(s): 5584 - 5587, 2011.
- [9] Rangan, K., Vigneswaran, T. "An Embedded Systems Approach to Monitor Green House", IEEE Conference Publications. Page(s): 61 - 65, 2010.
- [10] Lihong, Z., Lei, S., "Measurement and Control System of Soil Moisture of Large Greenhouse Group Based On Double CAN Bus", IEEE Conference Publications. Page(s) :518-521, 2011.
- [11] Yuquan, M., Shufen, H., Qingzhu, W., "New Environment Parameters Monitoring and Control System for Greenhouse Based on Master-Slave Distributed", IEEE Conference Publications. Page(s): 31-35, 2010.
- [12] Qingzhu, W., Shuying, M., "Development of Multi-span Greenhouse Measure and Control System", IEEE Conference Publications, Page(s): 1 - 4, 2010.
- [13] Porciello, G.P.; Doerr, D. "Advanced Process Control for Moisture Monitoring and Control Applications", IEEE Conference Publications. Page(s): 58 - 64, 1999.

# Task Execution Reliability of Resource Allocation with Tasks Replication in Mobile Ad Hoc Grid

Sri Chusri Haryanti, Riri Fitri Sari  
Departement of Electrical Engineering,  
Faculty of Engineering, University of Indonesia,  
Depok, Indonesia  
[sri.chusri@ui.ac.id](mailto:sri.chusri@ui.ac.id), [riri@ui.ac.id](mailto:riri@ui.ac.id)

**Abstract**— This paper reviews task execution reliability in mobile ad hoc grid. We consider resource allocation for mobile ad hoc grids with centralized architecture in the presence of dependent tasks. Allocating appropriate resources for the tasks can avoid uncompleted tasks and ensure the service reliability. With the aim to increase service reliability, resource management can assign the same tasks to different resources for parallel execution (tasks replication). Analytical example is given to illustrate the reliability. The result reveals that assigning the same tasks to more than one resource nodes has increased the reliability. Assigning the same tasks to 4 or 3 resource nodes provides superior reliability than that of just 2 resource nodes.

**Keywords**— resource allocation, mobile ad hoc grid, reliability, tasks replication, dependent tasks

## I. Introduction

In recent years, mobile ad hoc computational grid is a challenging research topic. Mobile ad hoc computational grid allows collaboration of mobile nodes to build a Grid, join existing Grid or contribute in a Grid spontaneously. Nodes can dynamically request and receive a sharing of resources in a Grid computing system, and be active in the services offered by other nodes in the Grid. Mobile Ad hoc computational grid facilitates autonomous interaction without requiring pre-configuration or policy management [1].

Resource allocation plays a crucial role in determining the performance of the overall grid system. Resource allocation algorithm that is suitable for mobile ad hoc environment is expected to minimize task completion time. Mobile ad hoc environment is characterized by lack of infrastructure in the network, nodes mobility and limited power of mobile nodes. Thus, it is highly critical to provide a reliable resource allocation scheme that ensures the completion of the tasks.

One simple, but potential method for obtaining fault resilience is task replication. In a grid with network infrastructure, task replication is primarily used as a fault tolerance technique in case of a system outage [2]. Replication is a technique based on an assumption that the success probability of completing the task will increase when it is done by multiple resources. In case of a task running on an unreliable execution environment, multiple replicas of the task

run on different machines. As long as not all replicated tasks fail, the task will be successfully executed [3].

## II. Resource Allocation With Tasks Replication On Mobile Ad Hoc Grid

### A. Problem context and Objectives

Grid Computing is a system that allows computational resource sharing between nodes that are connected in one network in completing specific tasks [4]. Originally, it has been used to solve huge and complex problems in science and engineering areas.

Rapid advancement in mobile computing systems has enabled the use of mobile nodes as a contributing entity to Grid. Recently, several methods have been proposed for integrating mobile nodes with grid computing systems, in which mobile nodes can share computing resources in mobile and ad-hoc environments. It is called mobile ad hoc computational grid. As the complexity of human life increased, the problem size becomes relative. People may require computing resources from others to solve computationally-intensive common problems.

Unpredictable node mobility across the coverage area in mobile ad hoc grid may lead to a task failure. Node mobility across the coverage area will not only affect the task execution on a node but also affects dependent tasks execution on the other nodes. Therefore, mobility of a single node can have a large effect on an application performance. This paper presents two approaches for avoiding a task failure due to node mobility. First, selecting nodes, which have corresponding mobility as the resource nodes. This will ensure the use of nodes with long-term connectivity for executing the tasks. The second is task replication which is expected to increase service reliability.

### B. Resource Allocation Scheme

In grid computing systems, Resource Management System (RMS) controls sharing resources among the nodes [5]. This paper considers resource allocation for mobile ad hoc grids

with centralized architecture. The resource allocation service process in a star topology as depicted in Fig. 1. The RMS is in the center which is directly connected with the node resources through communication channels. Here, the node which requires resources from other nodes is responsible of resource allocation service.

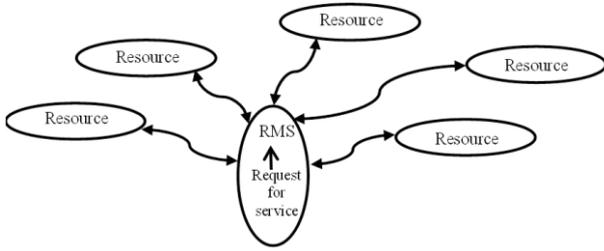


Fig. 1. Mobile ad hoc grid with a star architecture

We consider a number of nodes that could connect and communicate in a mobile ad hoc network. When a user needs resources from other users to execute an application, it will send the application to resource allocation service. Then, resource allocation service will enable resource discovery service which afterwards broadcasts a discovery message. Nodes within a range that are willing to share computing resources will send a reply message. In the reply message, characteristics such as processing power, memory, and remaining battery power are enclosed. These attributes could be used to select nodes. The execution of tasks depends on the application's type. If the mobile resource nodes are not enough to execute an application, the resource allocation service may wait for other nodes to join the grid. When tasks execution has finished, the results will be gathered by the requesting node that submitted the application.

Before allocating the tasks, all nodes that are willing to share resources are mainly selected based on their mobility. Nodes which have a certain degree of corresponding mobility pattern are selected into a cluster of resource nodes. The idea is allocating the tasks only to the nodes belong to this cluster. Only these nodes will execute the existing tasks to ensure that most of the tasks will be properly resolved. Furthermore, we apply tasks replication as a failure tolerance method. Here, we investigate resource allocation service for different tasks replication number. However, it should be a limitation of replication number, due to the scarcity of resources in constrain environment of mobile ad hoc grid.

### III. Resource Allocation Reliability Analysis

Resource allocation is certainly critical for a reliable mobile ad hoc grid. There have been papers investigating the reliability of resource allocation for grid with infrastructure including [6-9] and likewise reliability of mobile ad hoc network including [10-13]. However, reliability of resource allocation for mobile ad hoc grid has not been studied.

As stated in [9], the services in existing grid systems are usually organized in a hierarchical manner. They contain

different layers that are interconnected through a set of interfaces. Those are program, resource, request, network and management layer. The discussion of grid service reliability analysis with hierarchical model includes reliability of request layer, reliability of management layer, and reliability of network, program and resource layer [9]. This paper will only present reliability of program layer. It is task execution reliability portion of centralized resource allocation service with tasks replication.

#### A. Reliability of Task Execution

Built upon [7], the reliability of tasks execution depends not only on the reliability of each tasks, but also on the reliability of the execution dependencies of them. In the tasks execution phase, tasks will be undertaken in different resources. Each resource can only handle one task when it is available. However, the same task will be assigned to several resources. If the same task is done by several resources, it is considered completed when the first output is arrived back to the RMS.

It is assumed that RSM is totally reliable. The time of task processing by the RMS is also assumed to be ignored. This is because it is very small when compared with the tasks processing time.

In this paper, a job is composed of  $m$  tasks with  $c_j$  complexity and the amount of data that will be interchanged between RMS and a resource  $a_j$  ( $1 \leq j \leq m$ ). If task  $i$  needs an output data from task  $k$ , then task  $i$  can be executed only if task  $k$  has been completed. The task execution time is defined as the time from the beginning of the input data transmission from the RMS to a resource, to the end of output data transmission from the resource to the RMS [7].

The task execution time of task  $i$  by resource  $j$ ,  $t_{ij}$  has two possible values. If the task has been failed,  $t_{ij} = \infty$ . Otherwise, if the task has been completed successfully, then

$$t_{ij} = \hat{t}_{ij} = \frac{c_i}{x_j} + \frac{a_i}{s_j} \quad (1)$$

where  $c_i$  is the computational complexity of task  $i$ ,  $x_j$  is the processing speed of the resource, and  $s_j$  is the data transmission speed (bandwidth) of communication channel.

If failure rates of resource and communication link is constant, the probability of successful task execution is :

$$p_j(\hat{t}_{ij}) = e^{-(\lambda_j + \pi_j)\hat{t}_{ij}} \quad (2)$$

where  $\lambda_j$  is the failure rate of the resource  $i$  and  $\pi_j$  is the failure rate of the communication channel  $i$ , with  $Pr(t_{ij} = \hat{t}_{ij}) = p_j(\hat{t}_{ij})$  and  $Pr(t_{ij} = \infty) = 1 - p_j(\hat{t}_{ij})$ .

It is assumed that for every task  $i$ , RMS allocates a set of resources  $\omega_i$  ( $\omega_i \cap \omega_j = \emptyset$ ). RMS can initiate every execution of task  $j$  after task  $k \in \phi_i$  is successfully completed. Thus, it can be determined that the random time of the start of task  $i$  execution,  $T_i$  is

$$T_i = \max_{k \in \phi_i}(\tilde{T}_k) \quad (3)$$

where  $T_k$  is the random completion time for task  $k$ . If  $\emptyset = \emptyset_i$ , task  $i$  can be immediately commenced :  $T_i = 0$ . If  $\emptyset \neq \emptyset_i$ , so the value becomes  $\tilde{T}_{il}$  ( $1 \leq j \leq m$ ).

With the start of execution  $T_i$  and execution time  $t_{ij}$  of task  $i$  by resource  $j$ , the random execution of task  $i$  by resource  $j$  is :

$$\tilde{t}_{ij} = T_i + t_{ij} \quad (4)$$

To obtain the distribution of  $\tilde{t}_{ij}$ , the probability of any realization of  $\tilde{t}_{ij} = \hat{T}_{il} + \hat{t}_{ij}$  has to be considered. It is equal to the product of three occurrences :

1. Task  $i$  execution starts at  $\hat{T}_{il} : q_{ij} = Pr(T_i = \hat{T}_{il})$
2. Resource  $j$  has not failed before task  $i$  execution starts :  $p_j(\hat{T}_{il})$
3. Resource  $j$  has not failed during task  $i$  execution :  $p_j(\hat{t}_{ij})$

Accordingly, the distribution of  $\tilde{t}_{ij}$ , with task  $i$  execution at  $\hat{T}_{il}(T_i = \hat{T}_{il})$

$$\begin{aligned} Pr(\tilde{t}_{ij} = \hat{T}_{il} + \hat{t}_{ij}) &= p_j(\hat{T}_{il})p_j(\hat{t}_{ij}) \\ p_j(\hat{T}_{il} + \hat{t}_{ij}) &= e^{-(\lambda_j + \pi_j)(\hat{T}_{il} + \hat{t}_{ij})} \\ Pr(\tilde{t}_{ij} = \infty) &= 1 - p_j(\hat{T}_{il} + \hat{t}_{ij}) = 1 - e^{-(\lambda_j + \pi_j)(\hat{T}_{il} + \hat{t}_{ij})} \end{aligned} \quad (5)$$

Random time execution of task  $i$ ,  $\tilde{T}_i$  is equal to the fastest a resource from  $\omega_i$  finishing the task,

$$\tilde{T}_i = \min_{j \in \omega_i}(\tilde{t}_{ij}) \quad (6)$$

In case that the number of tasks is  $m$ , the start time of task  $m$  is  $T_m$ , knowing the distribution of  $T_m$  in the form of  $q_{ml} = Pr(T_m = \hat{T}_{ml})$  for  $1 \leq l \leq L_m$ , the reability of service performance can be evaluated.

In estimating service reliability and performance, one can use different measures depend on the application. In the application where the execution time of each task is critical, the system reliability  $R(T^*)$  is defined as the probability of the correct output in time less than  $T^*$ .

$$R(T^*) = \sum_{l=1}^{L_m} q_{ml} \cdot 1(\hat{T}_{ml} < T^*) \quad (7)$$

### B. Illustrative Example

This analytical example illustrates  $R(T^*)$  for resource allocation on mobile ad hoc grid. Assume that there are eight resource nodes in the grid. The analysis of  $R(T^*)$  will be conducted for two, three and four tasks replication. The replication number of tasks for each scenario is fixed.

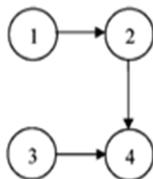


Fig. 2. Task execution precedence for the analytical example.

Assume that the RMS divides job into three tasks. Tasks 1 & 3 get the input data directly from the RMS; task 2 needs the output of subtask 1, and the job is completed when the RMS gets the outputs of both tasks 2 & 3. These task sequence is shown by the directed graph in Fig. 2.

Table 1 contains a summary of the failure rates of the resources, communication channels, and task execution times. If it is assumed that all resources are reliable, the failure rate of the resource ( $\lambda$ ) is 0. Considering that the mobility model of nodes is random point group mobility (RPGM), the failure rate of communication channel obtained from [14] is 0.0064. So  $\lambda_j + \pi_j$  is 0.0064.

TABLE I. PARAMETERS OF THE MOBILE AD HOC GRID SYSTEM FOR THE ANALYTICAL EXAMPLE.

No. of resource $j$	$\lambda_j + \pi_j$	$\hat{t}_{ij}$
1	0.00164	100
2	0.00164	130
3	0.00164	150
4	0.00164	180
5	0.00164	220
6	0.00164	300
7	0.00164	180
8	0.00164	150

In the first scenario, the first task is assigned to resources 1 & 2, the second task is assigned to resources 3 & 4, and the third task is assigned to resources 5 & 6.

$$\omega_1 = \{1,2\}, \omega_2 = \{3,4\}, \omega_3 = \{5,6\}$$

For the second scenario, the first task is assigned to resources 1, 2 & 3, the second task is assigned to resources 4, 5 & 6, and the third task is assigned to resources 2, 3 & 4.

$$\omega_1 = \{1,2,3\}, \omega_2 = \{4,5,6\}, \omega_3 = \{2,3,4\}$$

And in the last scenario, the first task is assigned to resources 1, 2, 3 & 4, the second task is assigned to resources 3, 4, 7 & 8, and the third task is assigned to resources 5, 6, 7 & 8.

$$\omega_1 = \{1,2,3,4\}, \omega_2 = \{3,4,7,8\}, \omega_3 = \{5,6,7,8\}$$

To evaluate the distribution of service time of each scenario, universal generating function (u-function) as in [7] is used. This technique is using a fast algebraic procedure and effectively proven for evaluating the reliability of multi state system [15]. Then calculating reliability using (7), it is obtained as:

The 1st scenario,	$R(T^*) = 0.3928$	for $250 < T^* \leq 280$ ;
2 task replica	$R(T^*) = 0.5239$	for $280 < T^* \leq 300$ ;
	$R(T^*) = 0.663$	for $300 < T^* \leq 310$ ;
	$R(\infty) = 0.8632$	

The 2nd scenario,	$R(T^*) = 0.5371$	for $230 < T^* \leq 250$ ;
3 task replica	$R(T^*) = 0.7004$	for $250 < T^* \leq 280$ ;
	$R(T^*) = 0.7611$	for $280 < T^* \leq 300$ ;
	$R(T^*) = 0.8006$	for $300 < T^* \leq 310$ ;
	$R(T^*) = 0.8032$	for $310 < T^* \leq 330$ ;

$$R(T^*) = 0.8033 \quad \text{for } 330 < T^* \leq 360;$$

$$R(\infty) = 0.8636$$

The 3rd scenario,  
 4 task replica

$$R(T^*) = 0.6629 \quad \text{for } 150 < T^* \leq 180;$$

$$R(T^*) = 0.8019 \quad \text{for } 180 < T^* \leq 220;$$

$$R(T^*) = 0.8381 \quad \text{for } 220 < T^* \leq 300;$$

$$R(\infty) = 0.8661$$



Fig. 3. Service Reliability for different replication number

The result of all scenarios can be seen in Fig. 3. It is shown that the service reliability increases as the number of task replica is increased. It is also shown that the increasing number of task replica will decrease the required service time, because the probability of successful task increases as the number of replica increases.

#### IV. Conclusion

The severe environment of mobile ad hoc network requires a fault-tolerant resource allocation for mobile ad hoc grid. One of the methods for obtaining fault resilience in a grid with infrastructure is task replication. Here, we analyze the reliability of task execution on resource allocation with tasks replication in mobile ad hoc grid. An analytical example has been delivered to show the reliability analysis. In line with a grid with infrastructure case, the result shows that assigning tasks replication provides superior reliability in mobile ad hoc grid. However, due to mobile ad hoc network characteristic the number of task replica has to be limited. In the future, we will use comprehensive hierarchical model in analyzing the reliability of resource allocation in mobile ad hoc grid. The optimum number of task replica for a certain failure probability will also be studied.

#### References

[1] K. Amin, G. Laszewski, and A. Mikler, "Toward an Architecture for Ad Hoc Grids," Proc. 12th Int'l on. Advanced Computing and Communications (ADCOM 04), pp. 15-18, 2004.

[2] R. Garg and A. K. Singh, "Fault Tolerance In Grid Computing: State of the Art and Open Issues," International Journal of Computer Science & Engineering Survey (IJCSES), vol.2, no.1, pp. 88-97, Feb 2011.

[3] S. Hwang; C. Kesselman; , "Grid workflow: a flexible failure handling framework for the grid," Proceedings. 12th IEEE International Symposium on High Performance Distributed Computing 2003, pp. 126-137, 22-24 June 2003.

[4] I. Foster, "What is the Grid? A Point Three Checklist", GRID Today, July 20, 2002.

[5] K. Krauter, R. Buyya, M. Maheswaran, "A Taxonomy and Survey of Grid Resource Management Systems for Distributed Computing," Software Practice and Experience, 32, pp. 135-164, 2002.

[6] Y.S. Dai, M. Xie, K.L. Poh, "Reliability analysis of grid computing systems," Dependable Computing, 2002. Proceedings. 2002 Pacific Rim International Symposium on , pp. 97- 104, 16-18 Dec. 2002.

[7] G. Levitin, Y.-S. Dai, and H. Ben-Haim, "Reliability and Performance of Star Topology Grid Service With Precedence Constraints on Subtask Execution," IEEE Transactions on Reliability, vol. 55, no. 3, pp. 507-515, Sep. 2006.

[8] J. Zhang, "An approach to analyze grid service reliability subject to failures," Computer Science & Education, 2009. ICCSE'09. 4th International Conference on. IEEE, pp. 343-347, Jul. 2009.

[9] Y.-H. Dai, Y. Pan, X. Zou, "A Hierarchical Modeling and Analysis for Grid Service Reliability," Computers, IEEE Transactions on, vol.56, no.5, pp.681-691, May 2007.

[10] J.L. Cook, P. Arsenal, and J.E. Ramirez-Marquez, "Recent research on the reliability analysis methods for mobile ad-hoc networks," Systems Research Forum, vol. 2, no. 01, pp. 35-41. World Scientific Publishing Company, 2007.

[11] J.W. Tantra, C.H. Foh, and D. Qiu , "On Link Reliability in Wireless Mobile Ad Hoc Networks," Vehicular Technology Conference, 2006. VTC-2006 Fall. 2006 IEEE 64th, pp.1-5, 25-28 Sept. 2006.

[12] T. Dimitar, F. Sonja, C. Bekim, and G. Aksenti, "Link Reliability analysis in ad hoc networks," In Proc. of XII Telekomunikacioni forum TELFOR, 2004.

[13] B. Chen, A. Phillips, T.I. Matis, "Two-terminal reliability of a mobile ad hoc network under the asymptotic spatial distribution of the random waypoint model", Reliability Engineering and System Safety, vol.106, pp. 72-79, Elsevier.

[14] S. K. Hwang and D. S. Kim, "Markov model of link connectivity in mobile ad hoc networks," Telecommunication Systems, vol. 34, no. 1-2, pp. 51-58, Dec. 2006.

[15] G. Levitin, A. Lisnianski, H. Ben-Haim, and D. Elmakis, "Redundancy optimization for series-parallel multistate systems," IEEE Transactions on Reliability, vol. 47, pp. 165-172, 1998.

# Multi Objective Optimization Based Intelligent Agent for NPC Behavior Decision

Supeno Mardi<sup>1</sup>, Mochamad Hariadi<sup>3</sup>, And Mauridhi  
 Hery Purnomo<sup>4</sup>  
 Dept. of Electrical Engineering  
 Institut Teknologi Sepuluh Nopember (ITS)  
 Surabaya, Indonesia  
 mardi,mochar, hery@ee.its.ac.id

Dwi Rolliawati<sup>2</sup>  
 Dept. of Computer System  
 Universitas Narotama  
 Surabaya, Indonesia  
 dwrolliawati@gmail.com

**Abstract**— The main actor of the game is based on non-playable character (NPC) behavior to respond the environment based on artificial intelligent method. This research simulates the behavior of buyer-seller agent on purchasing computer goods in computer game. The buyer agent has price and specification variable which is reacted in satisfaction factor of agent. The seller agent has price and profit variable which is took effect in Join Utility (JU) of agent. In this case, there is usually no single optimal solution, but a set of alternatives with different trade-offs. This research describes buyer-seller agent behavior by multi objective optimizations approach using Multi Objective Evolutionary Optimization (MOEA) Non Sorted Dominated Genetic Algorithm II (NSGA II). NSGA II provides pareto fronts value to the minimum and maximum functions. Based on simulation result, we generate 3 kinds of scenarios of buyer and seller agent. First, the seller agent with profit oriented behavior provides the value of JU twice from the buyers function. Second, the seller agent with customer oriented behavior provides balance JU from the buyer function. Third, the buyer agent with satisfaction oriented behavior. Stability results of simulation is evenly attained after the fifth generation with simulation parameters: chromosome/pop=1000, crossover probability (pc)=0.9, mutation probability (pm)=0.005, index of distribution crossover ( $\eta_c$ )=20, index of distribution mutation ( $\eta_m$ )=20, value of pool=pop/2 and number of tour=2.

**Keywords**— *intelligent agent, multiobjective, NSGA II, NPC behavior*

## I. INTRODUCTION

Computer game have several type of *Non-Playable Characters* (NPCs) agent. Two of them are buyer and seller NPCs. If NPC have human-like behavior, the buyer NPC must have intelligent when make decision to buy some thing. The NPC should choose from several selection of goods base some criterias, like minimum price and maximal quality.

Research of the buyer-seller agent relationship had researched by some researchers [1, 2, 3, 4, 5, 6, 9]. Imam [1] design buyer agent based on *hierarchical finite state machine* (HFSM) to simulate *Supply Chain Management* Procurement decision. Seller agent's strategis to select buyer in face of limited stock matematically formulated [2]. Still correlates of buyer agents, buyer agents developed based on fuzzy logic for automated negotiation in e-commerce[3]. Also Li[4] investigated the use of multi-objective optimization approach

to the buyers and sellers agents using techniques based priority matchmaking genetic algorithms. Methods of *Constraint Satisfaction Problems* (CSP) can also be used to measure the negotiations between buyer-seller [5]. Anon[6] investigate the approach to form buyer coalition with bundles of items by using the genetic algorithm. *Multi Objective Evolutionary Optimization* (MOEA) *Non Sorted Dominated Genetic Algorithm II* (NSGA II) had been employed by Adianto[7] to badminton agent using stamina and player action criteria. Asto[8] employed MOEA NSGA II agent on electricity supply serious game.

In this research, we proposed buyer-seller agent's decision behavior based multi objective optimizations approach using MOEA NSGA II to employ it for NPCs, from our previous research [9].

The paper is organized as follows. A brief description about buyer-seller behavior scheme is presented in section II. Discussions about multiobjective design for buyer-seller behavior described in section III. The experimental results are shown in section IV and conclusion in section V.

## II. BUYER-SELLER BEHAVIOR

We design Finite State Machine (FSM) for buyer agent in our novelty game, a REOG PONOROGO game. The job of buyer agent is find the best offer from several seller. Buyer do scoring function ,based on NSGA II, is to assess what is offered by the seller until the deal with the seller. Conversely the seller also have considerations with the profit taking , so as long still have profit, the seller also did the scoring from the buyer offers to end up doing a deal with a buyer.

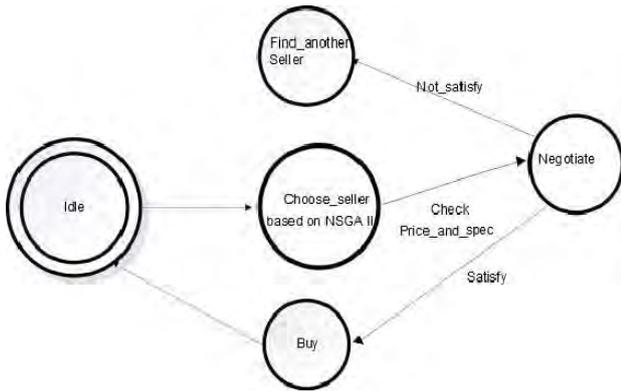


Figure 1 FSM of buyer agent

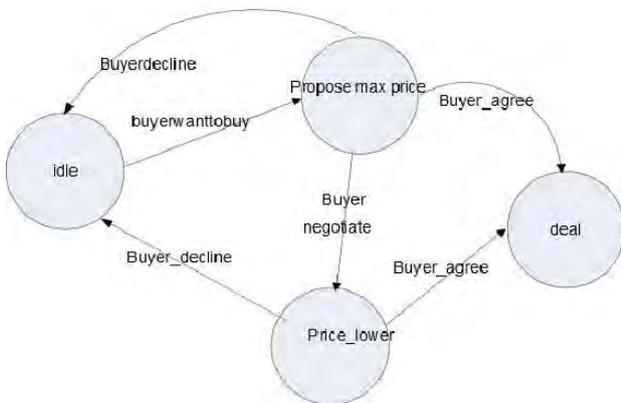


Figure 2 FSM of seller agent

### III. MULTIOBJECTIVE DESIGN

#### A. NSGA II

Nondominated Sorting Genetic Algorithm II (NSGA II) developed by Kalyanmoy Deb [10] which is a modification of the procedure of rank in NSGA. The algorithm of the original NSGA is first, initialize population. Once the population has initialized the population sorted by non-domination into each front. Each individual in each front rank rated (fitness) or by front where they belong. The individuals at the first front were given a fitness value is 1, while for individuals on second fronts given fitness value 2 and so on for the next.

#### B. Buyer seller multiobjective design

Population initialization is done by forming a population. In this study determined the amount of maximum population is 1000 chromosomes. chromosome generated from database laptop purchase. Chromosomes consist of 19 objective variables which offer sellers (processor, memory, hard drive, price), the minimum expected price from seller, expectations of buyers (processors, memory, hard drive, price), minimum capability buyers (processors, memory, hard drive) the maximum capacity buyer (price), the weight of interest /

preference buyers (processors, memory, hard drive) cumulative weight (specifications, prices) and quantity.

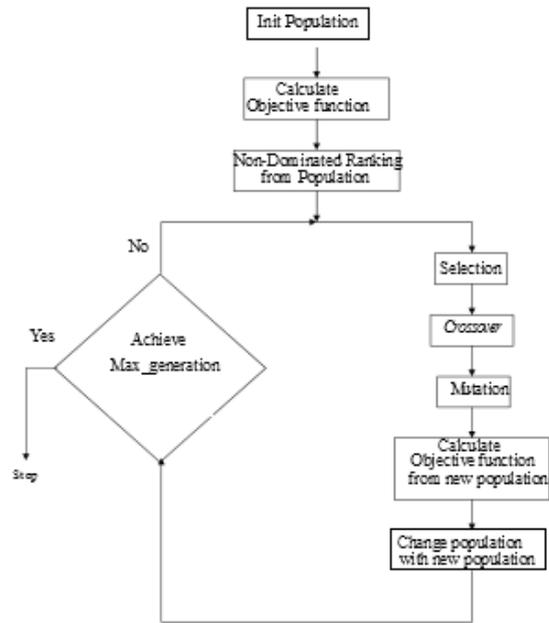


Figure 3 NSGA II Flowchart

#### C. Join Utility function

Li[4] use the matchmaking mathematical model for novel method to match buyers and suppliers in B2B e-marketplace. We use the matchmaking mathematical model [4] to form buyer and seller function. The buyer-seller functions then used by NSGA II [10] to make *pareto front*. From *pareto front* we calculate Join Utility (JU), which is *bargaining value* from the seller to the buyer's agent.

- Buyers function (f1),

QBigf is variable assessment (scoring) of the quality products offered, i is a buyer, g is the product

$$Qb_{ig} = \begin{cases} 1 & , agf \geq eif \\ \frac{agf - eif_{min}}{eif - eif_{min}} & , eif_{min} \leq agf \leq eif \\ -1 & , agf \leq eif_{min} \end{cases} \quad (1)$$

Where:

Eif = the expectation value of the buyer

Agf = bid price sellers

Eif min = minimal value ability of the buyer

Pbigf is variable assessment (scoring) of the price of products offered,  $i$  is a buyer,  $g$  is the product

$$Pb_{igf} = \begin{cases} \frac{eif_{max} - agf}{eif_{max} - eif} & 1, agf \leq eif \\ -1, agf \geq eif_{max} \end{cases} \quad (2)$$

Where:

Eif = the expectation value of the buyer

Agf = bid price sellers

Eif max = maximal value ability of the buyer

Then scoring of buyer (Bij) calculated by:

$$Bij = \sum W_i \times bigf \quad (3)$$

Finally the buyer function affected by the quantity of sales (Q), so the f1 become:

$$f1(x) = Bij \times Q \quad (4)$$

• Seller function (f2)

First we calculate the value of seller scoring:

$$S_{ji} = \begin{cases} \frac{Pbi - PSj_{min}}{PSj - PSj_{min}} & 1, Pbi \leq PSj \\ -1, Pbi \geq PSj_{min} \end{cases} \quad (5)$$

Where:

Sji: Seller scoring

Pbi: Bid price from buyer

PSj: the expectation value of the seller

PSjmin: maximal value ability of the Seller,

Then we calculate the seller function, affected also by bargaining value(JU) and quantity (Q):

$$f2(x) = JU \times S_{ji} \times Q \quad (6)$$

which on normal scenario, bargaining value JU is defined:

$$JU = 1 - f1(x) \quad (7)$$

#### IV. EXPERIMENT

We find the best value of the agents with consideration of maximizing buyer (cheap price, good specs, purchase quantity lots) and maximize the seller (profits, a lot of customers, big sales quantity). By implementing equation 1 to equation 7 in NSGA II, we generate 3 kinds of scenarios of buyer and seller agent.

1. First, the seller agent with profit oriented behavior provides the value of JU twice from eq.7 :

2. Second, the seller agent with customer oriented behavior provides balance JU, using eq.7

3. Third, the buyer agent with satisfaction oriented behavior: The value of JU halved from eq. 7.

The three category of scenarios is tested to NSGA II with simulation parameters as follows: chromosome/pop=1000, crossover probability (pc)=0.9, mutation probability (pm)=0.005, index of distribution crossover ( $\eta_c$ )=20, index of distribution mutation ( $\eta_m$ )=20, value of pool=100 and number of tour=2.

The experiment has a *pareto front* result as follows:

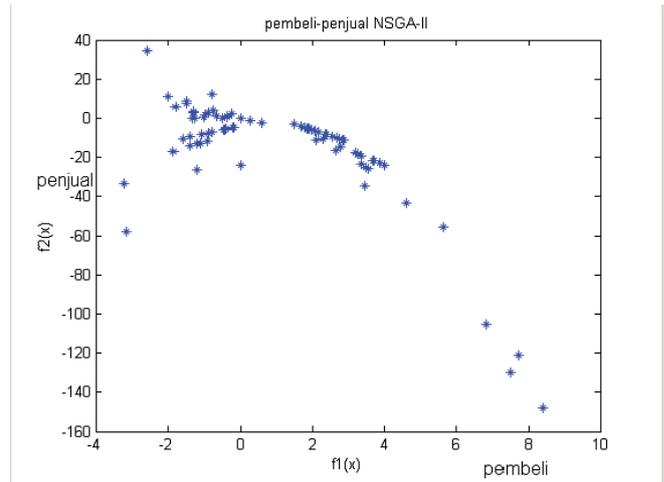


Figure 4. Value JU twice from normal JU

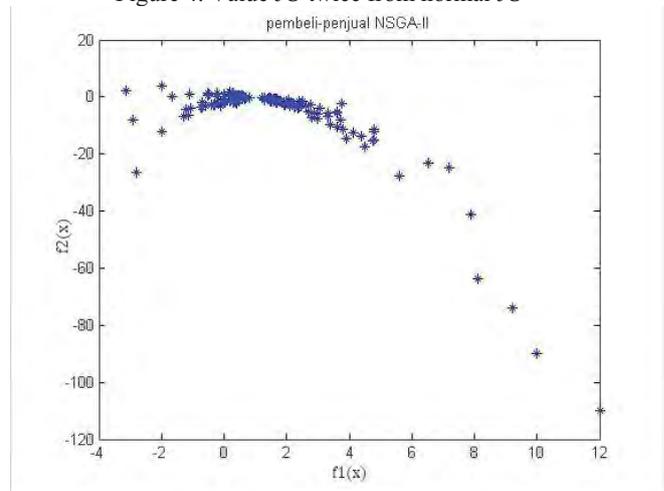


Figure 5. The simulation results with generation = 75

On generation =50 and 75 crowded points still in the same range as previous simulations (fig. 5), so it can be concluded for the generation of = 50 and thereafter obtain stable results. So that the pareto fronts of generation 50 can already be used to find a solution or the best value.

## V. CONCLUSION

We present NSGA II optimization method for seller agent decision in computer game. Employed to buyer-seller FSM, the buyer-seller agents can interact more immersive. Using NSGA II, we have the best result after 50 generation.

## REFERENCES

- [1] Mohamad Iman Prajitno, Bambang Wahyu W, Muh. Chosy'in, Supeno Mardi S, Moch. Hariadi, Desain Simulasi Pengambilan Keputusan Multiobjective Menggunakan Agen Cerdas, Seminar Nasional Manajemen Teknologi IX Program Studi MMT-ITS, 2009.
- [2] Claudia V.Goldman, Sarit Kraus, Onn Shehory, Agent Strategies : for sellers to satisfy purchase-orders, for buyer to select sellers, NSF under grant No.IIS980657, IBM, 2001.
- [3] R. Manjavacas, J.J Castro Schez, A Fuzzy Buyer Agent for An Automatic Negotiation Framework On E-Commerce, EUSFLAT – FLA, 2005.
- [4] Xiaohui Li, Tomohiro Murata, Priority based Matchmaching Method of Buyer and Supplier in B2B e-marketplace Using Multi-objektif Optimization, Proceedings of International Multi Conference of Engineers and Computer Scientists (IMECS), IAENG, Vol.1, 2009
- [5] Jong-Jin Jung, Geun-Sik Jo, Brokerage between buyer and seller agents using Constraint Satisfaction Problem models, ELSEVIER. Decision Support Systems 28 , pp 293–304, 2000.
- [6] Anon Sukstrienwong, Buyer Formation with Bundle of Items in E-Marketplaces by Genetic Algorithm, , Proceedings of International Multi Conference of Engineers and Computer Scientists (IMECS), IAENG, Vol 1,2010
- [7] Adianto, Supeno Mardi, Moch. Hariadi, Desain Perilaku Agen Pada Permainan Bulutangkis Dengan Menggunakan Multi-Objective Genetic Algorithm, Seminar Nasional Manajemen Teknologi IX Program Studi MMT-ITS, 2010
- [8] IGP Asto Buditjahjanto, Sistem Pendukung Keputusan Cerdas Untuk Optimasi Permasalahan Multi Obyektif pada Serious Game, Disertasi, Teknik Elektro- ITS, 2010.
- [9] Dwi Rolliawati, Supeno Mardi, Moch.Hariadi, I Ketut Eddy Purnama, Desain Perilaku Pembeli dan Penjual dengan Pendekatan MOEA NSGA-II, Seminar Nasional SITIA ITS, 2011
- [10] Kalyanmoy Deb, , Amrit Pratap, Sameer Agarwal, and T. Meyarivan, A Fast and Elitist Multiobjective Genetic Algorithm:NSGA-II, IEEE Transactions On Evolutionary Computation, Vol. 6, No. 2, April 2002

# Secondary Camera Placement in Machinema Using Behavior Trees

Delta Ardy Prima, Bela Bima ferial Java, Edward  
 Suryapto  
 Student of Department of Electrical Engineering, Sepuluh  
 Nopember Institute of technology  
 Surabaya 60111, Indonesia  
[delta.ardy11@mhs.ee.its.ac.id](mailto:delta.ardy11@mhs.ee.its.ac.id), [bela11@mhs.ee.its.ac.id](mailto:bela11@mhs.ee.its.ac.id),  
[edward11@mhs.ee.its.ac.id](mailto:edward11@mhs.ee.its.ac.id)

Mochamad Hariadi  
 Department of Electrical Engineering, Sepuluh Nopember  
 Institute of technology  
 Surabaya 60111, Indonesia  
[mochar@elect-eng.its.ac.id](mailto:mochar@elect-eng.its.ac.id)

**Abstract**—Machinema is a system that allows making movies in virtual environment created in real-time. In the process of making machinema movie, the camera position plays an important role in the process of cinematography. In the real world, the cameraman receives direction from the director to put the camera accordance with the desired viewpoint. Machinema works in real-time, it would a real camera system that can perform the roles of a director and cameraman in determining perspective on every scene in the film making. In the real world cinematography, the director used a variety of viewpoints such as establishing shot, track shot, bird eye, and close up to get an interesting story. If machinema is used to make a film resembling as in the real world then machinema should be possible to take shoot with various position. We designed an intelligent camera system that can accommodate the needs of the virtual cinematography by observing the rules of traditional cinematography in the real world. An intelligent camera system is capable of assisting in the process of making machinema movies. Our method uses behavior trees. The system we made allows the camera to perform as a director in terms of deciding the proper perspective based on priorities and possibilities to make the camera moves automatically and shoots like a cameraman in the real world. In this paper we implement the system we've created in virtual world using unreal engine.

**Keywords**—component; machinema; cinematography; behavior trees; unreal engine

## I. INTRODUCTION

Movies, television, and video games are among the most popular form of entertainment in these days. Of these movies has been around the longest, followed by television. It follows that video games can benefit from lessons learned from the movie and television industries. Creating the film, however, is a costly and time consuming endeavor that requires trained writers, producers, directors, actors, and others. Recently many hobbyists have turned to a portmanteau of machine and cinema, machinema or machinima.

Machinema refer to the innovation of leveraging video game technology and used pre rendered 3D images to greatly ease the creation of computer animation. Rather than creating complex graphical word, machinema artist manipulated the behavior of 3D games. By choreographing the characters as

the avatar or create their own character, they can “perform” the actions according to the script they are creating.

Filmmaking using machinema is a complex visual medium that combines virtual cinematography, avatars controlling, and editing to convey a story. The camera must film the right event at the right time to produce the right picture. Cinematography and editing are both complex art form in their own right.

In this paper we focus on the problems of selecting secondary camera placement and angles to capture the action of an event based on behavior trees. There are a number of challenges therein including visual composition, event triggering action, and coordination between main camera and the secondary camera. We described a secondary camera placement system for machinema movies.

## II. BACKGROUND

Cinematographers over time developed a rich canon of conventions for filming commonly recurring types of shots (A continuous take of camera recording) and sequences (an ordered series of shots). For example, cinematic convention suggests that in filming two characters facing one another in conversation, alternating shots of the two characters should depict one gazing left-to-right and the other right-to-left. In filming the rest shot of such a sequence, the camera is placed on one side of an imaginary line-of-interest passing through the characters, and successively placing the camera on the same side of this line preserves continuity by repeating the established facing directions of the characters. [1].

In composing the visual properties of a shot, a cinematographer may vary the size of a subject in the frame or the relative angle or height between camera and subject. Shot sizes include extreme close-up, close-up, medium, long, and extreme long in which a subject's size in the frame appears progressively smaller or more distant. A filmmaker can also use editing decisions such as shot duration and the frequency of cuts to artful effect. [1].

Many researchers have focused on integrating cinematographic principles into automatic camera control. These approaches provide sophisticated control to a user.

Christianson et al. [2] divide cinematography into simple fragments in a “Declarative Camera Control Language”. They also develop a “Camera Planning System” that partitions a character’s movement into individual actions. He et al. [3] encode a finite state machine that controls the camera’s position and parameters. This implementation does not work in real-time and is limited to simple scenarios involving two characters. Our approach works for multiple simultaneous events, operates in real-time, and expands to more robust scenarios, such as crowds, tracking an object/character, and conversations.

### III. CINEMATOGRAPHY

In the process of film-making cinematography play an important role to make the movie feels great not just a sequence of images. The angles, the frame and the other main cinematography principles must be applied to a movie.

Cinematography means Light and camera settings when recording photographic images for the cinema. Camera settings in cinematography consist of camera movement, camera placement, and camera angle. The developments of commercial game at the recent days have brought the good story telling almost the same as the movie. This requires a proper camera placement to increase player emotions that plays the game. Taking a particular point of view is expected to improve emotional player such as player to watch movies. However, for placing a camera in cinematography principle, we need a basic knowledge about creativity in cinematography

#### A. Framing the Scene

In the game, framing and composition are essential to communicate the situation. The depth of a particular frame may provide different information for each player. If frames are taken very close to the actor game such as close-up shot of the information obtained will be less and it could make the player confuse but can provide emotional closeness, for example, when a character is in a state of anger. Conversely, if the frames are taken tend to widen as establishing shot, the players will get more information from the surrounding environment but will get less emotion as shown in Figure 1.



Figure 1. Shot idioms in cinematography principles

#### B. Shots Idiom

- *Extreme Close up* : Generally refers to a shot showing only the eyes and mouth, but can also

indicate an even tighter Shot showing only one feature that is important to the current scene.

- *Medium Close up* : Sometimes referred to as two T’s (for teeth and throat), this shot shows the head down to the top Of the throat.
- *Full Close up*: Also known as a chocker, this contains the head and full throat.
- *Wide Close up*: Similar to Close Up, but thus shot includes the full shoulders.
- *Close Shot* : Sometimes referred to as three T’s (teeth, throat and ...), this shot is from breast area to up
- *Medium Close Shot* : This shot goes from just above the belt to the top of the head
- *Medium shot* : This shot is from the waist up, including the belt
- *Full Shot*: This shot is a full body shot with little or no space above or below in the frame.
- *Two Shot* : A Shot framing the two central character of the scene
- *Long shot* : Also known as a wide shot, this shot encompasses an entire scene.
- *Extreme long shot* : A shot that includes more than the scene, usually to establish location or geography that is Important to the scene

#### C. Camera Movement

The camera movement shapes and informs a shot’s meaning. Basic camera moves include three actions: pans, tilts, and tracks. In general, most complex camera moves are simply mixtures of these basic components. A camera pans when it rotates horizontally, either from left to right or from right to left, normally establishing a scene. The camera rotates vertically to tilt, either from up to down or from down to up. In a tracking shot, the entire camera moves, rather than simply changing the direction of its focus to provide detail. These moves provide 6 degrees of freedom allowing the camera to position correctly as shown in Figure 2.

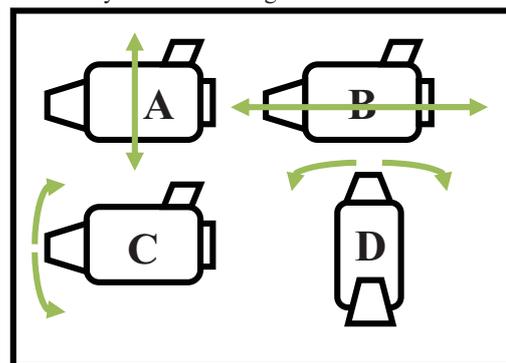


Figure 2. Camera movement, A Boom Movement, B Dolly, C Tilt, and D Pan

#### IV. IMPLEMENTATION

##### A. Methodology Overview

In this paper, we perform several step to process the behavior trees for camera in our machinema system.

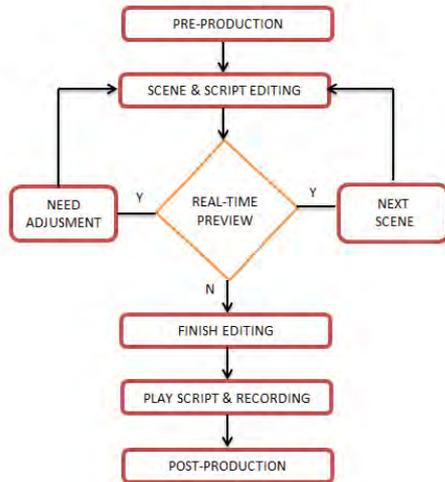


Figure 3. Machinema Workflow Process

Figure 3 shows how our system works. Pre-production process includes the 3D character modeling, material editing, texturing and pre-render process. Scene and script editing are the process creating the 3D environment and story line. In the real time preview we implemented the behavior trees for camera using trigger for our actor and camera system.

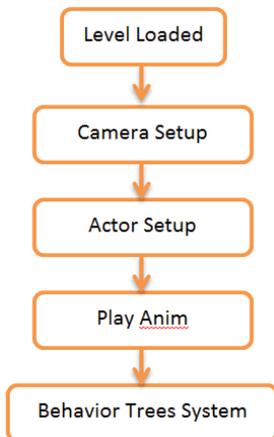


Figure 4. Sub System in Real Time Preview Process

While we created level for 3D environment scene for machinema production we also set up camera and actor according to the script created before. After all of the camera and actor ready, we can play animation according to the script, while animation is playing if some actor triggered special events, and then behavior trees are executed.

##### B. Behavior Trees for Single Camera

To accommodate the diverse needs of shot, the camera will have a complex movement. A behavior tree is a simple data structure that contains a chart or image to describe a complex action. We have used the Behavior trees to set the camera movement. The Chart of Behavior trees using the logic "AND / OR" in action, it's have a form of a statement Node and various commands to implement a variety of complex actions, in this situation like our project that means a wide range of idioms shot that can be taken by the cameramen.

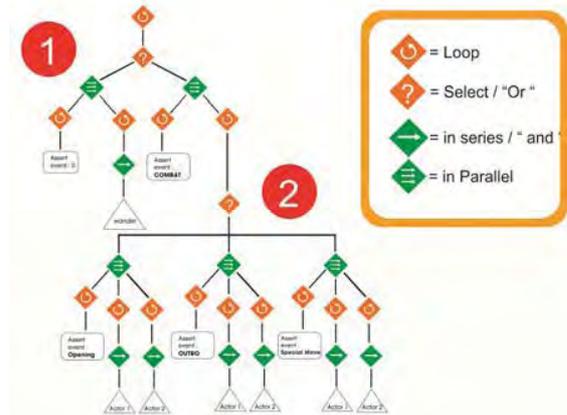


Figure 5. Behavior trees for single camera

Figure 5 shows the Behavior trees on one camera. Chart begins with the loop "and then followed by a" selector ". In the first condition, the camera is in condition to choose which of the branches that will be run. White diagrams mean that there are certain conditions that must be checked, in this case a camera that behaves as an agent will check what events are happening and give report to the selectors both conditions fail or succeed. Selector will attempt to execute each branch, and will stop if no condition report successful at every level. In the first condition, the left diagram is an example of where the camera does not accept assignment and the camera do the right diagram assignment of "Combat". Parallel Box indicates that the l execution run together, so the first condition in the picture above, on the left diagram when there is the assertion that there is no event happens then the camera will "Wander" until white box success in sending report selector. This enforces constraints on the cameras that the parallel node has one child that is constantly enforcing some constraints on the execution of its other child.

An object used in our study is the placement of the camera in a fighting game, the fighting game, usually beginning with the opening shot - a particular shot to make things more dramatic in accordance with the rules of Cinematography. When the character fight each other, sometimes can use a special moves that require the camera takes a particular shot, as well as closing the game. From Figure 5 on the condition that the two subsidiaries, Selector will select the conditions which will be run by the camera, the

camera will decide whether to take a shot for the Opening, Special move or for closure.

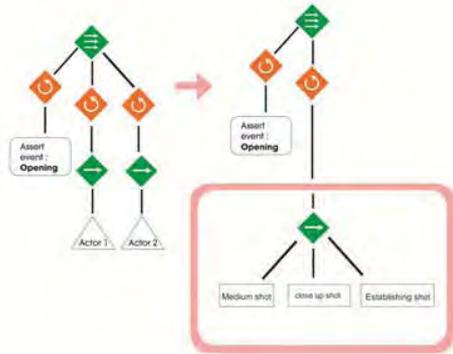


Figure 6. Behavior trees flow for shoot selection

Figure 6 is a graph that describes the behavior continued flow tree of figure 5, in Figure 6 we can see more detailed exposition of the camera, when “opening” event turn on the camera will run shot against the actor 1, then the camera will perform sequential range of idioms such as Medium shot, Close up shot, and establishing shot. Behavior trees also allow us to add the action to be selected with ease so that action will become more complex. After doing shot to actor 1, according to the graph, then the execution behavior also proceed to Actor 2.

### C. Behavior Trees for Secondary Camera

The use of behavior trees for secondary camera has the same principle behavior trees for one camera. The event triggered by the actor processed by behavior trees to select appropriate camera angle and camera shot for the action.

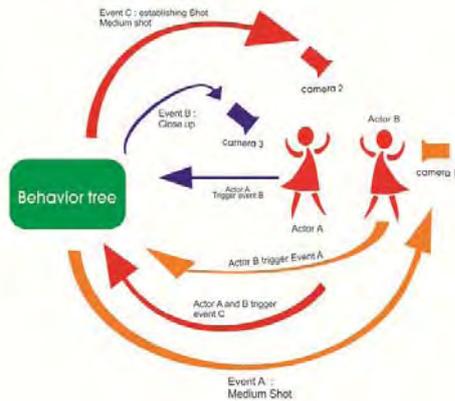


Figure 7. Behavior trees flow for shoot selection

Figure 7 above shows us how behavior trees work for multiple cameras. When actor A, triggered event B, its told the behavior trees system to select the appropriate camera angle

and placement during that event, in example when actor A has dialog event, the behavior trees select the Close-up shot for dialog event.

Actor B triggered event A, which is an “Ultimate” movement for actor B, so the camera select the medium shot for that action. Same when both actors triggered an opening event so the best shot for that event is Establishing shot.

## V. RESULT

Figure 8 shows screenshots of our test with two actors and two cameras. Using smart events, the shot is called depends on its priority for the scene. At the opening of the scene, the “establish shots” take place before any other shots. Camera 1 cuts to Camera 2 when another shot occurs. If the line of action happens to suitable for camera movement idioms, our system will automatically assign the movement to camera as transition between two shots. Figure 9 shows alternate shot from our camera system that shows close up and long shot camera shot.

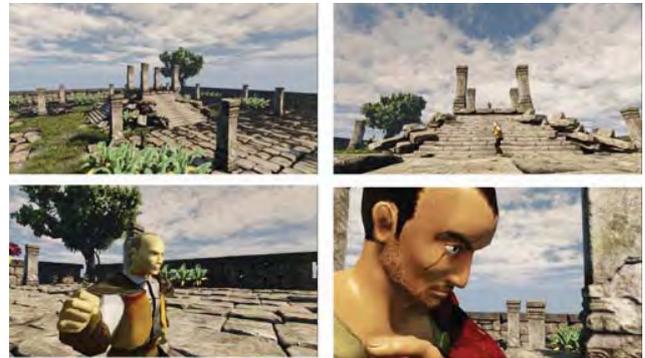


Figure 8. Screenshots of our test with two actors and two cameras

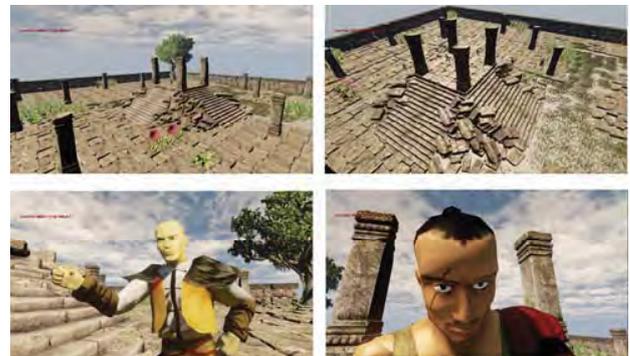


Figure 9. Alternate shots from the scene

## ACKNOWLEDGMENT

This work is supported in part by the Foundation of Beasiswa Unggulan.

## REFERENCES

- [1] D. Arijon. *Grammar of the Film Language*. Hasting House Publishers, 1976.

- [2] Christianson, D.B., Anderson, S.E., He, L.w., Salesin, D.H., Weld, D.S., Cohen, M.F.: Declarative camera control for automatic cinematography. In: Proceedings of the Thirteenth National Conference on Artificial Intelligence, AAAI 1996, vol. 1, pp. 148–155. AAAI Press, 1996.
- [3] He, L.w., Cohen, M.F., Salesin, D.H.: The virtual cinematographer: a paradigm for automatic real-time camera control and directing. In: Proceedings of the 23rd Annual Conference on Computer Graphics and Interactive Techniques, SIGGRAPH 1996, pp. 217–224. ACM, New York, 1996.
- [4] Markowitz, D., Joseph, T.K. Jr., Alexander S., Norman I.B. : Intelligent Camera Control Using Behavior trees. MIG 2011, LNCS 7060, pp 156-157 2011. Springer-Verlag, Berlin, 2011.
- [5] Christophe. L., Marc. C., Roberto. R., William. B., : The Director lens : An Intelligent Assistant for Virtual Cinematography. ACM 978-1-4503-0616-4, USA, 2011.
- [6] David K. Elson., Mark O. Riedl. : A Lightweight Intelligent Virtual Cinematography System for Machinema Production. AAAI Press, 2007.
- [7] Brian Hawkins. Real-Time Cinematography for Games. Charles River Media, INC. Hingham, Massachusetts, 2005.

# Analysis and Comparison of MD5 and SHA-1 Algorithm Implementation in Simple-O Authentication based Security System

Anak Agung Putri Ratna

Department of Electrical Engineering, Faculty of Engineering  
 Universitas Indonesia, Depok 16424  
 Tel : (021) 7270078. Fax : (021) 7270077  
 E-mail : ratna@eng.ui.ac.id

Ahmad Shaugi

Department of Electrical Engineering, Faculty of Engineering  
 Universitas Indonesia, Depok 16424  
 Tel : (021) 7270078. Fax : (021) 7270077  
 E-mail : ahmad.shaugi81@ui.ac.id

Prima Dewi Purnamasari

Department of Electrical Engineering, Faculty of Engineering  
 Universitas Indonesia, Depok 16424  
 Tel : (021) 7270078. Fax : (021) 7270077  
 E-mail : prima.dp@ui.ac.id

Muhammad Salman

Department of Electrical Engineering, Faculty of Engineering  
 Universitas Indonesia, Depok 16424  
 Tel : (021) 7270078. Fax : (021) 7270077  
 E-mail : salman@eng.ui.ac.id

**Abstract**—Simple-O, an automated essay grading application was developed at the Department of Electrical Engineering University of Indonesia. This application used MD5 + salt algorithm to perform protection for authentication password of users stored in its database. Unfortunately, due to a number of flaws contained in the MD5 algorithm, SHA-1 + salt algorithm was implemented in this application and then the comparison was carried out between those two algorithms. The experiments include time measurements and estimation of brute force attack for each algorithm. Processing time and CPU usage were also measured. In the brute force hash code scenario, it was tried to find plaintext from the ciphertext. In this scenario, both MD5 and SHA-1 was implemented and tested using Hashcat tool. The better the algorithm, the more time needed to brute force the ciphertext. In this scenario the password tested has 8 to 10 characters. The result from this testing shows that the implementation of SHA-1 algorithm is more robust against brute force attacks than MD5. The difference in processing time between SHA-1 + salt and MD5 + salt ranged from 0.001 seconds to 0.002 seconds for each length variation of the password from 8 to 10 character. While the difference in CPU usage is 0.545%, 0.985%, and 1.69% respectively for the password with 8, 9, and 10 characters length. These results indicate that while giving better security the implementation of the algorithm SHA-1 + salt does not impose on the performance of Simple-O application.

**Keywords**—Simple-O authentication system security, MD5 algorithm, SHA-1 algorithm, brute force attack, processing time, CPU usage

## I. Introduction

Development of web-based applications in the field of education has been growing rapidly. Various types of educational activities have been carried out by utilizing this technology. E-learning is the education system that uses electronic applications to support learning and teaching with

the use of the Internet media, computer network, or standalone computer. Along with the development of the current web technology, e-learning which originally only focused on distance learning system, has now been developed and has a broader scope, such as sites that provide a variety of learning materials, facilitates discussion, conduct online examination, etc.

With the continued development of e-learning today, the need for security systems is also increased. Therefore, various security methods has been applied to e-learning application, which aims to prevent attacks from outside or from inside that may be committed even by users of e-learning application itself.

Simple-O is one example of e-learning applications that is used to conduct online essay examination. This application was developed in the Department of Electrical Engineering, University of Indonesia. In this application, several methods were implemented, including in the authentication system which provide protection against username and password data. This system used MD5 algorithm to hash the password that was stored in the database. But with the increasing number of vulnerabilities found in the use of the MD5 algorithm, then the use of the MD5 algorithm in this system should be reviewed further. In this research we analyze the performance of SHA-1 algorithm in Simple-O authentication system and then compared with the implementation of the previous algorithm.

## II. Simple-O Authentication System and Hash Function

### A. Simple-O [1][2]

Simple-O is a web-based application, which is used to perform online examination as well as grading the testing

result automatically. To access the system, examinees or students must access the Simple-O Web and going through the authentication system by providing a correct username and password at first. To give security to the system, the passwords are stored in the database not in their original form, but encrypted. Encryption is needed so that if someone can penetrate the database, he/she will not be able to see all password stored in the database.

Simple-O implements hash function to protect its user passwords. With the implementation of hash algorithm, when a user logs in to the system, the system will find the hash code of the password, then the results will be compared with the value of the hash code that are stored in the database to authenticate the user. If it has the same hash code, then the user will be able to go to the home page of the Simple-O application.

**B. Hash Function [3]**

Hash function is one branch of cryptography, like encryption and message authentication code (MAC). The difference is that hash function does not require any special key to do the coding like on encryption and MAC. Hash function is a function that maps any message with the variety of length, into a fixed-length hash value, called a hash code, which is used as authenticators. Hash code is a function of all bits in any message, which is used to detect errors of the message. One bit changes in original message will produce a different hash code.

There are two approaches that can be used to attack the security of a hash function. Two kinds of approaches are cryptanalysis and the brute-force attack. A cryptanalysis attacks will exploit the logic weaknesses of the hash algorithm that are being used. While the strength of a hash function can be tested by brute force attack, depends on how long the hash code generated by an algorithm and the complexity of the process of the algorithm.

Hash algorithm is usually combined with the use of salt. Salt is an additional scrambler with a specified value that usually combined with the hash code in a form of a specific function. Value and function in salt can be determined freely. The use of salt is aimed to increase the complexity of the ciphertext hash result, making it more difficult to brute force. There are various types of hash function algorithms, while the MD5 and SHA-1 algorithm are the two most commonly used algorithms.

**1) Message Digest 5 [4]**

Message digest 5 or MD5 is one of message-digest algorithm that was developed by Ron Rivest in 1991. MD5 algorithm takes an input in any of length and produces an output in the form of a digest with the length of 128 bits. Input received by this algorithm will be processed in a block size of 512 bits, which will then be divided into 16 sub-blocks, each is 32 bits. Fig. 1 shows the processing of input on MD5 algorithm.

MD5 is an algorithm developed to replace its predecessor, the MD4 algorithm. At the beginning of its publication, the MD5 hash algorithm is one of the nicest, but at 2004 the

weaknesses contained in these algorithms began to be found [5] [6]. The weakness contained on this algorithm is the collision that easily discovered on the results of the MD5 hash. The collision is the existence of two different inputs but have the same hash result ciphertext. This weakness is caused by a wrong design of the MD5 algorithm itself, and then exploited so collision in this algorithm can be found quickly.

Since the MD5 algorithm is used in Simple-O applications, the MD5 weakness could also have an impact on applications Simple-O. If there is someone who actually does not have the right of access to the account as a lecturer, then by brute force attack against the application he could have discovered the password of the account of a teacher, and when he managed to find the account, he will have all privileges held by a lecturer on a variety of information contained in the system.

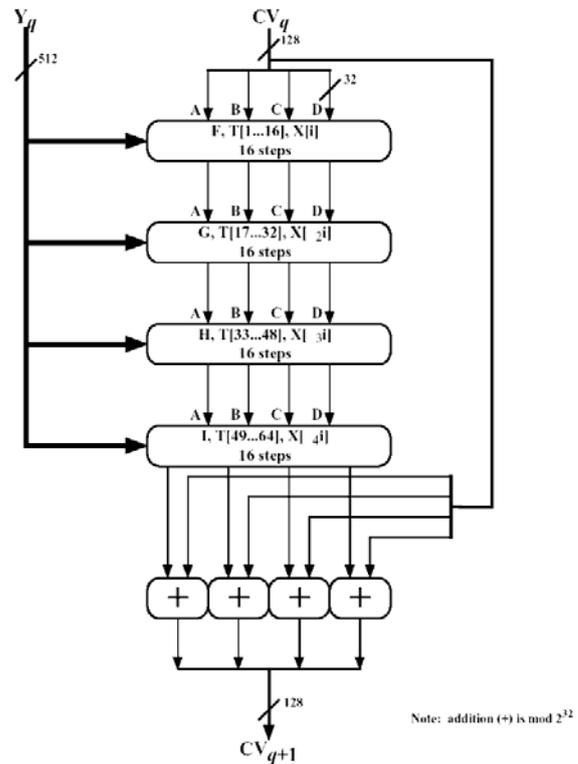


Fig. 1. The processing of the input at 512-bit block of the MD5 [3]

**2) Secure Hash Algorithm – [3] [6]**

SHA was developed by the National Institute of Standards and Technology (NIST) and published as a Federal Information Processing Standards (FIPS 180) in 1993. When the weakness of the algorithm is found, then the various revisions made to make a better algorithm, and the revision is published in FIPS 180-1 in 1995 and became a reference to the manufacture of the new algorithm called SHA-1.

SHA-1 input can accept a maximum of less than 64 bits, and 160 bits long output. This input restrictions that became one of the strengths of this algorithm, because the number of

input restrictions will reduce collisions that may occur in the use of these algorithms. SHA-1 processing input in a block size of 512 bits, and then divide it into 16 sub block that each measuring 32 bit. Fig. 2 displays the input processing algorithm SHA-1.

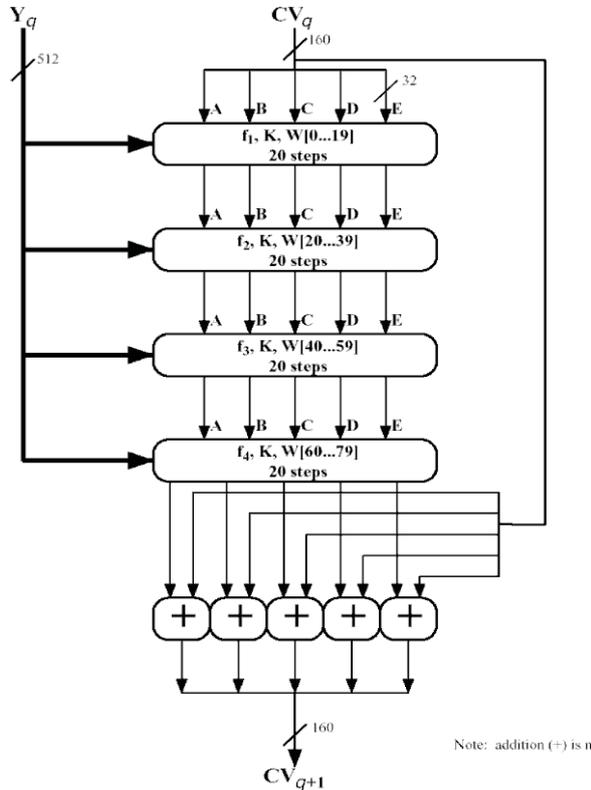


Fig. 2. The processing of the input at 512-bit block of the SHA-1 [3]

### 3) MD5 and SHA-1 Comparison

MD5 codes any stream of bytes into a 128 bit value while SHA1 codes any stream of bytes into a 160 bit value. Therefore the SHA1 will provide more security compared to MD5. The MD5 algorithm is **cheaper** to compute, however MD5 is found to be more vulnerable for collision attacks [5]. Comparison of both algorithms in terms of output length, memory usage, processing time, variance and time to brute force can be seen in more detail can be seen in Table I.

TABLE I. MD5 AND SHA-1 ALGORITHM COMPARISON [6]

Analyzing Subject	MD5	SHA-1	Better Algorithm
Output length	128 bit	160 bit	SHA-1
Memory usage	30060 byte	30267,6 byte	MD5
Processing time	17,233 ms	17,633 ms	MD5
Variance	$0,9013 \times 10^{-3}$	$0,4857 \times 10^{-3}$	SHA-1
Time for brute force	$6,8841 \times 10^{29}$ years	$2,8825 \times 10^{39}$ years	SHA-1

## III. Experimental Design

In this experiment we used two desktop PCs using as a local server and a client. Both PCs are connected in a local network. Both server and client PCs using AMD Athlon CPU, 3GHz and DDR1 memory, 1 GB. Besides these two PC, also used a standalone PCs that are not connected to the network. This PC is used to perform brute-force testing of the ciphertext of the algorithm MD5 and SHA-1 so that it can find the original plaintext from the ciphertext. This PC uses Intel® Core™ 2 Duo E7400, 2.8GHz, and DDR3 memory, 2 GB.

From the software side, some of the supporting software is used to establish a testing system and used during the test. The software is the OS Ubuntu 11.10 - Oneiric Ocelot and LAMP, which is used to form a local network for testing, and Hashcat to brute force a hash code.

## IV. Comparison and Analysis

### A. Brute Force Testing

In this scenario, we conduct brute force attack against the ciphertext from various passwords with a length of six to nine characters. The goal is to measure how long it took to find the plaintext from a ciphertext when a brute force attack is performed against the hash code stored in Simple-O database. The test was performed by using Hashcat software.

There are two kinds of results from this testing—the testing time and the estimated time of the brute force attack. The testing time is the time when the test results obtained from the process of brute force until it gained the original plaintext from the ciphertext that was brute forced. The testing time results are obtained from the process of brute force to plaintext with a length of 6 characters, both hashed with SHA-1 or MD5 algorithm. For plaintexts which are greater than six characters, we took the estimated time only. This is because the process for brute force attack from the password which is longer than six characters will takes a very long time.

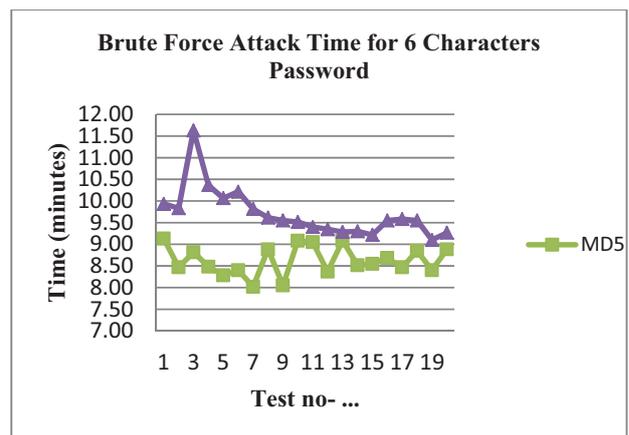


Fig. 3. Time comparison of brute force testing against 6 characters password

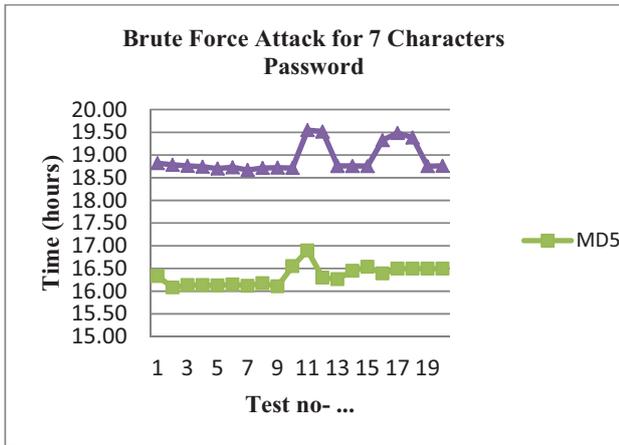


Fig. 4. Time comparison of brute force testing against 7 characters password

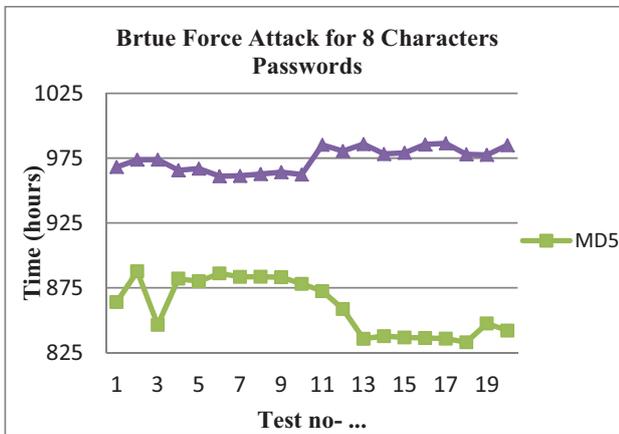


Fig. 5. Time comparison of brute force testing against 8 characters password

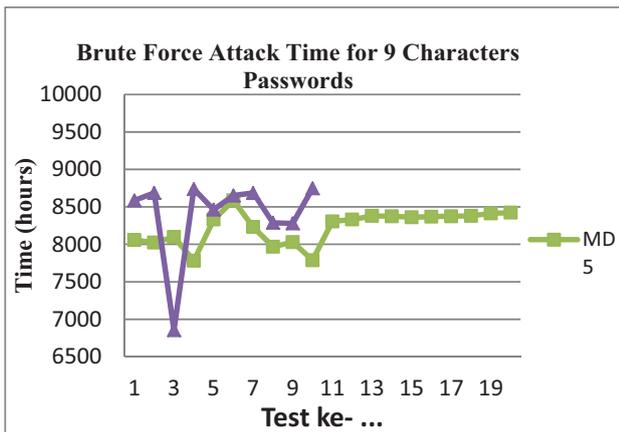


Fig. 6. Time comparison of brute force testing against 9 characters password

TABLE II. AVERAGE AND DIFFERENCE OF TIME AND ESTIMATION TIME FROM BRUTE FORCE TESTING

Characters Long	Average Time		Differences	Explanation
	MD5	SHA-1		
6 characters	8.62	9.71	1.08	In minutes
7 characters	16.34	18.92	2.59	In hours
8 characters	860.51	974.06	113.54	
9 characters	8229.95	8397.80	167.86	

Fig. 3 displays the time to brute force the password of 6 characters. Fig. 4 to Fig. 6 show the estimated time for a brute force password each 7, 8, and 9 characters. While Table II displays the average and the difference in estimation time to brute force. It can be seen that in the testing for 6 characters, the time difference is not too long, though the results still indicate that a brute force for SHA-1 takes longer. When performing a brute force password with a length of 7, 8 and 9 characters, the brute force time is getting longer. The difference in estimation time becomes the parameter that shows the complexity and strength of SHA-1 algorithms which is better when compared with MD5.

One thing that should still be considered, the process of a brute force itself is not necessarily in accordance with the estimation time. It could be faster or even longer than the estimation time. But estimation time can be used as a parameter to indicate the strength of each algorithm.

*B. Processing Time Measurement*

This scenario aims to measure the length of processing time for a user to log in to the Simple-O applications. This testing shows a comparison results from the implementation of MD5 and SHA-1 in Simple-O. This scenario was conducted with 4 kinds of combinations of hash, which are MD5, SHA-1, MD5 with salt, and SHA-1 with salt. In each implementation of the algorithm, we used a combination of three combinations of password length; 8, 9, and 10 characters as in the previous scenario.

TABLE III. AVERAGE AND DIFFERENCE OF TIME AND ESTIMATION TIME FROM BRUTE FORCE TESTING

Algorithm	Average Times (seconds)		
	8 Characters	9 Characters	10 Characters
MD5	0.02846675	0.02860271	0.02885417
MD5+salt	0.02817892	0.02812147	0.02806399
SHA-1	0.02948047	0.02920856	0.02929798
SHA-1+salt	0.02957196	0.03002721	0.03001589
<b>Differences of SHA-1+salt and MD5+salt</b>	<b>0.00139304</b>	<b>0.00190574</b>	<b>0.0019519</b>

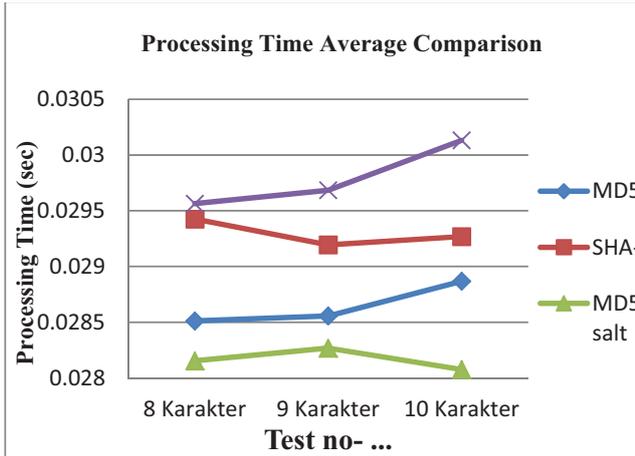


Fig. 7. Comparison of average processing time

Table III and Fig. 7 show the average and the difference of processing time. Based on the above test results, the time difference that occurs in every variation, both algorithms and passwords have margin in the range of  $10^{-4}$  seconds. Due to the very small difference, it can be concluded that the processing time required for the implementation of the MD5 algorithm, salt + MD5, SHA-1 and SHA-1 + salt tend to be similar. Therefore we conclude that the implementation of SHA-1 with salt in Simple-O will not overload the system.

### C. CPU Usage Measurement

In this testing we measure the CPU usage when a user log in to Simple-O. This testing will show a comparison of CPU usage in the implementation of MD5 and SHA-1 in Simple-O application. Same as the previous scenario, this scenario conducted with 4 kinds of combinations of hash algorithms which are MD5, SHA-1, MD5 with salt, and SHA-1 with salt. In each implementation of the algorithm, we used three combinations of password length; 8, 9, and 10 characters as in the previous scenario.

TABLE IV. AVERAGE AND DIFFERENCE OF CPU USAGE

Algorithm	Average CPU Usage (%)		
	8 Characters	9 Characters	10 Characters
MD5	9.555	9.955	10.565
MD5+salt	9.845	10.285	10.96
SHA-1	10.355	10.955	12.4
SHA-1+salt	10.39	11.27	12.65
<b>Differences of SHA-1+salt and MD5+salt</b>	<b>0.545</b>	<b>0.985</b>	<b>1.69</b>

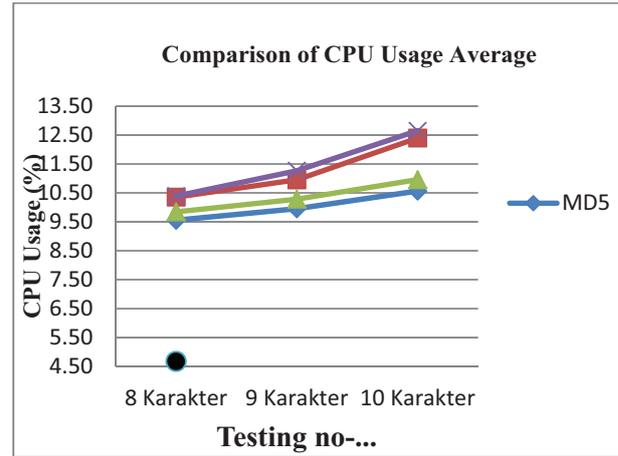


Fig. 8. Comparison of Average CPU usage

Table IV and Fig. 8 display the average and the difference in CPU usage for each password character length used, in any variation of hash algorithm for the login process. In this graph, we mark the idle processor which took CPU usage of 4.68%. This idle processor CPU usage can be considered as reference point. From Fig. 8 it can be seen in the graph that the MD5 algorithm used the lowest CPU resource for every variation of the average length character password, which is then followed by a MD5+salt, SHA-1 and SHA-1+salt.

The testing result shows that the use of SHA-1+salt will increase CPU resource usage when the login process. The difference between SHA-1 + salt compared to MD5 + salt in CPU usage for log in process is 0.56% for 8 character password, 0.99% for 9 character password, and 1.69% for a 10 character password. It is shown that the percentage difference increases along with password length. But the differences are not too significant for a password up to 10 characters long, which is 1.69%.

For passwords with more than 10 characters in length, the difference is predicted to increase. This may indicate that the use of the algorithm SHA-1 + salt will weigh Simple application-O, especially when many users are accessing the same time. However, the server load is predicted not going to be too big, given the length of the character of the password of each user will vary greatly, because not all users use passwords with a length of 10 characters or more, there are also users who use a password that is less than 8 characters.

## v. Conclusion

From the test results and analysis, we can conclude that test results and comparison of brute force attack for passwords of length 6, 7, 8, and 9 characters, indicating that the algorithm SHA-1 algorithm is stronger than MD5. The brute force attack time for 6 characters in SHA-1 was 9.71 minutes in average while in MD5 was 8.65 minutes. The estimated time of brute force attack for SHA-1 for 7, 8, and 9 characters passwords was 18.92 days, 974.06 hours, and 8397.8 hours each, while for MD5 was 16.34 hours, 860.51 hours, and 8229.95 hours.

SHA-1 has a processing time that is not much different than MD5, even relatively the same. MD5 algorithm has a processing time 0.029 seconds for each variation of the password length (8, 9, 10 characters), MD5 + salt for 0.028 seconds, SHA-1 for 0.029 seconds, while SHA-1 + salt has 0.03 seconds. While for the use of CPU resources, SHA-1 uses more resources than MD5, but the differences were not so big. MD5 algorithm used 9.56%, 9.96%, and 10.57% CPU resource for password length of 8, 9, and 10 characters respectively. While MD5 + salt used 9.85%, 10.29%, and 10.96%, SHA-1 used 10.36%, 10.96%, and 12.4%, and SHA-1 + salt used 10.39%, 11.27%, and 12.65 % respectively.

From the three testing's conducted, we can conclude that SHA-1 + salt gives better security for password protection in Simple-O compared to MD5 + salt while not overload the performance of existing systems, and the use of SHA-1 for securing authentication system hopefully can be used widely in the future to replace the use of MD5.

## References

- [1] Putri Ratna, Anak Agung; Budiardjo, Bagio; & Hartanto, Djoko. (2007). "SIMPLE: Sistem Penilaian Esei Otomatis untuk Menilai Ujian dalam Bahasa Indonesia". Jurnal Makara Seri Teknologi, volume 11, April 2007, ISSN : 1693-6698.
- [2] G. Handoyo, *Pengembangan Sistem Keamanan SIMPLE-O*, Skripsi, Universitas Indonesia, 2010. unpublished.
- [3] W. Stallng, *Cryptography and Network Principles and Practices*, 4th Ed., New Jersey: Prentice Hall, 2005.
- [4] R. Rivest, *The MD5 Message-Digest Algorithm*, Network Working Group, 1992.
- [5] X. Wang, D. Feng, X. Lai and H. Yu, "Collisions for Hash Functions," in *Crypto*, 2004.
- [6] A. A. Pamungkas, "Implementasi Algoritma Sistem Kriptografi MD5, SHA-1 dan RC4 pada Aplikasi Mobile Internet Berbasis Java," *Jurnal Penelitian dan Pengembangan Telekomunikasi*, vol. 11, no. 1, June 2006.

# Software Requirements Specification Analysis Using Natural Language Processing Technique

Agung Fatwanto  
Informatics Department  
UIN SunanKalijaga  
Yogyakarta, Indonesia  
agung.fatwanto@uin-suka.ac.id

**Abstract**—Understanding software requirements has been widely acknowledged as a crucial task in software development projects. This problem emerges since software requirements, which are originally specified using a particular natural language, are often ambiguous and incomplete. The condition will be completely different if the requirements are specified using formal language in which ambiguity and incompleteness could be obviously found and thus quickly anticipated. Transforming “natural” software requirements into a more formal specification may therefore reduce their ambiguity and incompleteness. This paper hence proposes a method to transform software requirements specified in a natural language to formal specification (in this context is object-oriented specification). The proposed method uses natural language processing technique.

**Keywords**—*software requirements specification; natural language processing; object-oriented*

## I. INTRODUCTION

Understanding software requirements during software development projects is an effortful task. It is common for requirements, which are normally specified using a particular natural language, adorned with ambiguity and incompleteness. Forming a shared view between stakeholders or potential users and developers hence requires significant works. Both parties have to share their internal view regarding the system under consideration in order to obtain a common understanding.

Technical difficulties, which normally occur during the understanding process, usually come from the fact that software requirements are specified in a particular natural language. Specifying requirements in a natural language frequently make them prone to ambiguity and incompleteness. Specifying requirements using a formal language, in the contrary, could raise their clarity and completeness. In most practices, however, software requirements are specified using a particular natural language due to its flexibility and simplicity.

This paper therefore proposes a method to transform software requirements that originally specified using a natural language to more formal specification in order to minimize ambiguity and incompleteness and, at the same time, maintaining the flexibility and simplicity of the old ways of specifying requirements using natural language. This paper is structured as follows: i) Section I discusses the background of this study, ii) Section II presents the other works on this subject, iii) Section III describes the proposed

method, and iv) Section IV discusses the applicability of the proposed method.

## II. LITERATURE REVIEW

A number of works on utilizing the natural language processing technique for analyzing software requirements specification have been conducted. These studies related to the translation of software requirements specified in natural language to formal specification. These studies mainly deal with the translation of software requirements specified using natural language that does not consider the dynamic aspect of software system. My proposed method, on the other hand, offers a translation of a dynamic requirements specification (written in a scenario-like format) to formal specification (in this case is object-oriented model).

The methods as proposed by these studies, based on their utilized translation approach, can be classified into two category: translation using artificial intelligence theory (rule-based approach) and translation based on grammatical analysis (natural language processing approach).

The rule-based approach uses artificial intelligence theory as the tool for analyzing software requirements specification written in free (unconstrained) natural language. The objective of this approach is to derive formal from informal specification. Specification Acquisition From Expert (SAFE) [3], the Requirements Apprentice (RA) [4], and Specifier [5] are the example of method applying the rule-based approach. These methods use no linguistic analysis in translating the informal into formal specification.

Different from the rule-based approach, the natural language processing approach uses grammatical knowledge to analyze the software requirements specification written in free (unconstrained) natural language. The objective of this approach is also to derive a formal specification from the informal one. Conceptual Model Builder (CM-Builder) [6], LIDA [7], Language Extended Lexicon (LEL) [8], Metamorfosis [9], and Natural Language Processing (NLP) [10] are the example of method applying the natural language processing approach.

All of these methods, however, do not consider the dynamic requirements specification, which is actually an inherent part of software requirements specification.

## III. THE REQUIREMENTS SPECIFICATION ANALYSIS

As an effort to bridge the gap between flexibility and simplicity of “natural” requirements specification with clarity and completeness of formal specification, I propose a

requirements specification analysis method using natural language processing approach. Within this method, requirements specification text will be analyzed using syntactic analysis (or parsing) technique.

A stream of text from requirements specification will be parsed using a particular syntactic analysis method. The parsing activity is performed to sentences that compose requirements specification. This activity is conducted in order to classify a sentence into its grammatical constructing elements.

Requirements specified in natural language will be parsed using Reed-Kellogg sentence diagramming system [11]. According to the Reed-Kellogg system, a sentence can be analyzed to obtain its simple structure following the particular schemata:

*Sentence* ← *Subject* + *Predicate*

The predicate must contain a verb that requires other sentence elements (object) in order to complete the predicate. The object is normally a direct object. Nevertheless, the object can be in the form of a predicate noun or adjective. In cases where other sentence composing elements (such as adverb, adjective (including article), or prepositional phrase) are found, these elements are only act as the descriptor for the main elements. A sentence, based on the Reed-Kellogg system, can further be analyzed according to the following schemata:

*Sentence* ← *Subject* | *Verb* | *Direct Object*; or

*Sentence* ← *Subject* | *Copula* | *Predicate*

An example for the first type of sentence is "PDA searches elector" while an example for the second is "PDA is expensive".

By adopting the Reed-Kellogg system, requirements that are specified in a natural language will then be filtered into a constrained natural language. The format is as follows:

*Requirement* ← *Subject* + *Verb* + *Target* + [*Way*]

A requirement represents an action, an activity performed by an agent who affects/changes one state of an entity/object (an agent or a resource). Subject represents the agent who executes the behavior (the activity prescribed by the verb). Verb describes the activity taken by the agent (subject). Target can be physical or conceptual entity (object). The entity (object) has a number of properties (attributes), which will be affected by the activity. Meanwhile, way defines the way in which an action will be taken. Way can either defines a manner or a utilized instrument (a means) to take the prescribed action. In this specification format, the subject, the verb, and the target are required whereas the way is optional.

Requirements specification example, which describes a system for tracing electors' participation in a particular election using handheld devices called as the Voter Tracking System (VTS), is used for this paper. The example is taken from a real-world industrial project. A snippet of the VTS requirements specification example is written as follows:

*"Normally when an elector attends a polling place to vote, a polling official will search a paper copy of the electoral roll for the name and address of the elector. Once the elector's details are found the polling official places a small black mark next to the name, and/or rules through the name, to*

*show that the elector has attended to vote. The copy of the electoral roll issued to each official is called a certified list.*

*Once the election is complete, the Electoral Commission compares all the certified lists to establish who has voted. In recent elections, the certified lists have been scanned to improve the accuracy and time taken for the comparison. After the 2004 election the ACT Electoral Commission engaged a company to scan all 918 certified lists. The cost of printing and storage of these certified lists was considerable and the use of large paper lists was becoming cumbersome. Further, after the 2004 ACT election, the ACT Electoral Commission experienced accuracy problems with the scanning of the lists, resulting in a much higher number of non-voter notices being issued than was necessary. (Note: Voting is compulsory).*

*The Commission identified two key business problems:*

- *The need for a faster, more efficient and cheaper method of searching for and marking voter's names on the electoral roll, and*
- *The need for a more cost effective technique to accurately and efficiently access information as to who has voted, post election"*

Using the filtering format as previously proposed, the "natural" requirements specification will then need to be analyzed and re-specified in order to be aligned with the proposed specification system. An example that can be derived from the "natural" VTS requirements specification is written as follows:

*(PDA)<sub>s</sub> (searches)<sub>v</sub> (elector)<sub>t</sub> (based\_on\_family\_name)<sub>w</sub>*

In this example, PDA (personal digital assistance) acts as the subject. It executes the behavior as prescribed by the verb (in this case is searching). Elector is the entity (object) that will be affected by the searching activity. Meanwhile, the term "based\_on\_family\_name" prescribes the way in which searching activity will be performed.

The proposed method also further defines the structure for specifying software requirements, in addition to the specification of clause or sentence, by adopting a scenario-like structure. There are two reasons why a scenario-like structure was adopted. *First*, it can incorporate the dynamic aspect of software systems. It is important since the study aims to accommodate the way to specify the dynamic parts of software systems within the proposed method. *Second*, scenario-like structure is an intuitive and familiar medium even for novices.

The proposed method also defines that, beside specified in a scenario-like structure, requirements also have to be expressed in the form of event-state-action structure. This kind of structure can be used to specify the dynamic parts of software systems. It was designed following the way to specify scenario. In this case, event is an incident that causes the activation of one or more actions. An action is an activity performed by an agent who affects/changes one state of an entity/object (an agent or a resource). Meanwhile, a state is a condition of a particular entity/object (an agent or a resource). Each state represents a phase in the lifecycle of an entity/object. A state can be categorized as initial and final

state. An initial state defines a pre-condition that has to be attained prior to the execution of an action. Meanwhile, a final state defines a post-condition that is attained after the execution of an action. This type of specification format describes that an action is triggered by an event whereas an event causes one or more actions. An action changes the condition of a state.

An example for software requirements specification following this format is provided in Table 1. In this table, an initial scenario for identifying elector during a particular election using PDA is specified. If we analyze the requirements as specified in Table 1, we can see that it forms a flow of a scenario. Taken from the example, when the current state of the system is PDA shows home screen and if there is an event that PO enters name then the action taken is that PDA will search elector. Next, if there is an event that PDA found elector at the time when the PDA searching elector, then the system will take an action to show elector. This flow of scenario can be easily followed from the event-state-action list specification.

TABLE I. SCENARIO SPECIFICATION FOR IDENTIFY ELECTOR

Event	State	Action		
		Agent	Activity	Object
PO enters name	{PDA} shows  home_screen	{PDA}	searches	elector
{PDA} found elector	{PDA} searches elector	{PDA}	shows	elector
PO clicks  home_button	{PDA} shows elector	{PDA}	shows	home_screen

There is a rule that needs to be imposed when using this specification format. *First*, any agent or object which represents the system being developed, such as PDA in this example, must be written between curly bracket ({...}). *Second*, any agent or object that represents the interface, such as home\_button and home\_screen in this example, has to be written between vertical bar (|...|). The reason for having this rule is to distinguish the elements of the system from the systemic objects (the system being developed and the interface) which will be crucial during the translation process. The translation method is, however, beyond the scope of this paper.

As the specification written in Table 1 is a type of initial version, hence it needs to be revised in order to come up with a more complete, consistent, and unambiguous requirements. According to the proposed method, the initial scenario should be: (i) elaborated and refined, (ii) its conflicts need to be identified and resolved, and (iii) its feasibility needs to be studied. The result of these refining processes is provided in Appendix A.

#### IV. DISCUSSION

The proposed method was designed to transform software requirements specified in natural language format into more formal specification. Using the proposed set of rules adopted from the Reed-Kellogg system, a "natural" requirements specification can be transformed in order to

obtain a set of formal requirements specification written in a scenario-like format.

The proposed method is actually an extension of work from [12] and [13] in which these studies face a couple of limitations. The particular limitation that is related to this study is that the methods as specified in these papers can only translate software requirements specified in a specific format (in this context is the Concern-Aware Requirements Engineering format). The capability to translate software requirements specified in any other formats is beyond the scope of these papers. This study therefore proposes a method to transform "natural" requirements specification into a more formal format that hopefully can be further translated into object-oriented models as specified in [13]. This study, however, still lacks of a clear procedure on how to map from a "natural" requirements specification written in a very flexible (loose) format into their associated formal specification.

As a recommendation for future work, a study on how to clearly map a sentence found in the "natural" requirements specification with their counterpart in the transformed formal specification should be conducted.

#### REFERENCES

- [1] S. Mellor and M. Balcer, Executable UML: A Foundation for Model-Driven Architecture. Indianapolis, IN: Addison-Wesley Professional, 2002.
- [2] A. Fatwanto, "Specifying Translatable Software Requirements Using Constrained Natural Language," in Proceeding of the 7<sup>th</sup> International Conference on Computer Science and Education, IEEE Computer Society, 2012, pp. 1047-1052.
- [3] R. Balzer, N. Goldman, and D. Wile, "Informality in Program Specification," IEEE Trans. On Software Engineering. US, vol. 4, no. 2, March 1978.
- [4] H.B. Reubenstein and R.C. Waters, "The Requirements Apprentice: Automatic Assistance for Requirements Acquisition," IEEE Trans. On Software Engineering. US, vol. 17, no. 3, March 1991.
- [5] K. Miriala and M.T. Harandi, "Automatic Derivation of Formal Specification from Informal Description," IEEE Trans. On Software Engineering. US, vol. 17, no. 10, October 1991.
- [6] H. Haramain and R. Gaizauskas, "CM-Builder: An Automated NL-Based Case Tool," in Proceeding of the 15<sup>th</sup> International Conference on Automated Software Engineering, IEEE Computer Society, 2000, pp. 45-53.
- [7] S.P. Overmyer, B. Lavoie, and O. Rambow, "Conceptual Modeling Through Linguistic Analysis Using LIDA," in Proceeding of the 23<sup>rd</sup> International Conference on Software Engineering, USA, IEEE Computer Society, 2001, pp. 401-410.
- [8] L.M. Cysneiros and J.C.S. do Praitto Leite, "Non-Functional Requirements: From Elicitation to Conceptual Models," IEEE Trans. On Software Engineering. US, vol. 30, no. 5, 2004, pp. 328-350.
- [9] I. Diaz, J. Sancez, and O. Pastor, "Metamorfosis: un Marco Para en Analisis de Requisitos Funcionales," in Anais do Workshop en Engenharia de Requisitos, pp. 233-244, 2005.
- [10] A. Montes, H. Pacheco, H. Estrada, and O. Pastor, "Conceptual Model Generation from Requirements Model: A Natural Language Processing Approach," in Proceeding of the 13<sup>th</sup> International Conference on Application of Natural Language to Information Systems, UK, Lecture Notes in Computer Science, Vol. 5039, 2008, pp. 325-326.
- [11] A. Reed and B. Kellogg, Higher Lessons in English., 1877. (In Wikipedia: Sentence Diagram, en.wikipedia.org/wiki/Sentence\_Diagram, last accessed: April 21<sup>st</sup> 2013).
- [12] A. Fatwanto, "Translating Software Requirements from Natural Language to Formal Specification," in Proceeding of the International Conference on Computational Intelligence and Cybernetics, IEEE Computer Society, 2012, pp. 148-152.
- [13] A. Fatwanto, "Software Requirements Translation from Natural Language to Object-Oriented Model," in Proceeding of the

## APPENDIX

The following table specifies the revised version of requirements for “identifying elector”.

Event	State	Agent	Activity	Object	Action	Way
PO clicks  screen(clicked)	{PDA} shows  home screen	{PDA}	responses	instruction	(*if screen(clicked)= search-button  then {PDA} generates search(family, given)*)	
{PDA} generates search(family, given)	{PDA} responses instruction	{PDA}	searches	elector(family, given)	(*(*if (family)!=null and (given)!=null then (*for each elector (*if elector(family)=(family) and elector(given)=(given) then {PDA} writes [electorID]*)*) (*(*if#[electorID]=1 then {PDA} generates found(electorID)* else (*if #[electorID]++=+1 then {PDA} generates multifound[electorID]*) else (*if #[electorID]=0 then {PDA} generates notification(not found)*)*)* else (*if (family)!=null and (given)=null then (*for each elector (*if elector(family)=(family) then {PDA} writes [electorID]*)* (*(*if#[electorID]=1 then {PDA} generates found(electorID)* else (*if #[electorID]++=+1 then {PDA} generates multifound[electorID]* else (*if #[electorID]=0 then {PDA} generates notification(not found)*)*)* else (*if (family)=null then {PDA} generates notification(family)*)*)	
{PDA} generates found(electorID)	{PDA} searches elector(family, given)	{PDA}	reads	electorate(electorID)	{PDA} reads elector(electorID)---electorate(electorateID) and generates show elector(electorID, electorateID)	
{PDA} generates show elector(electorID, electorateID)	{PDA} reads electorate(electorID)	{PDA}	shows	elector(ALL- ATTRIBUTES)	(*(*if (electorateID)=0 then {PDA} shows(background color=red) elector(ALL- ATTRIBUTES)*) else (*if (electorateID)=1 then {PDA} shows(background color=green) elector(ALL- ATTRIBUTES)*) else (*if (electorateID)=2 then {PDA} shows(background color=blue) elector(ALL- ATTRIBUTES)*)*)	
{PDA} generates multifound[electorID]	{PDA} searches elector(family, given)	{PDA}	reads	elector(electorID, status)	(*for each [electorID] {PDA} writes[(electorID, elector(status))]*) and {PDA} generates show [(electorID, status)]	
{PDA} generates show [(electorID, status)]	{PDA} reads elector(electorID, status)	{PDA}	shows	[elector(family, given, address)]	(*for each [electorID, status] (*(*if (status)=voted then {PDA} shows(font color=red) elector(family, given, address)*) else (*if (status)=not-voted then {PDA} shows(font color=black) elector(family, given, address)*)*)*	

{PDA} generates notification(not found)	{PDA} searches elector(family, given)	{PDA}	shows	notification(not found)	
{PDA} generates notification(family)	{PDA} searches elector(family, given)	{PDA}	shows	notification(family)	
PO clicks  screen(clicked)	{PDA} shows elector(ALL-ATTRIBUTES)	{PDA}	responses	instruction	(*if (clicked)=OK-button  then {PDA} generates  home-screen *) else (*if (clicked)=marking-voter then {PDA} generates marking(electorID)**)
PO clicks  screen(clicked)	{PDA} shows [elector(family, given, address)]	{PDA}	responses	instruction	(*if (clicked)=electorID then {PDA} generates found(electorID)*) else (*if (clicked)= home-button  then {PDA} generates  home-screen *)
PO clicks  screen(clicked)	{PDA} shows notification(family)	{PDA}	responses	instruction	(*if (clicked)=OK-button  then {PDA} generates  home-screen *)
PO clicks  screen(clicked)	{PDA} shows notification(not found)	{PDA}	responses	instruction	(*if (clicked)=OK-button  then {PDA} generates  home-screen *)
{PDA} generates found(electorID)	{PDA} responses instruction	{PDA}	reads	electorate(electorID)	{PDA} reads elector(electorID)---electorate(electorateID) and generates show elector(electorID, electorateID)
{PDA} generates  home-screen	{PDA} responses instruction	{PDA}	shows	home screen	

# P2P Locality Awareness Architecture In Ethernet Passive Optical Networks

Andrew Tanny Liem  
Department of Computer Science  
Klabat University  
Manado, Indonesia  
andrew.t.liem@gmail.com

**Abstract**— The P2P live streaming nowadays becomes more popular and begins to take a larger share of bandwidth together with the Internet video calling. Furthermore, a large scale peer-to-peer (P2P) live streaming has recently been successfully and commercially deployed to provide either live streaming or on-demand video streaming. Cisco predicts that 60% of video traffic worldwide will be consumed by these P2P applications in 2015, which is enough to make any Internet Service Provider (ISP) straitened. In particular, the major challenge that has received significant attention is that many network oblivious P2P applications without locality awareness of ISP boundaries that lead to inefficient Internet resource utilization due to the Inter-ISP traffic cost. Consequently, we propose P2P locality awareness architecture in Ethernet Passive Optical Network (EPON) that mitigates Inter-ISP traffic by optimizing peering locality for P2P live streaming. We design mechanisms in ONU. These mechanisms can reduce inefficient Internet resource utilization at the server sides and improve each peer QoS.

**Keywords**—P2P Live streaming; Locality Awareness; EPONs; QoS;

## I. Introduction

In recent times, peer-to-peer (P2P) system begins to generate huge amount of bandwidth due to their popularity and nature. Among P2P applications, the P2P live streaming applications whose resilience and performance depend on the random connections across the network, consume the biggest part of the available resources provided by the Internet Service Providers (ISPs) infrastructure and increase the market demand for more stable and faster broadband services [1]. Recently P2P live streaming systems are becoming the next Internet killer applications as testified by the growing success of commercial systems, such as PPLive, SopCast and UUsee [2]. They allow to “watch television” over the Internet, granting to anyone to become a content provider by limiting the infrastructure costs, while giving the chance to break broadcasting constraints so that anyone can watch any content anywhere, at any time. Although it gives huge opportunities for the ISPs, however it comes together with the large network engineering problems such as costly routes and infrastructure.

The Inter-ISP connections could have been avoided if the P2P systems would not choose random neighbors [3] and another

aspect of the problem should be considered is that P2P live streaming application is becoming popular with highly sensitive QoS and Quality-of-Experience (QoE) requirements. In order to tackle aforementioned problems that arise with P2P live streaming in particular, a solution could be reached if the P2P systems would get modified and adopt an ISP-friendly behavior. ISP-friendliness means that the network applications show low levels of redundancy and costly traffic. The level of ISP-friendliness is often traded with system performance if pushed too far. It simply means that the choice of neighbors in P2P overlays should be designed carefully to exploit the locality for the underlying routing strategy. Therefore, many network service providers begin to control P2P traffic by implementing the ISP-friendly design approach in order to reduce the Inter-ISP traffic cost. ISP-Friendly approaches aim to mitigate Inter-ISP traffic by optimizing peering locality since the peers from the same ISP (i.e., Intra-ISP traffic) respond faster to the requesting peer. This also in conjunction with current studies showing that in P2P live streaming more than 80% of a peer’s downloaded streaming traffic in popular channels are served by peers in the same ISP whereas the unpopular channels are less than 50%. In other words, most of the P2P live streaming applications have achieved strong ISP-friendly awareness since the level of traffic locality with respect of popular channels is very high. This fact is also somehow connected to the study in [4] that the localized P2P is projected to grow 65% of IP video traffic and 60% of all Internets by 2013. Figures 1 and 2 show the total predicted localized P2P video until 2013 and the localized P2P that traverses in the access network only, respectively. It can be observed that in 2013 the total localized P2P video is exceeding 20 Exabytes/month. It is also shown that with the increasing number of P2P video titles available from each subscriber the bandwidth utilization is also increasing.

However, up until now, most studies in EPONs have not addressing the the traffic locality awareness, which very important issue since P2P live streaming traffics that served by peers in the same EPON are gradually increasing. By keeping the P2P streaming traffic localized, it can vastly decrease the bandwidth load at the server side and Inter-ISP traffic cost. To our knowledge, there are few studies discuss on implementing the Intra-ISP traffic mechanism in the EPONs system. Thus, architecture with sophisticated resource management that

supports not only Intra-ISP traffic mechanism but also provides better QoS and QoE, particularly for P2P live streaming is required. Consequently, we propose P2P locality awareness architecture in Ethernet Passive Optical Network (EPON) that mitigates Inter-ISP traffic by optimizing peering locality for P2P live streaming. We design mechanisms in ONU which consists of a buffer-map with a routing table. These mechanisms can reduce inefficient Internet resource utilization at the server sides and improve each peer QoS. Moreover, we exploit the passive splitter in order to support Intra-ISP traffic communications (i.e., ONU-to-ONU or Peer-to-Peer) in the same ISP. Simulation results have shown that our propose architecture has lower packet delay and bandwidth waste.

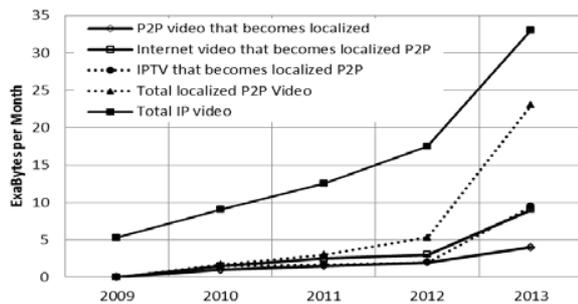


Figure 1(a) Localized P2P Projected [4]

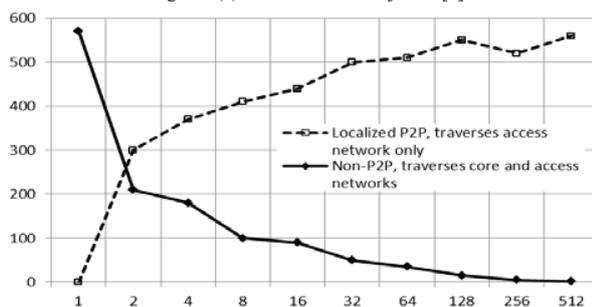


Figure 1(b) Localized P2P Traverses in Access Network [4].

However, up until now, most studies in EPONs have not addressing the the traffic locality awareness, which very important issue since P2P live streaming traffics that served by peers in the same EPON are gradually increasing. By keeping the P2P streaming traffic localized, it can vastly decrease the bandwidth load at the server side and Inter-ISP traffic cost. To our knowledge, there are few studies discuss on implementing the Intra-ISP traffic mechanism in the EPONs system. Thus, architecture with sophisticated resource management that supports not only Intra-ISP traffic mechanism but also provides better QoS and QoE, particularly for P2P live streaming is required. Consequently, we propose P2P locality awareness architecture in Ethernet Passive Optical Network (EPON) that mitigates Inter-ISP traffic by optimizing peering locality for P2P live streaming. We design mechanisms in ONU which consists of a buffer-map with a routing table. These mechanisms can reduce inefficient Internet resource utilization at the server sides and improve each peer QoS. Moreover, we exploit the passive splitter in order to support

Intra-ISP traffic communications (i.e., ONU-to-ONU or Peer-to-Peer) in the same ISP. Simulation results have shown that our propose architecture has lower packet delay and bandwidth waste.

## II. RElated Work

According to [5], the ISP-friendly approaches can be divided into three taxonomies i.e., ISP-Friendly P2P approach, ISP approach and ISP-P2P cooperation approach. In ISP-Friendly P2P design the construction of P2P overlay topologies is one of the primary concerns. This affects both Inter-ISP traffic and user perceived service quality, since overlay connections among peers are determined by the way peers obtain content from its neighbors. In general, ISP-friendly P2P schemes attempt to direct peers to connect to adjacent neighbors within the same ISP for traffic localization. As for the ISP approach simply means that the ISPs can proactively help to regulate and guide P2P applications to reduce Inter-ISP traffic cost and increase the desired network efficiency. Lastly, the ISP-P2P cooperation approach is the collaborative traffic control between P2P applications and ISPs in achieving efficient utilization of network resources without sacrificing application performance, given that ISPs are best positioned to determine the locality, link costs, and ISP policies. Relevant information including topologies, policies, routing, and traffic pattern are accessible for P2P application trackers or peers via the information interfaces provided by ISPs.

On the other hand, recently optical network is regarded as one of the best solutions in the access networks due to large amounts of bandwidth only in one single fiber. By 2015, fiber will cover 20-30 percent of all households and 30-50 percent in 2020 [6]. Currently, Japan, China and Korea are developing large-scale EPON deployments, which are built by multiple system operators [6]. By the end of 2011, Japan already has 21 million subscribers, followed by Korea and China, respectively. As for 2012, EPON networks have passed more than 60 million households, and more than 20 million broadband subscribers are served by EPON [6]. China Telecom has the fastest and biggest growing fiber-to-the-x (FTTx) network operators in the world, which on track to pass additional 30 million subscribers in 2012 [15]. EPONs representing the convergence between Ethernet and Fiber infrastructure have been discussed in IEEE 802.3ah as one of the extensions of Gigabit-Ethernet [7].

The EPON architecture consists of a centralized optical line terminal (OLT) and a number of splitters. The OLT connects to multiples associated optical network units (ONUs) over point-to-multipoint topologies to deliver broadband packets and reduce costs relative to the maintenance power. In addition, the OLT has the entire channel bandwidth to broadcast the control messages and data packets to each ONU since the directional properties of the splitter or coupler is used. However, in the upstream direction, the entire ONUs

must share the common transmission channel towards the OLT, and only a single ONU may upload upstream data in its transmission timeslot to avoid data collisions. Therefore, the IEEE 802.3ah standard has developed a Multipoint Control Protocol (MPCP), thus each ONU transmits within a dedicated timeslot and the OLT receives a continuous stream of collision-free packets from each ONU.

MPCP is merely a supporting protocol that facilitates the implementation of various bandwidth allocation algorithms in EPON. The MPCP relies on two Ethernet control messages, GATE and REPORT, to allocate bandwidth to each ONU. The GATE message is used by the OLT to allocate the upstream transmission window to each ONU and the REPORT message is used by ONUs to report its local queue-length to the OLT. An ONU can support up to eight priority queues as defined in 802.1q [8]. After receiving all the report messages based on queue state information from entire ONUs, the OLT executes a Dynamic Bandwidth Allocation (DBA) to calculate and allocate the timeslots to each ONU. The DBA plays a key role to provide more efficient bandwidth allocation for each ONU to share network resources and offer the better Quality of Services (QoS) for the end users.

Despite the abovementioned advantages of EPONs, there are still many challenges to supporting P2P live streaming in the EPONs. One of the issues is that due to the ISP-friendly approach, the traffic locality awareness becomes a key concern. Since 80% of most popular downloaded P2P live streaming channels are served by peers in the same ISP (i.e., Intra-ISP traffic). Moreover; video bandwidth will increase due to the evolution from HDTV formats towards super HD and ultra HD and 3D formats [9]. Nonetheless, recently most studies in EPON [10-13] only discussed on how to allocate the bandwidth without considering the importance of Intra-ISP traffic localization mechanism that can reduce not only the resource consumption at the server side, but also decrease the Inter-ISP traffic cost.

### III. System ARchitecture

Our high-level architecture contains three modules that are ONU modules, Star Coupler modules, and OLT modules. The architecture consists of  $N$  ONUs with extra receivers: one is to accept the downstream signal from OLT to ONUs tuned at 1550nm, the other is to accept the loop-back signal coming from the upstream direction tuned up at 1310nm; the 3:N star coupler (SC) with isolator for redirecting the packets among ONUs connected to the end users and the OLT.

#### A. OLT Modules

In OLT, the ISP information interface and P2P Locality Awareness DBA scheme for P2P lives streaming are proposed. The ISP information interface is the collaboration between ISP and P2P providers so that they can start exchanging messages such as the neighbor list that P2P providers send, newly join peers and so on. They also should

form the relationships satisfying the demands for inter/intra-domain reduction of ISP and guarantee the P2P streaming QoS. By implementing ISP Information interface, the OLT will try to reduce the traffic from each peer within its domain by discovering their Autonomous System (AS) number and Round-Trip-Time (RTT) estimation (e.g., hop time, distance, load balancing, etc). In other words, the peer most likely will prefer to connect with a local peer in the same AS or ISP with a small upload capacity than external peer with higher upload capacity. Therefore, the OLT will filter or block the inter-ISP traffic if there are local supplier peers for the request, thus reducing the inter-ISP cost yet increasing the QoS and QoE. Moreover, at every given time the OLT will send a signaling traffic to the ONU using the Single Copy Broadcast (SCB) so that each ONU can update its peers list for the routing mechanism.

The Dynamic Bandwidth Allocation (DBA) scheme can be distinguish into two paradigms, which are offline-paradigm and online-paradigm. In online-paradigm, although it has less control of channel transmission time, however the ONU is scheduled for upstream transmission as soon as the OLT receives the REPORT without waiting to receive the request from the rest of the ONUs. In contrast, the offline-paradigm has the capability to allocate the bandwidth fairly; however the OLT will begin bandwidth allocation computation after collecting the REPORT messages from all ONUs, thus introduce the idle period problems. Nonetheless, we prefer offline-paradigm since the OLT takes into account all ONUs request, and therefore the process of bandwidth allocation can be globally optimized. Based on aforementioned advantages of offline-paradigm, we propose offline limited-DBA scheme that support the Inter-ISP traffic with four priority queues at each ONU, which are EF, AF, BE and intra-ISP queues, respectively

#### B. Passive Splitter

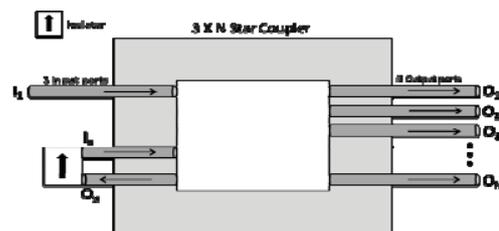


Figure 2. 3xN Star-Coupler (SC)

The passive splitter module is shown in Figure 2. An optical signal introduced into any input port is distributed to all output ports. Our SC design consists of 3:N ports, where two input ports (i.e.,  $I_x$  and  $O_x$ ) of it are connected to each other through an optical isolator as shown in Figure 6. The function of this is to redirect the upstream traffic back from  $O_x$  to  $I_x$  and broadcast to all ONUs through the  $N$  output ports.  $I_1$  is used for the downstream input port channel from OLT to all ONUs and vice versa. The  $O_1, O_2, \dots, O_N$  output ports are also used to broadcast signals to each ONU from the OLT. Finally,

the optical isolator is used to allow the transmission from  $O_x$  to  $I_x$  in only one direction and to prevent unwanted feedback.

### C. ONU Modules

Figure 3 shows the working principle of ONU mechanisms that an ONU has six different modules - packet classifier, ingress rules, buffer-map management, routing mechanism, uplink scheduling and reporting queue mechanism. First, when the user request arrives at the ONU, the packet classifier will check the request; whether it is Intra-ISP traffic or Inter-ISP (i.e., EF, AF and BE queue) traffic based on the routing table and ingress rules. Afterwards, all the requests will be mapped into the queues (i.e., EF queue, AF queue, BE queue and Intra-ISP queue). Finally, the intra-uplink scheduling will decide when to send all the queues report to the OLT to satisfy all the traffic types. In this paper, the Priority-Queuing (PQ) is used for the intra-uplink scheduling. In a PQ, traffics are divided into  $K \geq 2$  classes numbered 1; 2;...;K. The lower the priority, the higher the class number would be. In other words, priority  $i$  traffics are given preference over priority  $j$  traffics if  $i < j$ . In the case of our proposed intra-uplink scheduling, the EF traffic have the highest priority along with intra-ISP traffic, followed by AF and BE traffic, respectively.

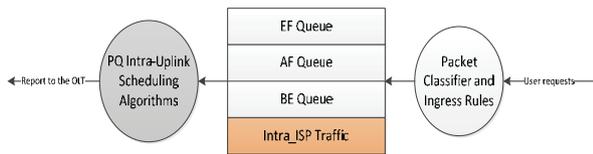


Figure 3. PQ Scheduling Mechanism at ONU

## IV. Performance evaluation

TABLE I  
SIMULATION PARAMETERS

Parameters	Value
Number of ONUs in the system	32
Upstream/ Downstream link capacity	1Gbps
OLT-ONU distance (uniform)	10-20km
ONU buffer size	10MB
Maximum transmission cycle time	1ms
Guard time	5μs
DBA Computation time	10μs
Control message length	0.512μs

In this section, we show the results of our simulation experiments conducted to evaluate the packet delay of Intra-ISP and Inter-ISP as well as the system throughputs. The scenario of the simulation includes the downstream and upstream channels that are set to 1 Gb/s; the distance from ONU to OLT ranges from 10 to 20 km and each ONU has a finite buffer of 10 Mbytes up to 20 Mbytes; and the traffic modeling is self-similarity and long-range-dependence (LRD) to generate highly bursty BE and AF traffic classes with the Hurst parameter of 0.7 and packet sizes are uniformly distributed between 64 and 1518 bytes. Moreover, the high-priority traffic (e.g., voice application) is based on Poisson distribution and the packet size is fixed to 70 bytes [14].

Finally, we the traffic proportions of aforementioned traffics are followed [15], which stated that approximately 40% of total traffics are used for video data. In this paper, we just assumed that 14% of the AF traffics are Intra-P2P-live streaming. Table I summarizes the simulation parameters.

### A. Packet Delay

Figure 4 shows the packet delay for 32ONUs with “244” traffic proportion (i.e., 20% of EF, 40% of AF, and 40% of BE) versus the offered load. It can be observed that the Intra-ISP packet delay has the highest packet delay. The reason is that in our proposed DBA as mentioned above, the Intra-ISP traffic will be postponed until a given cycle time condition is satisfied (i.e., ten percent of cycle time). Although it has higher packet delay compared to the AF Inter-ISP traffic, however, the packet delay is kept below 3ms which still can satisfied the P2P live streaming packet delay requirement. Finally, our proposed scheme can also reduce the AF inter-traffic load, thus decreasing the packet delay. This is because in the proposed architecture some packets are redirected back due to the locality awareness in ONUs.

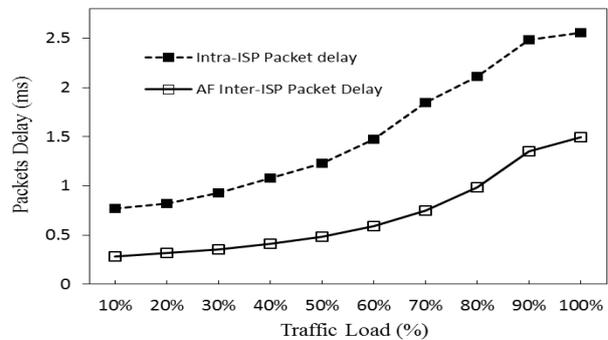


Figure 4. Packet Delays

### B. Bandwidth Waste

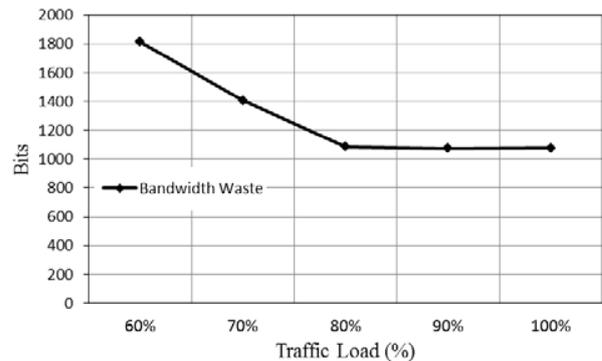


Figure 5. Bandwidth Waste

Bandwidth waste is occurred because there are differences between the grant and report timeslots. It means that the OLT could grant more than the requested timeslots from each ONU. As can be seen in Figure 5, when the network load is high the bandwidth waste is decreasing. This fact might happen because we adopt the limited DBA for our proposed DBA (i.e., limit the maximum timeslots for each

ONU). Therefore, when the offered load is high most of each ONU timeslot will be filled, thus the bandwidth waste is reduced. Moreover, bandwidth waste also might happen since we calculated the intra-ISP traffic based on the RTT between ONU to OLT, although it's supposed to be ONU to ONU which is less than the distance between ONU to OLT. Noted that the grant message is calculated as: report timeslots of  $ONU_i + RTT(ONU_i \text{ to OLT}) + \text{guard time}$ . The reason why we used the RTT between ONU to OLT instead of RTT between ONU to ONU is that we want to keep the conventional DBA working principles. Nevertheless, the bandwidth waste is approximately below 1200 bits when the traffic load is 100%.

### Conclusion

This paper has proposed P2P Locality Awareness Architecture in Ethernet Passive Optical Networks. In the proposed architecture we implemented the ISP Information interface in the OLT. This interface will try to reduce the traffic from each peer within its domain by discovering their Autonomous System (AS) number and Round-Trip-Time (RTT) estimation so that the peer most likely will prefer to connect with a local peer in the same AS or ISP with a small upload capacity than external peer with higher upload capacity. Simulation results have shown that our architecture has good system performance in terms of packet delay and bandwidth waste.

### References

- [1] X. Hei, C. Liang, J. Liang, Y. Liu and K.W. Ross, "A Measurement Study of a Large-scale P2P IPTV System," *IEEE Transaction on Multimedia*, vol. 9, issue 8, pp. 1672-1687, Dec. 2007.
- [2] C. Wu, B. Li and Z. Zhao, "On Dynamic Server Provisioning in Multichannel P2P Live Streaming," *IEEE/ACM Transaction on Networking*, vol. 19, no. 5, pp. 1317-1330, Oct. 2011.
- [3] A. Karagkounis, "Locality Awareness and ISP-Friendliness for P2P Live Streaming Applications," Master Degree Project Stockholm, Oct. 2012.
- [4] K. Kerpez, "P2P Networking and Its Relationship to NG-PON," in *IEEE Global Communication Conference Exhibition & Industry Forum*, Dec. 2009.
- [5] J. Dai, F. Liu and B. Li, "The Disparity between P2P Overlays and ISP Underlays: Issues, Existing Solutions, and Challenges," *IEEE Network*, vol. 24, issue 6, pp. 36-41, Dec. 2010.
- [6] G. Kramer, L. Khemosh, F. Daido, A. Brown, H. Yoon, K.I. Suzuki and W. Bo, "The IEEE 1904.1 Standard: SIEPON Architecture and Model," *IEEE Communication Magazine*, vol. 50, issue 9, pp. 98-108, Sept. 2012.
- [7] Media Access Control Parameters, Physical Layers and Management Parameters for Subscriber Access Networks," *IEEE Draft P802.3ah/D1.0TM*, Aug. 2002.
- [8] Virtual Bridged Local Area Networks, *IEEE Standard 802.1q*, 1998.
- [9] P. Chanclou, A. Cui, F. Geilhardt, H. Nakamura and D. Nettet, "Network Operator Requirements for the Next Generation of Optical Access Networks," *IEEE Network*, vol. 26, issue 2, pp. 8-14, March/April 2012.
- [10] C.M. Assi, Y. Ye, S. Dixit and M.A. Ali, "Dynamic Bandwidth Allocation for Quality-of-Service over Ethernet PONs," *IEEE Journal on Selected Areas Communications*, vol. 21, no. 9, pp. 1467-1477, Nov. 2003.
- [11] J. Chen, B. Chen, and L. Wosinska, "Joint Bandwidth Scheduling to Support Differentiated Services and Multiple Service Providers in 1G and 10G EPONs," *IEEE/OSA Journal of Optical Communications and Networking*, vol. 1, issue 4, pp. 343-351, Sept. 2009.
- [12] J.W. Peng, C.J. Chang and P.L. Tien, "PRNN/ERLS-based Predictive QoS-promoted DBA Scheme for Upstream Transmission in EPON," *Photonic Network Communications*, vol. 20, no. 1, pp. 17-26, Aug. 2010.
- [13] S.R. Sherif, A. Hadjiantonis, G. Ellinas, C. Assi and M.A. Ali, "A Novel Decentralized Ethernet-based PON Access Architecture for Provisioning Differentiated QoS," *IEEE/OSA Journal of Lightwave Technology*, vol. 22, issue 11, pp. 2483-2497, Nov. 2004.
- [14] X. Bai and A. Shami, "Modeling Self-similar Traffic for Network Simulation," Technical report, NetRep-2005-01, 2005.
- [15] Cisco., Oct. 2010, "Cisco Visual Networking Index: Usage," White Paper., Available at: [http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/Cisco\\_VNI\\_Usage\\_WP.html](http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/Cisco_VNI_Usage_WP.html).

# On Robotic/Tactical Behavioral Layer of an Agent in a Continuous Topography Agent Base Model for Traffic Simulation

Ade Jamal

Department of Informatics, Faculty of Science and Technology  
 University Al Azhar Indonesia  
 Jakarta, Indonesia  
 adja@uai.ac.id

**Abstract**—Development of traffic simulation software has been being interest of scientist and engineer from different field since the year '50. Various approaches have been used to model the simulation, from the very old one, the macroscopic model to the relatively new model, namely agent based mode in the framework of microscopic model where every single vehicle processes as function of time. Hybrid microscopic approach by incorporating cellular automata with agent based model has got many attentions in the last decade. The most recent technique, namely a continuous topography where agent based model is combined with finite state automata gain, is discussed here. Layer architecture for agent model is invoked here to make the complex system more clearly to understand. One of the layers will represent the tactical behavioural layer on which the finite state machine will be applied. The dynamic process of a sample of complex manoeuvre will be discussed briefly using statechart and sequence diagram.

**Keywords**—traffic simulation; agent based model; finite state machine;

## I. Introduction

In the earlier phase of research and development of traffic simulation software, a macroscopic model based on continuum hydrodynamic kinematic law was used where traffic flow is described as continuum. Modern traffic simulation has been being studied and developed based on microscopic model where trajectory of every single vehicle is calculated as function of time. Since the influences of mathematicians and computer scientist on the traffic simulation research are getting more significant, two important techniques, namely the cellular automata (CA) and the agent based model (ABM) have been incorporated in this research area. CA was first time used in the microscopic traffic model by introducing the two lane model with periodic boundary conditions [1]. The combination of CA and ABM was later on incorporated to model pedestrian movement using regular square structured multi-grid topography [2].

Traffic participant movements are directed by topography model of the traffics environment. In the CA based two- or multi-lane model, vehicle's movement can take place in two ways, first completely unrealistic sideway and forward [1]. On the more complex regular grid structured topography using

CA and ABM combination, traffic participants basically can move in any direction depending on the grid cell shape and size. Using hexagonal shaped cell gives more possibilities of movement direction than using square shaped cell. Furthermore, the smaller the cell size, the more accurate the movement trajectory can be modeled. Making more complex cell shape and smaller cell size requires significantly extra computational resources in term of power and memory.

The CA based traffic model is received many interests during 90's as it can run large and relatively complex traffic simulations such urban traffic with only comparatively low computational resources [3]. As the strength of CA model is efficiently used of computer resources, then the previously improvement by increasing cell shape complexity and using smaller cell size should not be followed. Ulf Lotzmann [4] has proposed a completely other approach by introducing a continuous topography model. In this model, agent based system is still retained but cellular automaton principle is thrown away. The finite state automata takes place the role of CA to control the agent behavior.

The present research will study this new model of topography as has been shown in the previously published paper that the model of lane changing movement in the new approach needs more complex mathematical model comparing that the old CA based model [5]. This paper will focus more in the finite state machine of the tactical agent's behavioral layer where all physical layer of agent will be determined autonomously.

## II. A Continuos Topography Agent Based Model Traffic Simulator

The traditional approach of microscopic model based for traffic simulation was modelled as single lane, i.e. the system consists of a one dimensional grid with periodic boundary. Two basic models are very often used i.e. car-following model [6, 7, 8, and 9] and lane-changing model [6] in the microscopic single lane model. Later on a mathematicians and physician scientist [1] has incorporated cellular automata (CA) to introduce a two lane model consisting of two parallel single

lane models with periodic boundary conditions and additional rules defining the exchange of vehicles between the lanes. This CA approach lasts not longer than one decade in the year 90's, until software scientists introduced the so called agent based model (ABM) to traffic simulation software [10]. The ABM approach has been a successful technique in the recent traffic simulator software in the last decade [11,12].

Dijkstra [2] has combined CA and ABM to model pedestrian movement using a regular grid based topography model. While in the single or multi-lane microscopic model, traffic participant can only move forward or lateral only in every (sub)-step, in the regular grid structure CA based topography, any traffic participant can move in any direction as long as no obstacles blocking the movement depending on the grid shape and size. In contrary to CA model where its topography is characterized by regular grids in various forms e.g. square or hexagonal shape, the current approach takes a continuous topography hence the agent is able to move more freely and independent from any restriction such as grid shape or grid size.

An agent is an autonomous entity that cannot be controlled by external interference but and it perceives events from its environment and then react accordingly. How agent perceives and reacts to this perception must be governed by a logical system. In the case CA and ABM combination, a simple CA algorithm is invoked since the perception area covers only the neighbouring grid cell of the agent. In the continuous topography model, a communication system like a sensor system is used to receive any event's data only in the perception area as shown in Fig. 1 two agents are out of communication areas. In this case the simple algorithm incorporated by CA must be replaced by more complex finite state automata or finite state machine (FSM) as explained in [13].

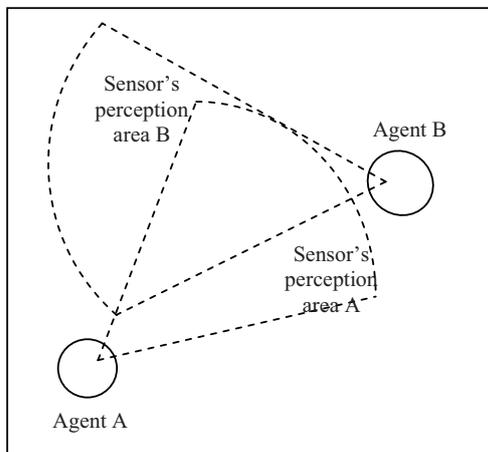


Fig. 1. Agent's communication system

Following the footprint of works in [4, 11, 14], the ongoing research [5, 15] distinguishes the agent model in two abstract layers, i.e. a physical layer and behavioural layers. The physical layer depicts the real-world attributes of an agent such as location coordinates, velocity, direction and other

physical parameters attached to the agent's entity. This physical layer is the only layer that has interface to outside world of agent, either for dynamic process or for visualization.

The behavioural layers model how the agent will behave in response to its environment. This layer is further separated into two functional layers, namely the operational behavioural layer and the strategic behavioural layer. The first layer is also called the robotic operative behavioural layer in [4, 14] or tactical layer in [11]. This tactical behavioural layer will interact directly with the physical layer describing the perception and reaction of the agent in a very short time. The second layer is the strategic layer which has an intelligent behaviour for decision making such as route selection. The strategic layer will perceive the robotics perception and then will provide an intelligent action to be performed by tactical layer accordingly. This intelligent layer is called Artificial Intelligent (AI) layer in [4, 14]. Figure 2 shows the agent model and the interaction within agent's layers and the topography. This article as described in the title will focus only in the tactical behavioural layer.

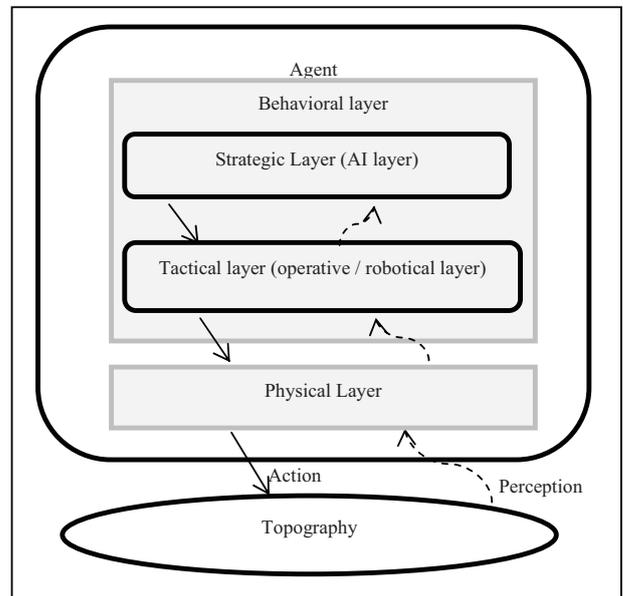


Fig. 2. Layer wise agent model and interaction with each layer and topography

### III. Agent's Tactical Layer

In [4] an agent can be taught as a reactive agent who has ability to interact with other agent but can only passively communicate. Hence the name "reactive" means that this type of agent cannot recognize its environment actively. The specialization of this reactive agent is a proactive agent that defined as subclass of reactive agent. The sub-class proactive agent is the most important agent as the most of traffic vehicles fall in this agent category. This type extends the reactive agent with capability to perceive events from the agent's environment and then react accordingly. In the present research, an agent will be distinguished in different manner,

i.e. passively immobile agent and actively mobile agent. The difference lies in the structural relationship where these two type agents are both sub-classes of a common abstract agent. Some of physical attribute will belong to the abstract class of agent, such as shape, position and sensors. Their capability will be different for each type, for sure the passive agents will not occupy a strategic behavior, but do have a tactical behavior however much simpler than the actively mobile agent.

The more complex tactical layer of actively mobile agent requires Finite State Machine (FSM) approach to model the autonomous dynamical process as can be represented by nested state chart diagrams [13].

#### A. Finite State machine

Finite State machine is an abstract machine that can be in one of a finite number of states but in only one state at a time, called current state. By a triggering event or condition, the state can be changed from one to another state; this process is called a transition. A particular FSM is defined by a number of its states and triggering event for each transition. For a complex machine, a particular state can consist of many sub states which form complete FSM in a hierarchy level. The state activity and action in the more complex state (super state machine), will trigger an event for a transition on the state machine below (sub-state machine) by supplying the state transition function and its input parameters. However, when the transition function cannot handle the input information for instance because of missing or unknown data, a trigger signal for state change on the automaton at the level above (its super state machine [13]) might be fired by the sub state machine.

The tactical layer of actively mobile agent is further split into three sub-layers, namely:

- Level one (the lowest level) represents basic actions which are usually conducted without thinking by humans (e.g. turning the steering wheel).
- Level two deals with activities composed of basic actions (e.g. hold the center of a lane).
- Level three subsumes all required plans for complex activities a human is aware of when executing (e.g. lane change operation).

The state activities on the lowest level directly modify the physical agent attributes during the lapse of time. Due to the time-discrete simulation model, the activities are adjusted for the duration of a discrete time step. Furthermore, state activity and transition function are executed at every time step. The transition functions for level three are provided by the AI strategic behaviour layer.

Each layer of robotic behaviour is equipped with a sensor communication and a perception filter processor. The filter is used to reduce the input data that are not significant to the state machine and in order to decide whether the information from the perception input data is not sufficient for underlying level.

#### B. Level One FSM

The first level of tactical layer consists of states that represent four basic actions which are normally done without thinking by human driver, namely:

- Idle: the vehicle remains steady in the current state. Speed  $v$  and heading direction  $\phi$  remain constant.
- Accelerated: the driver accelerates or decelerates the vehicle by accelerating intensity  $a$  to the desired speed  $v$ .
- Bent: the driver turns the steering wheel with the angular radius  $m$  in order to gain a new direction  $\alpha$  where linear speed  $v$  remains constant and the heading direction  $\phi$  is modified accordingly.
- Unsteady bent (accelerated and bent): combination of accelerate and bend where both linear speed  $v$  and the heading direction  $\phi$  are modified.

Fig. 3 shows the state chart diagram of the level one FSM for the four basic action, where for each underlying movement action a mathematical model based on Newtonian governing equation are given in [5, 15].

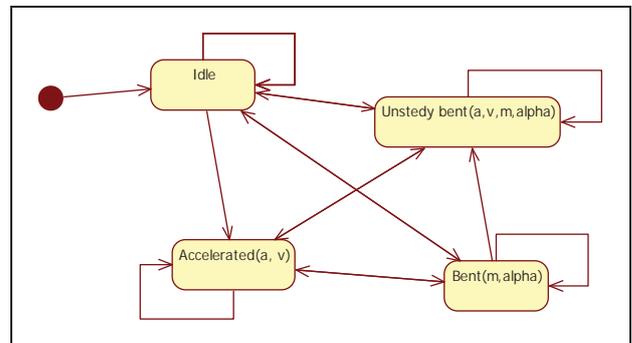


Fig. 3. Statechart diagram FSM Level One

#### C. Level Two FSM

The state at level two describes various basic driving manoeuvres, namely:

- Lane-Centered: the driver steers the vehicle in the center of a lane.
- Lane-Bordered: the driver steers the vehicle in the direction of the (left or right) lane border with the angle  $\alpha$ .
- Off-Lane: the driver steers the vehicle onto a topographic region not marked as a road (e.g. crossing, parking etc.), heading towards a target "tg" decelerated to desired velocity  $v$ .
- Turned: the driver steers the vehicle into a bend.
- Lane-Center & Lane-End-Ahead: the driver steers the vehicle in the center of a lane and reaches the end of the lane.

Fig. 4 shows the state chart diagram of the level two FSM for the five basic manoeuvres that in turns composed of basic actions from the level one FSM. Before each activity from level two will be triggered, a moderate calculation must be performed to determine some input parameters from the level one basic action based on the result of perception data from the environment. For instance Lane-Centred manoeuvres calculation is presented in [5], and the other manoeuvres will be presented in [15].

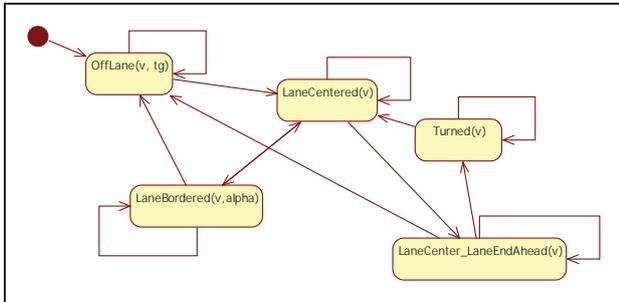


Fig. 4. State chart diagram FSM Level Two

#### D. Level Three FSM

Level three FSM will cover various complex driving manoeuvres, such as:

- Go-Ahead: the driver follows the course of the road with intended velocity  $v$  considering traffic rule and road situation.
- Lane-Changing: the driver performs a lane change to the left or right side according to parameter “direction”
- Cross: the driver passes an intersection with intended velocity  $v$ , heading towards outbound lane “out”
- Drop-Off: the driver stops the vehicle for short time along shoulder of the road (border lane), usually to drop off or pick up passengers.

Fig. 5 shows these four samples of complex manoeuvres in the state chart diagram of level three FSM. The level three manoeuvres can consist of one or more level two activities and will be explained later using sequence diagram.

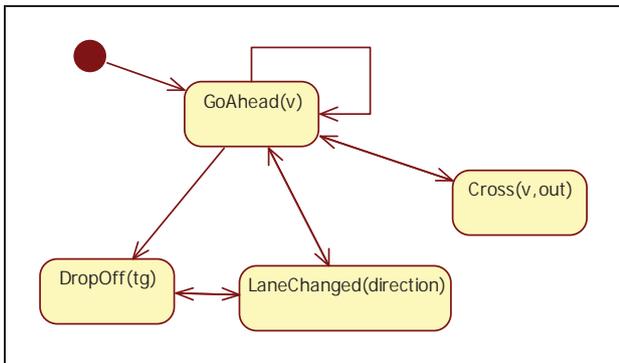


Fig. 5. State chart diagram FSM Level Three

## IV. Dynamic Process of tactical Behaviour Layer

In [14], an example of the complex manoeuvres of level three robotic layer, in this case the crossing capability of an agent. Here the other manoeuvres will be briefly discussed. The Fig. 6 shows a picture of a situation for a car traffic where agent a1 hindered by slower moving agent a2 ( $v_2 < v_1$ ). The current state of a1 is {L1: Idle; L2: Lane-Centred; L3: Go-Ahead}. The agent a1 have two possible actions i.e. changing lane to b2-b3 or following car agent a2. Fig. 7 depicts the dynamic process of lane changing movement as sample complex manoeuvres.

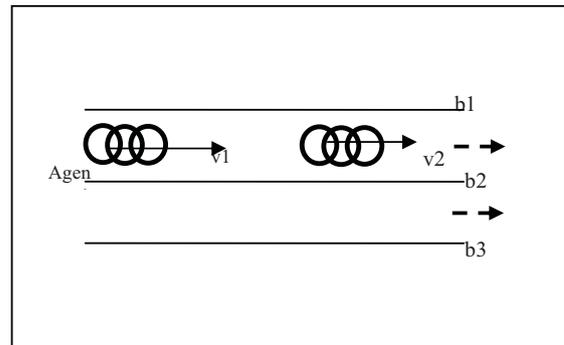


Fig. 6. Sample traffic situation two agents in one lane

## V. Conclusion

A new approach of agent based model traffic simulation software was discussed in this paper. There are two important differences in the new technique i.e. continuous topography in compare with the traditional cellular grid based topography and utilization of finite state automata in place of cellular automata. These two issues yield more complex mathematical model and computational model. A layered architecture is invoked in the agent model to make the model definition easier to develop and applying nested finite state machine gives a successful result.

The layer which describes how the agent will perceive and react to environment’s event and situation is named a behavioural layer. This layer is divided into tactically operative behavioural and intelligent strategic behavioural layer. The tactical behavioural layer, also called robotical layer is further split into three level of nested finite state machine, from the simplest movement, e.g. accelerating, in level one up to the most complex manoeuvres in the level three such as lane changing movement. How these three sub layers of tactical behavioural layer interact in the dynamic process of simulation are clearly described using sequence diagram.

## Acknowledgment

This work is funded by research grant from LP2M UAI.

### References

- [1] M. Rickert, K. Nagel, M. Schreckenberg, A. Latour, *Two lane traffic simulations using cellular automata*, LANL Report No. LA-UR 95-4367, 1995
- [2] J. Dijkstra, A. J. Jessurun, H. J. P. Timmermans, *A multi-agent cellular automata mode of pedestrian movement*, in Pedestrian and Evacuation Dynamics (Eds: M. Schreckenberg and S. D. Sharman), Springer-Verlag, 2001
- [3] J. Esser, M. Schreckenberg, *Microscopic simulation of urban traffic based on cellular automata*, in International Journal of Modern Physics C, Vol. 8 No. 5, pp. 1025-1036, 1997
- [4] U. Lotzmann, *Design and Implementation of a framework for the integrated simulation of traffic participants of all types*, In Proceeding of the 2nd European Modelling and Simulation Symposium, 2006
- [5] A. Jamal, *A Continuous Topography Approach for Agent Based Traffic Simulation, Lane Changing Model*, in Proceeding of the 1<sup>st</sup> International Conference Science, Electronic and Instrumentation, ICCSE2012, University of Gajahmada, Yogyakarta, 2012.
- [6] H. T. Fritzsche, *A model for traffic simulation*, Traffic Engineering & Control 35(5), pp. 317-321, May 1994
- [7] M. Brackstone, M. McDonald, *Car-following: a historical review*, Transportation Research Part F 2, Elsevier Science Ltd., pp. 181-196, 1999
- [8] J. J. Olstam, A. Tapani, *Comparison of car-following models*, VTI medelände 960A, Swedish National Road and Transport Institute, 2004
- [9] K. Nagel, M. Schreckenberg, *A cellular automaton model for freeway traffic*, In Journal de Physique I, France, 2, pp. 2221-2229, 1992
- [10] B. Burmeister, A. Haddadi, G. Matylis, *Application of multi-agent systems in Traffic and transportation*, in Software Engineering, IEE Proceedings, Vol. 144 (1), pp.51-60, 1997
- [11] F. Klugl, H. Wahle, A. L. C. Bazzan, M. Schreckenberg, *Towards anticipatory traffic forecast- modelling of route choice behaviour*, in Proceeding of Workshop 'Agents in Traffic Modelling', 2000
- [12] A. L. C. Bazzan, F. Klugl, *Multi Agent Systems for Traffic and Transportation Engineering*, Information Science Reference, 2009
- [13] D. Harel, *Statecharts: A Visual Formalism for Complex System*, in Science of Computer Programming 8, North-Holland pp.231-274, 1987
- [14] U. Lotzmann, *A Multi-Purpose Agent-Based Simulation Framework for Complex Traffic Simulation Applications*, in Multi Agent Systems for Traffic and Transportation Engineering, (Editor Anna L.C. Bazzan, Franziska Klugl) Information Science Reference, 2009
- [15] A. Jamal, *Model Matematis Topografi Kontinu Dari Simulasi Lalu Lintas Berbasis Agen*, in Jurnal Al-Azhar Indonesia Seri Sains dan Teknologi (in Indonesian) (to be published) 2013

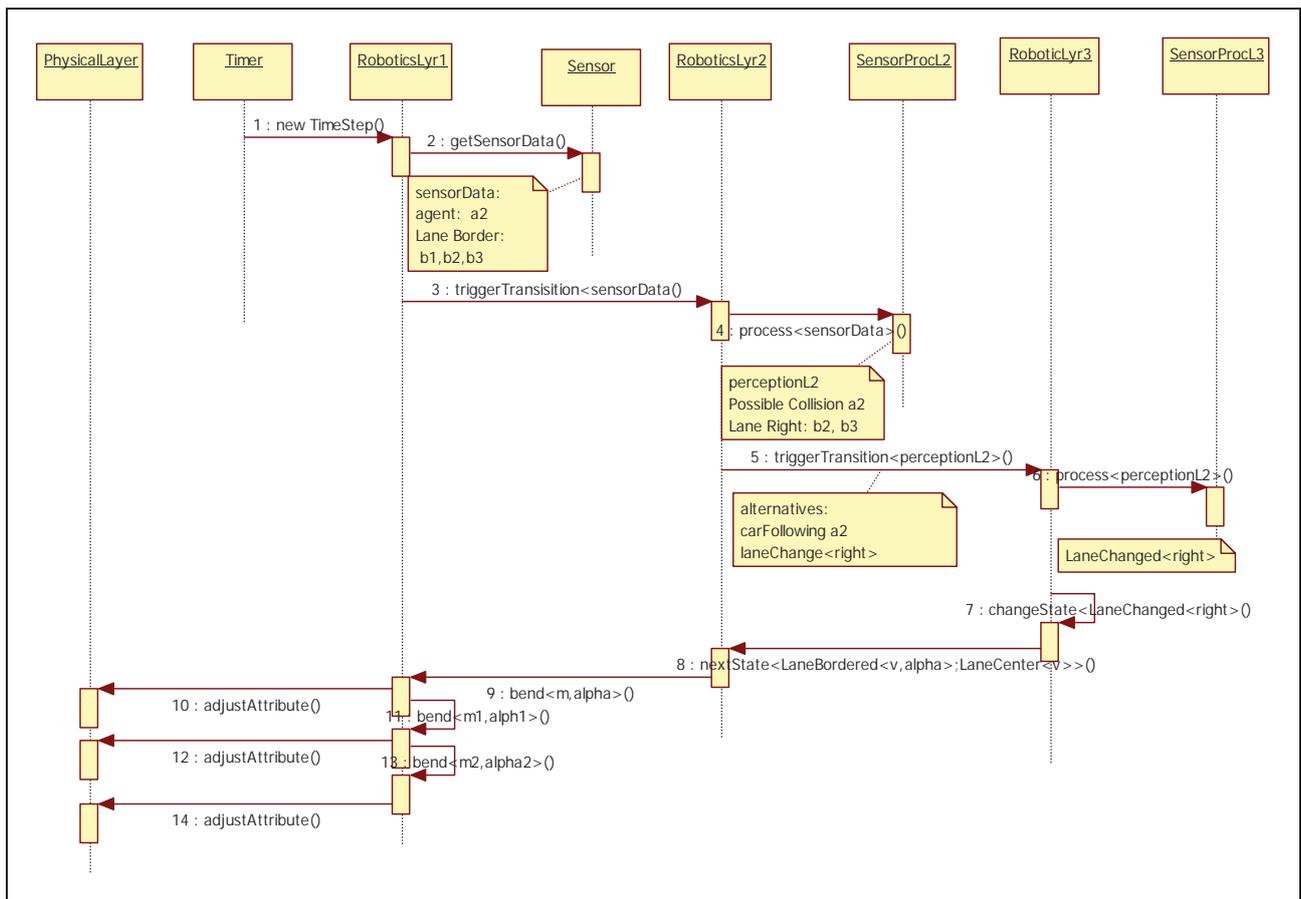


Fig. 7. Sequence diagram interaction three levels FSM in lanechanging manoeuvres

# Improved Discrete Event Simulation Model of Traffic Light Control on A Single Intersection

Sony Sumaryo<sup>1</sup>, A. Halim<sup>2</sup>, K. Ramli<sup>3</sup>  
 Department of Electrical Engineering, Faculty of Engineering  
 Universitas Indonesia  
 16424 Depok, Indonesia

<sup>1</sup>sony.sumaryo@ui.ac.id, <sup>2</sup>ahalim@ee.ui.ac.id, <sup>3</sup>k.ramli@eng.ui.ac.id

**Abstract**—Transportation systems are complex dynamic systems that hard to be modeled exactly. The correct model need model verification and validation. This paper presents an improved discrete event simulation model of traffic light control on a single intersection. Model is developed using SIMULINK / SimEvent toolbox provided by MATLAB. We proposed the improved model using controller with two input switches and two output switches combined with traffic signal logic block. In this research, the fixed time controller algorithm is located within traffic signal logic block. The intersection model uses four approaches, and each approach consists of one through stream and one right turn stream. Each stream is modeled as an M/M/1 queue. FIFO discipline is applied to the vehicles queue in each stream. Inter arrival time between vehicles is modeled using exponential distribution. Model validation is done in two different scenarios of inter-arrival time between vehicles 15 s (for low traffic volume), and 5 s (for high traffic volume) respectively. Experiment results show that the number of vehicles in queue and average waiting time of low traffic volume is lower than high traffic volume. That means the model has functioned correctly.

**Keywords**—discrete event model; traffic light control; single intersection; validation; distribution

## I. INTRODUCTION

Transportation systems are complex dynamic systems that hard to be modeled exactly [1]. For this reason, many current methods do not have good theoretical bases. However, without modeling the system appropriately, the characteristic of transportation system cannot be identified correctly. Furthermore, it is hard to evaluate existing algorithms and to recognize potential problems and improve them. The model needs to be verified and validated. A model should be developed for specific purpose and its validity determined with respect to that purpose [2]. So far as we know most existing research works [3,4,5,6,7,8,9,10,11] have developed the single intersection model for implementation of the specific algorithm. Moreover those research works did not describe how to develop the model and how to perform validation.

Consider the simplified version of the model development process in Fig. 1 [2]. The problem entity is the system (real or proposed), idea, situation, policy, or phenomena to be modeled; the conceptual model is the mathematical / logical / verbal representation of the problem entity developed for a particular study; and the computerized model is the conceptual model implemented on a computer. The conceptual model is developed through analysis and modeling phase, the computerized model is developed through a computer

programming and implementation phase, and inferences about the problem entity are obtained by conducting computer experiments on the computerized model in the experimentation phase.

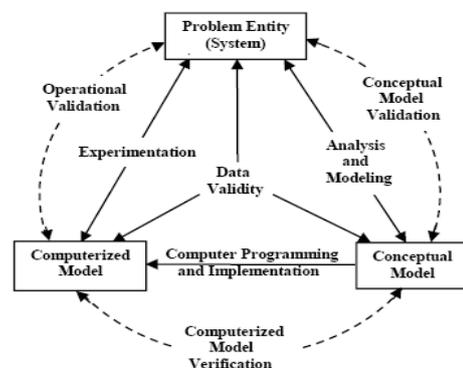


Fig. 1. Simplified version of the modeling process [2].

This research has two goals:

- Propose the improved traffic light discrete event simulation model using controller with two input switches and two output switches combined with traffic signal logic block. In this research, the fixed time controller algorithm is located within traffic signal logic block. The advantage of this model is that it can be used to test any traffic light algorithm without major modification and also can be modified to fit for real system.
- Validate model through evaluation the number of vehicles in queue and average waiting time.

## II. DESCRIPTION AND MODEL OF SINGLE INTERSECTION

### A. System

The real common intersection consists of four approaches (east, west, north and south) [3,4,5,6,7,8,9,10,11] with two or three streams in each approach. The approach that consists of three streams [3,6,8,9] are one through stream, one right turn stream and one left stream while the approach that consists of two streams [4,5,7,11] are one through stream and one right turn stream. The signalized intersection is equipped with a fixed time traffic control system.

### B. Conceptual Model

The traffic light control on a single intersection model shown in Fig. 2 is designed based on the real traffic light system. In this model, there are four approaches (east, west, north and south) with total 8 streams. Each approach consists of two streams are one through stream and one right turn stream. At this time pedestrian crossing and the left turn stream are not considered. The input flow rates in each stream are assumed to be provided by sensors accurately.

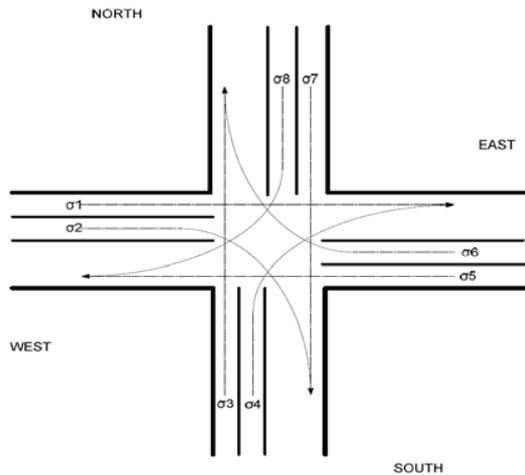


Fig. 2. Single intersection traffic stream model.

Each stream is modeled as an M/M/1 queue (based on Kendall notation) and it is built based on the three main concepts in queuing theory which are customers, queues, and servers. The first and the second M in M/M/1 stand for “memoryless” distribution of interarrival time and service time, respectively. The “1” indicates that the single intersection has single server with specific service time.

First-In-First-Out (FIFO) discipline is applied to the vehicle queue in each stream. From queuing theory, the vehicles in this model are known as customers while service time is the time for the vehicles to depart from queue and to cross the intersection in their own stream.

Based on research works [4,6,8,12], the characteristic of arrival traffic according to Poisson process. Many other models have been used for describing the arrival process of vehicles on the approach. However, most of them are more complex, but the Poisson model is still used for most practical purposes [12]. With Poisson flow, the probability of arrival of  $m_i$  vehicles of traffic stream  $\sigma_i$  to an intersection, during interval  $\tau$ , is expressed by the equation [12]:

$$P_{m_i}(\tau) = p[m_i \text{ vehicles arrive in interval } \tau] = \frac{(q_i \tau)^{m_i}}{m_i!} e^{-q_i \tau} \quad (1)$$

$q_i$ : constant, arrival rate

The interarrival times for a Poisson process with rate  $q_i$  are IID (Independent and Identically Distributed) exponential random variables with mean  $1/q_i$ . The Poisson model is good for describing the real arrival process on an intersection

approach in the case when the ratio between volume and approach capacity is not high [12].

Modelling each stream as an M/M/1 queue is still suitable for real traffic system that observed, since the intersections or network that we are observed is a single intersection with not too high traffic volume. If the network is large with huge traffic volume then the suitable model is Stochastic Fluid Model-SFM [13]. Based on research [1,3,4,5,6,8] and much more, the number of vehicles and the average waiting time in each stream are popular performance indices for traffic light signal control.

Traffic light control is divided into four signal groups (D1, D2, D3, D4), that are D1: for approach west (stream 1 and stream 2), D2: for approach south (stream 3 and stream 4), D3: for approach east (stream 5 and stream 6) and D4: for approach north (stream 7 and stream 9). A signal group is the set of traffic streams that are controlled by identical traffic light indication. If a signal group is active it means green light indication. Green light indication for vehicles means allowed passage the intersection, while red light indication means forbidden passage. In this research, sequence and duration for signal groups is determined using fixed time algorithm.

Fig. 3 shows the sequence and duration of signal groups. Label “1” indicates the signal group is active while label “0” is not active. The durations of signal group are labeled  $t_1, t_2, t_3,$  and  $t_4$  for signal group D1, D2, D3, and D4 respectively. In this simulation the durations of each signal group are 100 s.

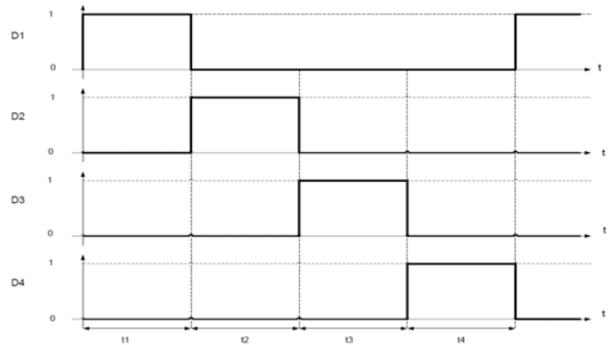


Fig. 3. Signal group

### C. Computerized Model

The single traffic intersection model developed in MATLAB using SIMULINK and SimEvent toolbox is shown in Fig. 4. SimEvents software incorporates discrete-event system modeling into the Simulink time-based framework, which is suited for modeling continuous-time and periodic discrete-time systems [14]. In time-based systems, state updates occur synchronously with time. By contrast, in discrete-event systems, state transitions depend on asynchronous discrete incidents called events. Since we are interested in the number of vehicles and the average waiting time in each stream and we are not interested in the details of how an vehicle move and cross the intersection-for example-then we can use discrete-event simulation.

The discrete event simulation model of traffic light control on a single intersection in this research is an improvement model from discrete event model that developed by Devdatt Lat [15]. The improvement that we are proposed is using two input switches and two output switches that controlled by Traffic Signal Logic block as implementation of traffic light control algorithm, and modeling each traffic stream in each approach (see also Fig. 2) with using a time based entity generator (for generation of customers), a queue and a server. As describe at paragraph above, each stream is modeled as an M/M/1 queue and traffic arrival is modeled by inter arrival between vehicles using exponential distribution. First-In-First-Out discipline is applied to the vehicles queue.

Fig. 4 shows the signal group D1, D2, D3 and D4 are implemented using input port IN1, IN2, IN3 and IN4 at input switch 1 and input switch 2 respectively. The sequence of input port of input switch 1 and 2 is controlled by the output signal of traffic signal logic block that connected to the input port "p" of input switch. Output switch 1 and 2 have function so that the customer (vehicle) can arrive at the approach destination.

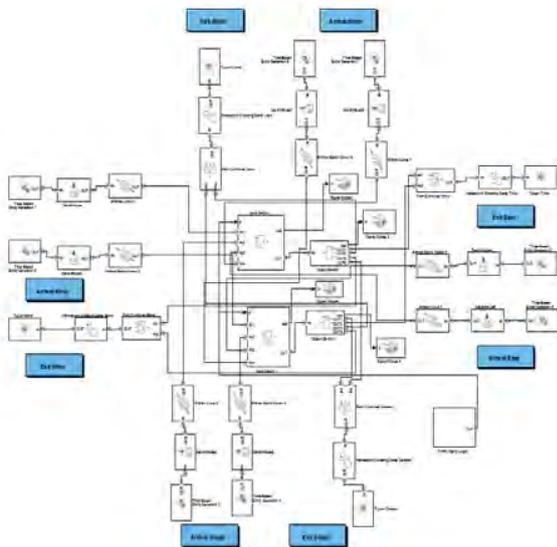


Fig. 4. Simulink / SimEvent block diagram of single intersection traffic model.

Inside Traffic Signal Logic Block (in Fig. 5), the duration of green time is determined by Event Based Sequence block and then executed by server block. The sequences of Signal Group activation are determined by another Event Based Sequence 1 block. The output signal of traffic signal logic block (from output port of the signal latch block) will control the sequence of input port activation of input switch 1 and input switch 2. Since the model implemented using Simulink / SimEvents, model verification through with ensuring that an error free simulation language has been used.

The advantage of this model can be used to test any traffic light algorithm without major modification of the model since traffic light algorithm located within a traffic signal logic block.

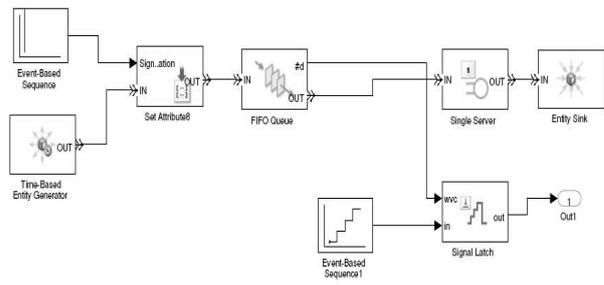


Fig. 5. Traffic signal logic block diagram

### III. RESULTS AND DISCUSSION

The objective of this simulation is to validate the model that has been built if the output simulation of the model has the same characteristic with the real traffic light control system. The outputs of the simulation that we evaluated as performance indices are the number of vehicles in queue and average waiting time in each stream. The simulation time is 1000 s. Duration each signal group D is 100 s and two different scenarios of inter arrival time between vehicles are 15 s (for low traffic volume), and 5 s (for high traffic volume) for all stream respectively.

Fig. 6 shows the numbers of vehicles in each queue using inter arrival time 15 s in stream 1 (red curve) and 5 (blue curve). From the figure it looks if the signal group of stream is active, the number of vehicles in the queue will be reduced compared to the inactive group signal. For clarity we take an example, stream 1 gets an active group signal (D1) for a duration of 100 s first, then the number of vehicles in the queue a bit. For time 100 s to 400 s where the signal group of stream 1 is not active (see also Fig. 3), the number of vehicles continues to grow. At the time of 400 s to 500 s, when the signal group is active, the number of vehicles is reduced. The number of vehicles increased again when the time 500 s to 800 s are currently no active signal group again and so on. The same characteristics were obtained for the other streams.

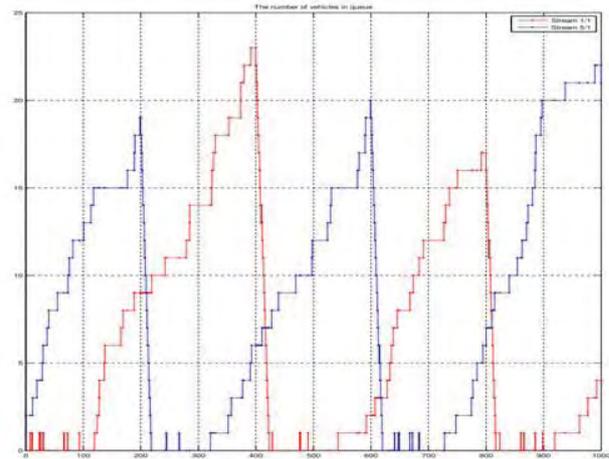


Fig. 6. The numbers of vehicles in each queue using inter arrival time 15 s.

If the inter arrival time between vehicles converted to 5 s, then the number of vehicles coming into the queue increasingly or high traffic volume. It resulted in the number of vehicles in queue greater than if inter arrival time between vehicles 15 s or low traffic volume. These characteristics are shown in Fig. 7. For example again, few the number vehicles in the queue of stream 1 (red curve in Fig.7) at time 0 s to 100 s. For time 100 s to 400 s when the signal group of stream 1 is not active the number of vehicles continues to grow. At the time of 400 s to 500 s, when the signaling group is active, the number of vehicles is reduced. The number of vehicles increased again when the time 500 s to 800 s are currently no active signal group again and so on. The same characteristics were obtained for the other streams. In Fig. 7 shows that the decrease of the number of vehicles in the queue (at the time of signal group is active ) is lower than in the scenario inter arrival 15 s (see Fig. 6). It is caused to the addition of vehicles to the queue is greater than the speed of vehicles crossing the intersection that simulated by setting service time 5 s.

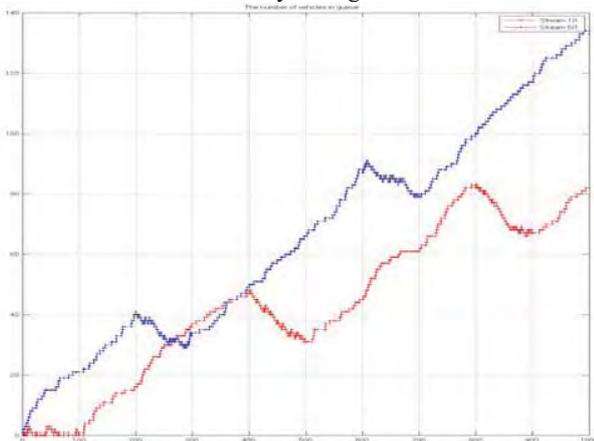


Fig. 7. The numbers of vehicles in each queue using inter arrival time 5 s.

Fig. 8 shows the average waiting time in each queue using inter arrival time 15 s in stream 1 (red curve) and 5 (blue curve). The MATLAB will update the average waiting time in queue for all entities (customers) that have departed from the queue. The customers will depart the queue if the signal group of the stream is active. For an example, stream 1 gets an active signal group (D1) for a duration of 100 s first, then the waiting time in that queue is very short. For time 100 s to 400 s where the signal group of stream 1 is not active, MATLAB does not update the average waiting time. At the time of 400 s to 500 s, when the signal group is active, it appears waiting time increases as the number of vehicles from the 100s to 400 s to grow. That increasing of the waiting time is till to a certain limit and then decreases again. Same characteristics occur at time 800 s to 900 s. The same characteristics were obtained for the other streams.

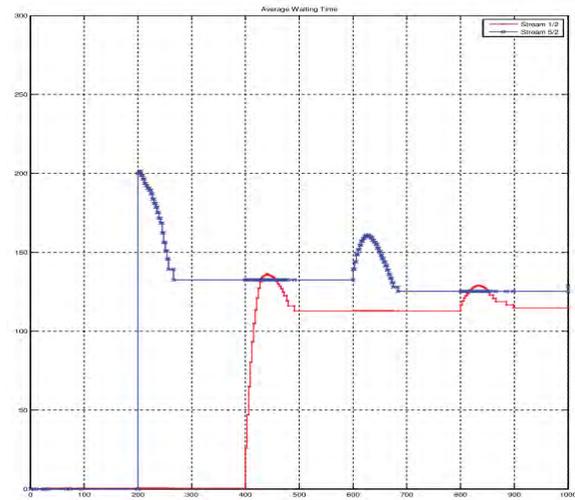


Fig. 8. The average waiting time in each queue using inter arrival time 15 s.

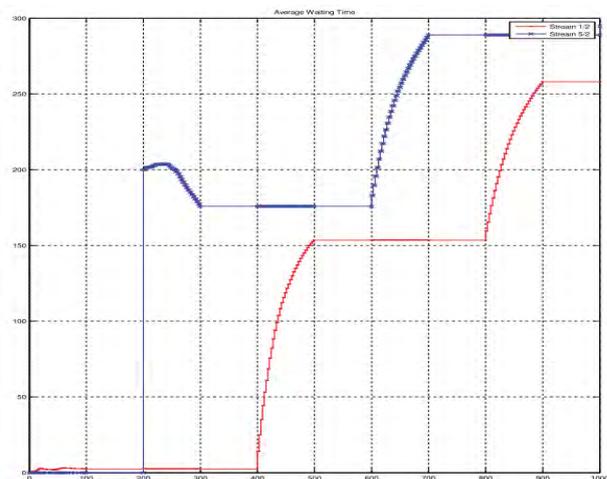


Fig. 9. The average waiting time in each queue using inter arrival time 5 s.

Fig. 9 shows the average waiting time in each queue using inter arrival time 5 s in stream 1 (red curve) and 5 (blue curve). As described for Fig. 7, if the inter arrival time between vehicles converted to 5 s, then the number of vehicles coming into the queue increasingly or high traffic volume. It resulted in the average waiting time in queue is greater than if the inter arrival time between vehicles 15 s or low traffic volume. For example, it is clear the waiting time in the queue of stream 1 at time 800 s to 900 s longer than the waiting time in the scenario of inter arrival time 15 s (see also Fig. 8). The same characteristics were obtained for the other streams.

#### IV. CONCLUSION

This paper proposed an improved discrete event simulation model of traffic light control on a single intersection. The improvement of the model is to use the controller with two input switches and two output switches combined with traffic signal logic block. Based on queuing theory, the model is easy

to develop using SIMULINK / SimEvent toolbox in MATLAB.

The simulation has shown that the model has functioned correctly. Experiment results also have shown that the number of vehicles in queue and average waiting time of low traffic volume is lower than high traffic volume. But it has to be configured carefully for service time at each server. The model can be extended further for multiple intersection and will be extended further in our ongoing research on using adaptive traffic light control algorithm.

#### REFERENCES

- [1] Li Jinyuan, Pan Xin, and Wang Xiqin, "State-space equations and first-phase algorithm for signal control of single intersections", *Tsinghua Science and Technology*, vol. 12, no. 2, pp. 231-235, Apr. 2007, ISSN 1007-0214 14/14.
- [2] Robert G. Sergent, "Verification and validation of simulation models", *Proceeding of the 2009 Winter Simulation Conference*.
- [3] Ehsan Azimirad, Nazer Pariz, and M. B.N. Sistani, "A novel fuzzy model and control of single intersection at urban traffic network", *IEEE System Journal*, Vol 4, No. 1, March 2010.
- [4] Azura Che Soh/Lai Guan Rhung, and Haslina Md. Sarkan, "MATLAB simulation of fuzzy traffic controller for multilane isolated intersection", *International Journal on Computer Science and Engineering*, Vol. 02, No. 04, 2010, 924-933.
- [5] Zoran Gacovski, Stojce Deskovski, and Kostandina Veljanovska, "Fuzzy traffic controller for urban intersection developed in Simulink/SimEvents", *13th IFAC Symposium on Control in Transportation Systems, The International Federation of Automatic Control*, September 12-14, 2012, Sofia, Bulgaria.
- [6] B. Madhavan Nair, and J. Cai, "A fuzzy logic controller for isolated signalized intersection with traffic abnormality considered", *Proceeding of 2007 IEEE Intelligent Vehicle Symposium Istanbul, Turkey*, June 13-15, 2007.
- [7] Lai Guan Rhung, Azura Che Soh, Ribhan Zafira Abdul Rahman, and Mohd Khair Hassan, "Fuzzy traffic light control using sugeno method for isolated intersection", *Proceeding of 2009 IEEE Student Conference on Research and Development (SCOReD 2009)*, 16-18 Nov 2009, UPM Serdang, Malaysia.
- [8] Leng Junqiang, and Feng Yuqin, "Research on the fuzzy control and simulation for intersection based on the phase sequence optimization", *International Conference on Measuring Technology and Mechatronics Automation*, 2009.
- [9] Michal Kutil, "Modeling and optimization of traffic flow in urban areas", *Doctoral Thesis, Czech Technical University in Prague, Faculty of Electrical Engineering Department of Control Engineering*, January 2010.
- [10] S. Harjono, A. Halim, and K. Ramli, "Simulation of improved hybrid petri nets intersection model considering traffic distribution", *International Journal of Soft Computing* 7 (4): 217-223, 2012.
- [11] Binbin Zhou, Jiannong Cao, Xiaoqin Zeng, and Hejun Wu, "Adaptive traffic light control in wireless sensor network-based intelligent transportation system", *IEEE*, 2010.
- [12] Slobodan Guberinic, Gordana Senborn, and Bratislav Lazic, "Optimal traffic control: urban intersections", *CRC Press*, 008.
- [13] Herman Sutarto, Rene Boel, "Perturbation analysis and sample-path optimization: stochastic flow models of urban traffic networks case", *Faculty of Engineering, Universiteit Gent*, 2011.
- [14] ....., "SimEvents-getting started guide", R2012a, *Matlab & Simulink, MathWorks*.
- [15] Devdatt Lad, "Vehicle traffic patterns at intersection (SimEvents)", 13 June 2008 (Updated 06 Aug 2012), *The MathWorks*.

# Rolling Element Bearing Fault Diagnosis Using Radial Basis Function Neural Network (RBFNN)

Mariza Devega

Master of Information System Department,  
 Diponegoro University

Toni Prahasto

Master of Information System Department,  
 Diponegoro University

Achmad Widodo

Department Of Mechanical Engineering,  
 Diponegoro University

**Abstract** — Roller element bearings is one of the vital parts of the machine elements that hold an important role. A machine can be very dangerous if a defect occurs on the bearing performance during the operation. Therefore a fault detection is important to prevent damage to other components of a machines. Various technique have been proposed for fault diagnostic of rolling element bearings. This paper investigate the fault detection and diagnosis for rolling element bearings from the vibration datas that are classified based on similarity of the data. An Intelligent system using Radial Basis Function Neural Network (RBFNN) created. RBFNN is a method used for data classification. It works faster than the back propagation that takes time. Furthermore RBFNN is appropriately used to large data. Gaussian is used as activation function of this RBFNN. The result shows the extent of the fault that occurs in rolling element bearing.

**Keywords**—*Intelligent System; Fault diagnosis; Rolling element bearings; RBFNN; vibration data.*

## I. INTRODUCTION

The usage of rotating machines increases in industrial world recently. Roller element bearings is one of the vital part of rotating machines. Roller bearings are normally used in heavy duty applications such as conveyor belt rollers, where they must hold heavy radial loads (Rao et al.,2012). Machine failure can lead to economic loss and safety problems due to unexpected and sudden production stoppages, therefore an early detection become important for rolling element bearing failure to prevent the damage to the other components in an industrial machine (Yang et al., 2004).

The object of this paper is enrich the study about Radial Basis Function Neural Network (RBFNN) in diagnosing rolling element bearings failure for the performance of the machine. Implementation of the artificial intelligence technology should be considered as investment in science especially in industrial world that provide the benefits for the company.

Following this introduction, section 2 of this paper presents defect problem and literature survey. Section 3 explain why choosing RBFNN and building the classifier.

Section 4 prepare data, training and testing, while section 5 is the conclusion.

## II. LITERATURE SURVEY AND PROBLEM DEFECT

### A. Literature Survey

Data used for classification is rolling bearing vibration data were measured using Acceleometer. The process of traditional condition monitoring and fault diagnosis can be summerized as : data acquisition, data processing, data analysis and decision making. Data represented as features that provides a best solution for classification problem that greatly reduces the requirement of transfer number and save storage space. that data are compressed as feature from many domain with keeping data information as high as possible. relative technique come out such as feature representation, feature extraction and feature selection (Widodo, 2005). Fig .1 below is illustrated the typical feature –based condition monitoring and fault diagnosis structured.

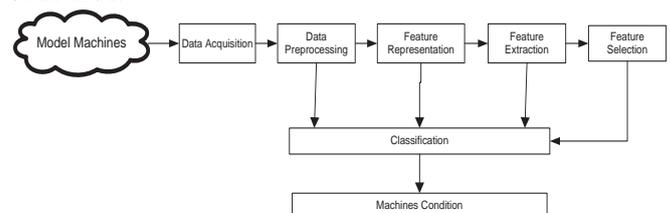


Figure 1: feature-based condition monitoring and fault diagnosis system

Data acquisition is a process of collecting and storing useful data from targeted engineering assets for the purpose of condition monitoring and diagnosis. After collecting the data, we go to data preprocessing, data preprocessing is a purge of the data that has been measured before it is processed. It aims to create a better quality of data. Feature extraction is an important step in recognition system, which directly depends on the classification performance of feature selection and extraction. The main benefit of feature extraction is to eliminate redundancy or repetition of data that represent a form of character by a set of numerical feature (wiley, 2005).

B. Problem Defect

The diagnosis of rolling element is based on inspection defect that occur. Defect in rolling element bearing can be categorized as localized and distributed defect. Localized defects include cracks, holes and fragments which is caused by fatigue in the round surface. Other categories are distributed defects, including surface roughness, waves on the incorrect surface and track and the rotary elements that have been worn.

Bearing faults can be categorized into distributed and localized defects. Distributed defects affect a whole region and are difficult to characterize by distinct frequencies. In contrast, single-point defects are localized and can be classified according to the following affected element (Vas (1993), Tandon and Choudhury (1997), Nandi and Tolitat (1999), Stack, Habetler and Harley (2004).

- Outer raceway defect
- Inner raceway defect
- Ball defect and Cage fault
- Surface irregularities, misaligned races, cracks, pits and spalls on rolling surfaces

III. BUILDING CLASSIFIER

Several methods known in the statistical classification of machine learning method. Neural network is one of the methods in machine learning which has a better capability than the statistical method.

Radial Basis Function Neural Network (RBFNN) is a neural network model with one unit in the hidden layer. Radial basis function neural network is a feed forward neural networks that are specific to transform a non-linear input to the hidden layer is further processed linearly at the output layer. The architecture of RBFNN can be seen in figure 2 below :

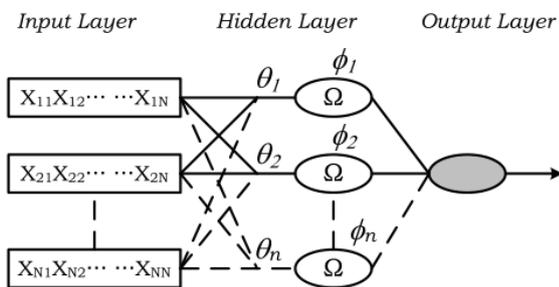


Figure 2 : Architecture of RBFNN

RBFNN can be applied to various domains such as modeling problems like time series data, classification, etc. RBFNN has advantages such as considering the overlap between training data vectors from different categories, so bias can be avoided. Moreover for a large training data are

not slowing its ability. So that's why RBFNN is suitable for the classification process that involves large data sets

Data obtained from the rolling bearings vibration data can be divided into 8 classes. 8 class selected based on the fault condition that often occur in rolling element bearings. 8 damage are Broken rotor bar, Bowed rotor, Faulty bearing, Rotor unbalanced, Eccentricity, phase unbalance, misalignment and normal motor data. Normal motor data is not kind of fault condition in a rolling element bearing, its just a normal data that aims to compare fault and normal data.

The use of RBFNN method above is to classification process. There are some of radial basis functions, such as Thin Plate Spline Functions, Multikudratik Functions, Inverse Functions and Function Multikudratik Gaussian. Radial basis function chosen is Gaussian Function, because it has a local nature that is if the input is close to the average (center), then the function will return the value 1, while if the input away from the average then the function will give a 0 value. Gaussian function is one of the radial basis function that gives the best results in pattern recognition.

The following is the equation of Gaussian Function :

$$\phi(z) = \exp\left[-\frac{(z-\mu)^2}{\sigma^2}\right] \quad (1)$$

Where,  $z$  is the data,  $\mu$  is the means and  $\sigma$  is the variance / standard deviation.

The classification procedure using the trained RBF is describe in figure 3:

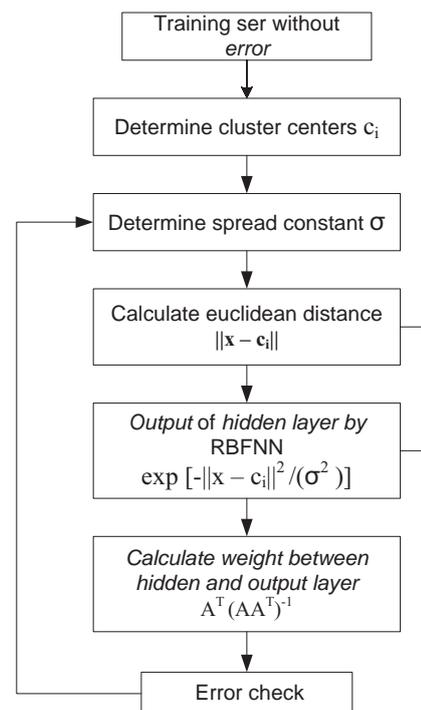


Figure 3: Flowchart of RBFNN

By looking at the model design RBFNN (figure 2), then the output can be defined by equation (2) below :

$$y = F(x) = \exp [-\|x - c_i\|^2 / (2\sigma^2)] \quad (2)$$

Where  $\mathbf{x}$  is the input vector of the network,  $\mathbf{c}_i$  is the  $i$ -th center vector, then  $\|\mathbf{x} - \mathbf{c}_i\|$  is the distance between the input vector to the center vector.  $\|\cdot\|$  is the euclidean norm distance, while  $y$  is the output of radial basis function.

Figure 3 explain how to get output of hidden layer. Cluster center  $\mathbf{c}_i$  can be found using k-means clustering algorithm. Since the used of gaussian function, the value given that are close to cluster center is 1 and the value that are far from cluster center is 0. Euclidean distance can be found by input vector minus cluster center. Output layer can be calculated with eq.2 while the weight of neuron calculated using eq.3.

Weights of neurons between the hidden and output neuron is calculated using equation (2). Where is the pseudo inverse has the same role as the network with the method of least mean square (LMS).

$$y = \mathbf{W}\mathbf{A}(\mathbf{x}, \mathbf{c}), \quad \mathbf{W} = \mathbf{y}\mathbf{A}^T (\mathbf{A}\mathbf{A}^T)^{-1} \quad (3)$$

Where  $\mathbf{W}$  is the weight matrix,  $\mathbf{A}$  is the output of the hidden layer and  $y$  is the output of the output layer.

This 2 figures below (fig.4 and fig. 5) are shown the results plot of random data and real data are classified into 8 classess

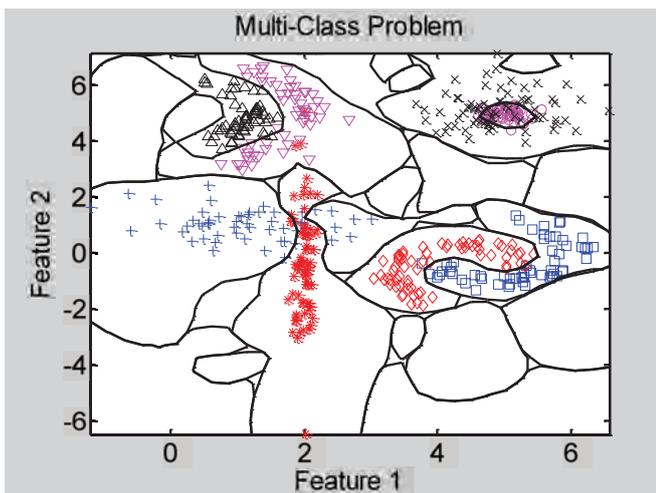


Figure 4 plot of random data

Figure 5 shows the result plot of real data are classified into 8 class.

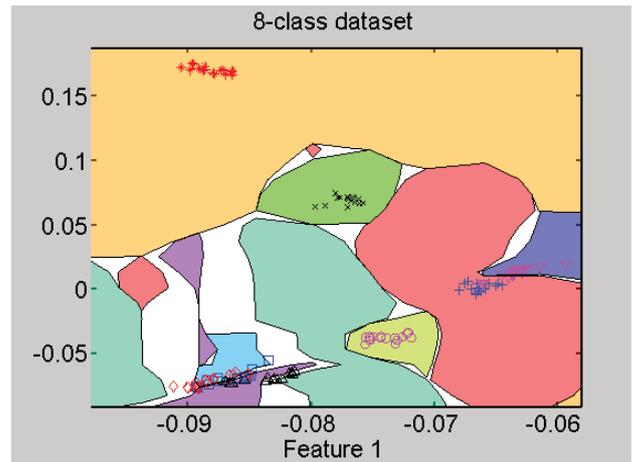


Figure 5 plot of real data

Figure 5 is 2 dimensional plot of vibration datas of rolling element bearing that already classified using RBFNN. From the figure we know that data are classified into 8 classes.

#### IV. DATA TESTING AND ANALYSIS

##### A. Data Testing

Obtained form the matrix data format is [160x5], where 160 is the data and 5 is a feature that has been reduced from 21 features using PCA. of 160 data classified into 8 classes where each class contains 20 datas. From the 20 datas then selected 16 datas for training and 4 datas to testing.

The error system can be detected by processing the data testing using RBFNN algorithm, where the valid data is divided by the number of data and then multiplied by 100%.

$$e = \frac{\text{number of misclassify}}{\text{number of data test}} \times 100\% \quad (4)$$

The accuracy is  $1 - e$

##### B. Analysis

By testing the process it was found that there are data that misclassify or out of the target class. Result shows that from the 8 classes, 3 classes have 100% accuracy and 5 classes shows different misclassification in a class. Overall the number of misclassify data is 5. Accuracy can be found by getting the number of error data first, and the result is 1 minus number of error data. The accuracy is 84,375%.

#### V. CONCLUSION

Rolling bearing damage can be fatal and resulted in an expensive termination fees. Therefore the process of rolling bearing monitoring is important for the maintenance of machinery and process automation. The process of monitoring the condition of the bearing

performance becomes something important for diagnosis. With the diagnosis of the damage is expected to facilitate the action or the treatment of the machine. Thus, the next will be able to improve the effectiveness, efficiency on machine performance. RBFNN has advantages such as considering the overlap between training data vectors from different categories, so bias can be avoided. Moreover for a large training data are not slowing its ability. RBFNN is suitable for the classification process that involves large data sets. From the result that the accuracy is 84,375% we can conclude that using RBFNN is quite good for fault diagnosis rolling element bearing.

#### ACKNOWLEDGMENT

The authors would like to thank Ir. Toni Prahasto, M.ASc, Ph.D and Dr. Achmad Widodo, ST, MT for the assistance in developing research in rolling element bearing fault diagnosis.

#### REFERENCES

- [1] Rao. Pai, Srinivasa. P, and Nagabushana. T.N, "Failure Diagnosis and Prognosis of Rolling-Element Bearings Using Artificial Neural Networks: A critical Overview", *International Journal of Physics : Conference Series 364*, 1-15, 2012.
- [2] Yang. Zhenyu, Merrild. Uffe. C, and Runge. Morten. T, "A Study of Rolling-Element Bearing Fault Diagnosis Using Motor's Vibration and Current Signatures", *Fault Detection, Supervision and Safety of Technical Processes*, 354-359. 2009.
- [3] Yang. Hongyu, Mathew. Joseph, and Ma. Lin, "Fault Diagnosis of Rolling Element Bearings Using Basis Pursuit", *Mechanical Signal and Processing*, 341-356. 2005
- [4] Widodo, Achmad., 2009 "Application of Intelligent System for Machine Fault Diagnosis and Prognosis", Universitas Diponegoro, Semarang.

# The pqr-coordinate in the Mapping Matrices Model of Kim-Akagi on Power Transformation based on Euler Angle Rotation Method

Indriarto Yudiantoro  
 Department of Electrical Engineering  
 Faculty of Industrial Technology, University of  
 Trisakti.  
 Jalan Kyai Tapa No. 1 Grogol Jakarta 11440.  
 Email: [indriarto@trisakti.ac.id](mailto:indriarto@trisakti.ac.id)

Ridwan Gunawan  
 Rudy Setiabudy  
 Department of Electrical Engineering  
 University of Indonesia, Depok 16424.  
 Email: [ridwan@eng.ui.ac.id](mailto:ridwan@eng.ui.ac.id), [rudy@eng.ui.ac.id](mailto:rudy@eng.ui.ac.id)

**Abstract-** The pqr-coordinate in the mapping matrices model of Kim-Akagi developed in order to find a solution to the problems of harmonic caused by non-sinusoidal power system and non-linear loads. This model is designed for the active/reactive power filter under energy balance and compensation condition. The pqr-coordinate is developed as well as space-vector transformation of the active/reactive power by using Euler angle rotation. The mapping matrices model of Kim-Akagi revisited by the Euler angle rotation method.

By using the Euler angles methods of twice rotation the available mapping matrices model of Kim-Akagi is resulted. Furthermore, the Euler angles methods of three times rotation will result in a correction factor. Also conducted to orthogonal test and invariant transformation properties and the results obtained show that space-vector transformation is part of Clarke transformation.

**Keywords-** Active/reactive power, mapping matrices model, Euler angle rotation method.

## I. INTRODUCTION

In general understanding, the active-reactive power on the electric power system with sinusoidal source and linear load has long been understood. In a single phase case, as the quantity of electric power produces average equal to zero. Average power produced does not contribute to the transfer of energy from source to load. However, if the source is non-sinusoidal and the load is non-linear then this concept does not apply [1]. The theory of instantaneous active-reactive power, otherwise known as the pq-theory, first published by Akagi, Kanazawa and Nabae in 1984 [2] and then refined into a pqr-theory in advanced research conducted by other researchers [3]-[4]. This theory was developed to overcome the problems caused by harmonics of non-linear loads on the 3-

phase 4-wire system. The term is also used for filtering power theory because problem cover all issues such as damping harmonic harmonics, harmonic isolation, harmonic termination, load balance, voltage regulation, power factor correction, and power flow control. In pq-theory gives explanation a definition of instantaneous active-reactive power in the time domain because there is no limit imposed on voltage or current. This theory applies to steady state and transient system for 3-phase 4-wire as a unit so it's not a superposition or sum of the single-phase to three. Clarke transformation is used to transform the system 3-phase 4-wire from coordinate-abc to coordinate- $\alpha\beta 0$ .

Analysis for the sinusoidal voltage or current source to the linear and non-linear load resulted shape of the power generated tetrahedron [5]-[6], is not triangular like the concept of average power, which is already understood that led to an understanding of the pqr-coordinate. The existence of r-axis in the pqr-coordinate related by neutral component (zero current), R-axis as the imaginary axis in the pr-plane together with axis-q-generating reactive power ( $Q_r$ ,  $Q_q$ ) affecting to the active power.

The mapping matrices model of Kim-Akagi [7] deals with instantaneous active-reactive power and voltage-current source is orthogonal vectors in a tetrahedron shape. In the pqr-coordinate transformation, Kim-Akagi made two consecutive transformation goals for voltage vector projection axis-q and axis-r is zero. Instantaneous active power generated from the multiplication dot product between voltage-current and cause condition the flow of energy between the two sub-systems. While the instantaneous reactive power resulting from the multiplication cross product between voltage-current and does not cause condition the flow of energy. Instantaneous active power is linearly independent, while instantaneous reactive

power depends on linearly three components to each other.

Power transformation in space-vector is the transformation of coordinate matrix-vector in reference frame stationary or rotating reference frame. Stationary reference frame (coordinate- $\alpha\beta$ ) called the Clarke transformation and rotating reference frame (coordinate-dq) is called the Park transformation. This transformation can be used to analyze the active-reactive power (PQ).

The research objective is to develop of pqr-coordinate on the mapping matrices model of Kim Akagi by Euler angle rotation method with twice and three times the rotation angle, and for certain boundary conditions can be applied to coordinate-pqr (Kim-Akagi model), coordinate- $\alpha\beta 0$  (Clarke transformation), and coordinate-dq0 (Park transformation).

## II. REVIEW THE MAPPING MATRICES MODEL OF KIM-AKAGI

Power transformation in a space-vector is stationary reference frame transformation (coordinate-  $\alpha\beta 0$ ) and a rotating reference frame (coordinate- dq0). This transformation can be used for analysis of the active-reactive power (PQ) and the control system on induction generator.

Transformation on coordinate-  $\alpha\beta 0$  (Clarke) is given as follows;

$$\begin{bmatrix} X_{\alpha} \\ X_{\beta} \\ X_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{2}{\sqrt{3}} & -\frac{2}{\sqrt{3}} \\ 0 & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \end{bmatrix} \begin{bmatrix} X_a \\ X_b \\ X_c \end{bmatrix} \quad (1)$$

Transformation on coordinate- dq0 (Park) is given as follows;

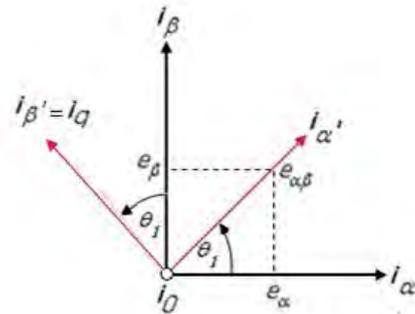
$$\begin{bmatrix} X_d \\ X_q \\ X_0 \end{bmatrix} = \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{\alpha} \\ X_{\beta} \\ X_0 \end{bmatrix} \quad (2)$$

The X-parameter can be in a voltage vector or a current vector. So far, researchers have to understand many phenomena of electric power system, especially in the analysis on the induction generator using a coordinate-  $\alpha\beta 0$  and / or coordinate- dq0. To overcome the problem of harmonics and non-linear loads then Kim-Akagi, based on research in [5], proposed a new coordinate transformation as a refinement of the coordinate-dq0 where the presence of a neutral component considered.

The pq-theory as an approach to the instantaneous active-reactive power in the time domain is developed from the Clarke transformation and applies to steady state or transient condition. The pqr-theory is

development of the pq-theory for the shunt active power filter system on 3-phase 4-wire. In pqr-theory analysis of active-reactive power (PQ), especially for the compensation components must use the neutral p-axis, q-axis and r-axis.

Kim-Akagi made two times transformation is from axis- $(\alpha\beta 0)$  to axis- $(\alpha'\beta'0)$ , and from axis- $(\alpha'\beta'0)$  to axis-(pqr) becomes stationary reference frame to rotating reference frame for instant active power ( $P_p$ ) and reactive power ( $Q_q, Q_r$ ). Elimination of neutral currents also conducted on r-axis with reactive power ( $Q_q$ ) derived from the q-axis.



Picture-1: Transformation plane-  $\alpha\beta$  to plane-  $\alpha'\beta'$ .

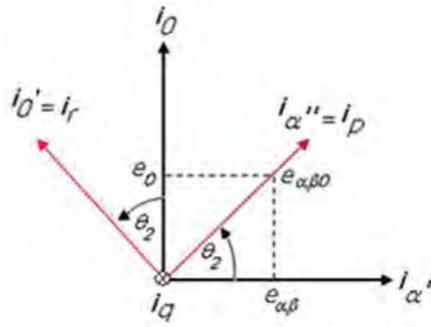
The first time is the transformation of the coordinate-  $\alpha\beta 0$  to coordinate- $\alpha'\beta'0$ . In the picture-1 transformation from coordinate- $\alpha'\beta'0$  to coordinate- $\alpha\beta 0$  is rotation by angle- $\theta_1$  and referred to as Park transformation, that is a transformation from coordinate-  $\alpha\beta 0$  to coordinate- dq0, where the axis- $\beta'$  is the q-axis.

$$\begin{bmatrix} i_{\alpha'} \\ i_{\beta'} \\ i_0 \end{bmatrix} = \begin{bmatrix} \cos \theta_1 & \sin \theta_1 & 0 \\ -\sin \theta_1 & \cos \theta_1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i_{\alpha} \\ i_{\beta} \\ i_0 \end{bmatrix} \quad (3)$$

in this case  $\cos \theta_1 = \frac{i_{\alpha}}{e_{\alpha\beta}}$ ,  $\sin \theta_1 = \frac{i_{\beta}}{e_{\alpha\beta}}$

and  $e_{\alpha\beta} = \sqrt{i_{\alpha}^2 + i_{\beta}^2}$

$$\text{thus obtained } \begin{bmatrix} i_{\alpha'} \\ i_{\beta'} \\ i_0 \end{bmatrix} = \begin{bmatrix} \frac{i_{\alpha}}{e_{\alpha\beta}} & \frac{i_{\beta}}{e_{\alpha\beta}} & 0 \\ -\frac{i_{\beta}}{e_{\alpha\beta}} & \frac{i_{\alpha}}{e_{\alpha\beta}} & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i_{\alpha} \\ i_{\beta} \\ i_0 \end{bmatrix} \quad (4)$$



Picture-2: Transformation plane-  $\alpha'0$  to plane- $pq$ .

And then the subsequent transformation is from  $\alpha'\beta'0$ -coordinate (or  $\alpha'q0$ -coordinate) to  $pqr$ -coordinate. In the picture-2, the transformation from plane-  $\alpha'0$  to plane-  $pq$  by rotation angle  $\square_2$ , that mean  $i_\alpha$  current on position of the  $\alpha'$ -axis to be  $i_p$  current on position of the  $p$ -axis in form of a tetrahedron shape.

$$\begin{bmatrix} i_p \\ i_q \\ i_r \end{bmatrix} = \begin{bmatrix} \cos \theta_2 & 0 & \sin \theta_2 \\ 0 & 1 & 0 \\ -\sin \theta_2 & 0 & \cos \theta_2 \end{bmatrix} \begin{bmatrix} i_{\alpha'} \\ i_{\beta'} \\ i_0 \end{bmatrix} \quad (5)$$

in this case

$$\cos \theta_2 = \frac{e_{\alpha\beta}}{e_{\alpha\beta\gamma}}, \quad \sin \theta_2 = \frac{e_{\alpha\gamma}}{e_{\alpha\beta\gamma}}$$

$$\text{and } e_{\alpha\beta\gamma} = \sqrt{e_{\alpha\beta}^2 + e_{\alpha\gamma}^2 + e_{\beta\gamma}^2}$$

thus obtained

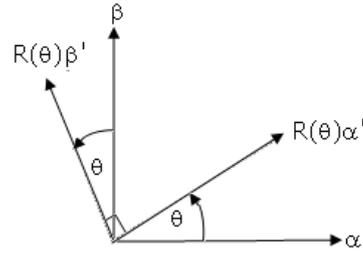
$$\begin{bmatrix} i_p \\ i_q \\ i_r \end{bmatrix} = \begin{bmatrix} \frac{e_{\alpha\beta}}{e_{\alpha\beta\gamma}} & 0 & \frac{e_{\alpha\gamma}}{e_{\alpha\beta\gamma}} \\ 0 & 1 & 0 \\ -\frac{e_{\alpha\gamma}}{e_{\alpha\beta\gamma}} & 0 & \frac{e_{\alpha\beta}}{e_{\alpha\beta\gamma}} \end{bmatrix} \begin{bmatrix} i_{\alpha'} \\ i_{\beta'} \\ i_0 \end{bmatrix} \quad (6)$$

If equation-4 is substituted into equation-6 is obtained as follows:

$$\begin{bmatrix} i_p \\ i_q \\ i_r \end{bmatrix} = \begin{bmatrix} \frac{e_{\alpha\beta}}{e_{\alpha\beta\gamma}} & \frac{e_{\beta\gamma}}{e_{\alpha\beta\gamma}} & \frac{e_{\alpha\gamma}}{e_{\alpha\beta\gamma}} \\ \frac{e_{\alpha\gamma}}{e_{\alpha\beta\gamma}} & \frac{e_{\alpha\beta}}{e_{\alpha\beta\gamma}} & 0 \\ -\frac{e_{\alpha\gamma}}{e_{\alpha\beta\gamma}} & -\frac{e_{\beta\gamma}}{e_{\alpha\beta\gamma}} & \frac{e_{\alpha\beta}}{e_{\alpha\beta\gamma}} \end{bmatrix} \begin{bmatrix} i_{\alpha'} \\ i_{\beta'} \\ i_0 \end{bmatrix} \quad (7)$$

### III. OVERVIEW OF EULER ANGLE ROTATION METHOD

Principle of Euler angle rotation on the group theory [7].



Picture-3: Rotation in  $\square$  angle

Projection of  $R(\theta)$  to the vector- $\alpha, \beta$  can be written as follows:

$$\alpha = R(\theta)\alpha' \cos \theta - R(\theta)\beta' \sin \theta$$

$$\beta = R(\theta)\alpha' \sin \theta + R(\theta)\beta' \cos \theta$$

in matrix form

$$\begin{bmatrix} \alpha \\ \beta \end{bmatrix} = \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix} R(\theta) \begin{bmatrix} \alpha' \\ \beta' \end{bmatrix}$$

By doing the inverse matrix can be explained as follows:

$$R(\theta) \begin{bmatrix} \alpha' \\ \beta' \end{bmatrix} = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \end{bmatrix} \quad (8)$$

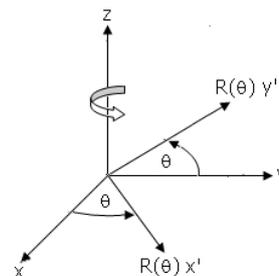
For the boundary condition  $\alpha = \alpha'$  and  $\beta = \beta'$  obtained matrix rotation  $R(\theta)$  as follows:

$$R(\theta) = \begin{bmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{bmatrix} \quad (9)$$

Some important properties of the matrix rotation  $R(\theta)$  in the Euler angles are as follows:

1.  $R^{-1}(\theta) R(\theta) = I$  (Identity)
2.  $\det R(\theta) = 1$  (Identity)
3.  $R(0) = I$  (Identity)

In the same, for three dimensional projections way the matrix rotation of the  $z$ -axis can be described as follows:



Picture-4: Plane- $xy$  rotated  $z$ -axis direction where the rotation matrix is in the  $z$ -axis;

$$R_z(\theta) = \begin{bmatrix} \cos \theta & \sin \theta & 0 \\ -\sin \theta & \cos \theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (10)$$

By using the principle of rotation of the equilateral triangle can be obtained rotation matrices for each axis, like a rotation about the  $x$ -axis,  $R_x(\theta)$ , and the  $y$ -axis,  $R_y(\theta)$ .

The rotation matrices in the  $x$ -axis as follows:

$$R_x(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \theta & \sin \theta \\ 0 & -\sin \theta & \cos \theta \end{bmatrix} \quad (11)$$

and the rotation matrices in the y-axis s follows:

$$R_y(\theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix} \quad (12)$$

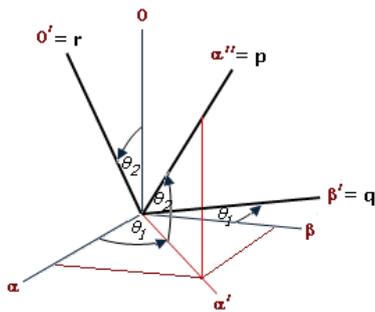
Euler angle rotation matrix formed by multiplying each axis rotation and can be described as follows:

$$R(\theta_1, \theta_2, \theta_3) = R_z(\theta_3) R_y(\theta_2) R_x(\theta_1) \\ = \begin{bmatrix} \cos\theta_3 & \sin\theta_3 & 0 \\ -\sin\theta_3 & \cos\theta_3 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\theta_2 & 0 & \sin\theta_2 \\ 0 & 1 & 0 \\ -\sin\theta_2 & 0 & \cos\theta_2 \end{bmatrix} \times \\ \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_1 & \sin\theta_1 \\ 0 & -\sin\theta_1 & \cos\theta_1 \end{bmatrix} \quad (13)$$

A coordinate rotation can be done with continuous configuration between two Cartesian coordinate. The coordinate- $(\alpha, \beta, 0)$  as a stationary reference frame and coordinate- $(\alpha', \beta', 0)$ ,  $(\alpha'', q, r)$ ,  $(p, q, r)$  as a frame of reference rotating. Rotation, noted as,  $R(\theta_1, \theta_2, \theta_3)$  is performed to move the rotation axis of the stationary reference frame into a frame of reference rotating with the boundary condition,  $0 < \theta_1, \theta_2 < 2\pi$  and  $0 < \theta_3 < \pi$ .

It can be seen that the rotation of the reference frame is carried out rotating continuously from a stationary reference frame. Method of Euler angle rotation is the rotation in each coordinate- $(\alpha, \beta, 0)$  in a stationary reference frame into the coordinate- $(\alpha', \beta', 0)$ ,  $(\alpha'', q, r)$ ,  $(p, q, r)$  reference frame spin axis so that it can be done in a systematic incorporation. Thus, the principle of rotation can be used to the mapping matrices model of Kim-Akagi in solving problems related to pqr-coordinate.

The process of two-times rotation on the angles  $\theta_1, \theta_2$



Picture-5: The rotation of two Euler angles.

In figure-5, the two simple rotation in Euler angles where the  $\square_1$ -angle must be shift the  $\alpha$ -axis into  $\alpha'$ -axis along with it's  $\beta$ -axis shifted to q-axis, and  $\square_2$ -angle raise  $\alpha'$ -axis be the p-axis, and along with it's the 0-axis shifted to r-axis.

Multiplication Euler angles for 2 variable angles  $\theta_1, \theta_2$  are as follows:

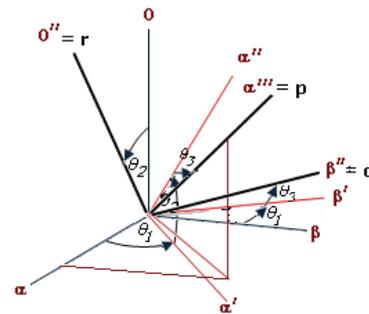
$$R(\theta_1, \theta_2) = R_N(\theta_2) R_z(\theta_1)$$

$$= \begin{bmatrix} \cos\theta_2 & 0 & \sin\theta_2 \\ 0 & 1 & 0 \\ -\sin\theta_2 & 0 & \cos\theta_2 \end{bmatrix} \begin{bmatrix} \cos\theta_1 & \sin\theta_1 & 0 \\ -\sin\theta_1 & \cos\theta_1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \\ = \begin{bmatrix} \cos\theta_2 \cos\theta_1 & \cos\theta_2 \sin\theta_1 & \sin\theta_2 \\ -\sin\theta_2 \cos\theta_1 & -\sin\theta_2 \sin\theta_1 & \cos\theta_2 \\ \sin\theta_1 & \cos\theta_1 & 0 \end{bmatrix} \quad (14)$$

in this case the  $R_N(\theta_2) = R_y(\theta_2)$  is the rotation in the direction of the y-axis as equation-12. These results together with model Kim-Akagi mapping matrices are as in equation-7 above shall be as follows:

$$R(\theta) = \begin{bmatrix} \frac{r}{\sqrt{p^2+q^2}} & \frac{q}{\sqrt{p^2+q^2}} & \frac{p}{\sqrt{p^2+q^2}} \\ \frac{r}{\sqrt{p^2+q^2}} & \frac{q}{\sqrt{p^2+q^2}} & 0 \\ \frac{r}{\sqrt{p^2+q^2}} & \frac{q}{\sqrt{p^2+q^2}} & \frac{p}{\sqrt{p^2+q^2}} \end{bmatrix}$$

The process of three-times rotation on the angles  $\theta_1, \theta_2, \theta_3$



Picture-6: The rotation of three Euler angles.

In figure-6, the  $\square_1$ -angle shift  $\alpha$ -axis into axis- $\alpha'$  along with it's  $\beta$ -axis shifted to the  $\beta'$ -axis, the  $\square_2$ -angle raise  $\alpha'$ -axis be the  $\alpha''$ -axis, and along with it's the 0-axis shifted to axis-r, and last time  $\square_3$ -angle shift  $\alpha''$ -axis to the p-axis along with it's  $\beta'$ -axis shifted into q-axis.

Multiplication Euler angles for 3 variables angles  $\theta_1, \theta_2, \theta_3$  are as follows:

$$R(\theta_1, \theta_2, \theta_3) = R_3(\theta_3) R_N(\theta_2) R_3(\theta_1)$$

Applicability of the transformation is when angles  $\theta_1, \theta_2, \theta_3 = 0$ , that is not the case then the Euler angle rotation event multiplication results in the transformation Clarke (coordinate- $\alpha\beta 0$ ) as follows:

$$\begin{bmatrix} X_{\alpha} \\ X_{\beta} \\ X_0 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{\alpha} \\ X_{\beta} \\ X_0 \end{bmatrix} = \frac{1}{\sqrt{3}} \begin{bmatrix} 1 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} X_{\alpha} \\ X_{\beta} \\ X_0 \end{bmatrix} \quad (14)$$

For the angles  $\theta_1, \theta_2 = 0$ , there is one variable rotation Euler angles, namely rotation about the z-axis to obtain the equation-2 transformation Park (coordinate-dq0) as follows:

$$\begin{aligned} \begin{bmatrix} X_p \\ X_q \\ X_r \end{bmatrix} &= \begin{bmatrix} \cos \theta_1 & \sin \theta_1 & 0 \\ -\sin \theta_1 & \cos \theta_1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{\alpha} \\ X_{\beta} \\ X_0 \end{bmatrix} \\ &= \sqrt{\frac{2}{3}} \begin{bmatrix} \cos \theta_1 & \sin \theta_1 & 0 \\ -\sin \theta_1 & \cos \theta_1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & \frac{2}{\sqrt{3}} & -\frac{2}{\sqrt{3}} \\ 0 & \frac{2}{\sqrt{3}} & \frac{2}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \end{bmatrix} \begin{bmatrix} X_{\alpha} \\ X_{\beta} \\ X_0 \end{bmatrix} \end{aligned} \quad (15)$$

For the angle  $\theta_3 = 0$ , occurs Euler angle rotation 2 variables, namely rotation about the z-axis and the continued rotation of the y-axis as a description of the equation-14 model of Kim-Akagi mapping matrices is obtained as follows:

$$\begin{aligned} \begin{bmatrix} X_p \\ X_q \\ X_r \end{bmatrix} &= \begin{bmatrix} \cos \theta_2 \cos \theta_1 & \cos \theta_2 \sin \theta_1 & \sin \theta_2 & 1 & 0 & 0 \\ -\sin \theta_1 & \cos \theta_1 & 0 & 0 & 1 & 0 \\ -\sin \theta_2 \cos \theta_1 & -\sin \theta_2 \sin \theta_1 & \cos \theta_2 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_{\alpha} \\ X_{\beta} \\ X_0 \end{bmatrix} \\ &= \sqrt{\frac{2}{3}} \begin{bmatrix} \cos \theta_2 \cos \theta_1 & \cos \theta_2 \sin \theta_1 & \sin \theta_2 \\ -\sin \theta_1 & \cos \theta_1 & 0 \\ -\sin \theta_2 \cos \theta_1 & -\sin \theta_2 \sin \theta_1 & \cos \theta_2 \end{bmatrix} \begin{bmatrix} 1 & \frac{2}{\sqrt{3}} & -\frac{2}{\sqrt{3}} \\ 0 & \frac{2}{\sqrt{3}} & \frac{2}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \end{bmatrix} \begin{bmatrix} X_{\alpha} \\ X_{\beta} \\ X_0 \end{bmatrix} \end{aligned} \quad (16)$$

and by incorporating the boundary conditions of each axis as follows:

- $\alpha \rightarrow p : f(\theta_1, \theta_2, \theta_3)$  as a function from angles  $\theta_1, \theta_2, \theta_3$
- $\beta \rightarrow q : f(\theta_1, \theta_3)$  as a function from angles  $\theta_1, \theta_3$ .
- $0 \rightarrow r : f(\theta_2)$  as a function from angle  $\theta_2$ .

The matrix rotation is obtained as follows;

$$R(\theta_1, \theta_2, \theta_3) = \begin{bmatrix} \cos \theta_2 \cos(\theta_3 + \theta_1) & \sin(\theta_3 + \theta_1) & \sin \theta_2 \\ -\sin(\theta_3 + \theta_1) & \cos(\theta_3 + \theta_1) & 0 \\ -\sin \theta_2 & 0 & \cos \theta_2 \end{bmatrix} \quad (17)$$

With using equation-2 (Clarke transformation) to obtain a matrix transformation as follows:

$$\begin{aligned} \begin{bmatrix} X_p \\ X_q \\ X_r \end{bmatrix} &= \begin{bmatrix} \cos \theta_2 \cos(\theta_3 + \theta_1) & \sin(\theta_3 + \theta_1) & \sin \theta_2 \\ -\sin(\theta_3 + \theta_1) & \cos(\theta_3 + \theta_1) & 0 \\ -\sin \theta_2 & 0 & \cos \theta_2 \end{bmatrix} \begin{bmatrix} X_{\alpha} \\ X_{\beta} \\ X_0 \end{bmatrix} \end{aligned} \quad (18)$$

in this case  $X \equiv i, V$  (as current or voltage)

## CONCLUSION

The instantaneous active-reactive power theory in the theory-pq or theory-pqr developed as an effort to solve the problem of harmonic and non-linear loads caused by sources that are non-sinusoidal, by using the model of mapping matrices, Kim-Akagi attempting to solve the problem. Active power filter also developed to support the theory. The pqr-coordinate on the model mapping matrices of Kim-Akagi is a refinement of the coordinate-dq0.

The pqr-coordinate as the mapping matrices model of Kim-Akagi is two times of rotation in Euler angle method. Rotation also developed three times of rotation in Euler angles as a correction factor. This transformation is a part of the Clarke transformation. With Euler angle rotation method, the mapping matrices model Kim-Akagi can be described and the result of the rotation of the 2 (two) Euler angles. Furthermore, rotation of the 3 (three) points generate a new transformation matrix for the coordinate-pqc. In certain circumstances the transformation matrix can be applied to coordinate- $\alpha\beta 0$  (Clarke transformation), coordinate-dq0 (Park transformation), and coordinate-pqr (Kim-Akagi).

## REFERENCES

- [1] E. H. Watanabe, H. Akagi and M. Aredes, "Instantaneous p-q Power Theory for Compensating Nonsinusoidal Systems". *International School on Nonsinusoidal Currents and Compensation*. Lagow, Poland, 2008.
- [2] H. Akagi, Y. Kanazawa and A. Nabae, "Instantaneous Reactive Power Compensators Comprising Switching Devices without Energy Storage Components". *IEEE Trans. Ind Appl.*, vol. IA-20, No. 3, pp. 625-630. May/June 1984.
- [3] H. Kim and H. Akagi. "The Instantaneous Power Theory on the Rotating p-q-r Reference Frames". *IEEE Intl. Conf. Power Electr and Drive Syst (PEDS)*, pp 422-427. July 1999. Hong Kong.
- [4] J.L. Willems. "A New Interpretation of the Akagi-Nabae Power Components for Nonsinusoidal Three-Phase Situations". *IEEE Trans Instr. and Measurement*, vol. 41, No. 4, pp. 523-527. Agst 1992.
- [5] E.H. Watanabe, R.M. Stephan and M. Aredes. "New Concepts of Instantaneous Active and Reactive Power in Electrical Systems with Generic Loads". *IEEE Trans Power Delivery*, vol.8, No.2, pp.697-703. April 1993.
- [6] M. Aredes, H. Akagi, E.H. Watanabe, E. Vergara and L.F. Encarnaçao. "Comparisons Between the p-q and p-q-r Theories in Three-Phase Four-Wire Systems". *IEEE Trans. Power Electron.*, vol. 24. no. 4. pp 924-933. April 2009.

- [7] W.K. Tung. "Group Theory in Physics". World Scientific Publ. Co. Singapore. 1985.

# Review of Microgrid Technology

**Hartono BS**

Faculty of Engineering, Universitas  
 Indonesia Depok 16424  
 hartono@esi-labs.com

**Budiyanto**

Faculty of Engineering, Universitas  
 Indonesia Depok 16424  
 yan.budiyanto@yahoo.com

**Rudy Setiabudy**

Faculty of Engineering, Universitas  
 Indonesia Depok 16424  
 rudy@eng.ui.ac.id

**Abstract**—The use of renewable energy source (RES) in meet the demand of electrical energy is getting into attention as solution of the problem a deficit of electrical energy. Application of RES in electricity generation system is done in a variety of configurations, among others in microgrid system. Implementation of microgrid systems provide many advantages both from the user and from the electric utility provider.

Many microgrid development carried out in several countries, because microgrid offers many advantages, including better power quality and more environmentally friendly. Microgrid development concern in technology generation, microgrid architecture, power electronics, control systems, protection systems.

This paper reviewing various technological developments related to microgrid system and case study about microgrid system development using grid tie inverter (GTI). Microgrid system can implemented using GTI, power transfer can occur from GTI to grid when GTI has power excess and grid supplying power to GTI when GTI power shortage.

**Keyword** : microgrid, microgrid architecture, microgrid control and managemen, grid tie inverter

## I. INTRODUCTION

The use of renewable energy source (RES) in meet the needs of electrical energy is getting into attention as solution of the problem a deficit of electrical energy, particularly for areas that are difficult to reach existing power grids. A variety of development related to the use of RES continues. Start from optimizing the use of energy sources, the development of the power conversion system up to the electrical power system architecture. Application of RES in electricity generation systems performed in a variety of configurations. Starting from the most simple systems such as the utilization of PV in solar home systems (SHS) to the application of RES in the microgrid system.

Production of electric power from RES such as solar power generation varies greatly depending on the source of the sun received at the time. This raises concerns on quality of generated power, especially if it is connected to the grid system, where solar power would be seen as a negative expense by net system because it has characteristics associated with uncontrolled fluctuation from energy sources [1]. This problem can be addressed by adding another generation systems more controlled, such as, the addition of energy storage systems (batteries) or forming a hybrid system by adding diesel generators or micro turbines[2].

Implementation of microgrid systems provide many advantages both from the user and from the electric utility provider. From the user's application of the microgrid is connected to the grid, it can improve network quality, reduce emissions and can reduce the cost to be incurred by the user.

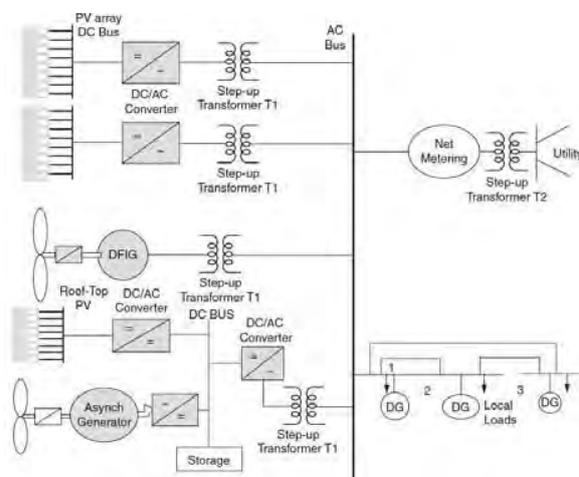
From the electric utility provider implementation of distributed generation systems with the ability microgrid can reduce the power flow on transmission and distribution lines, so as to reduce losses and reduce costs for additional power. Moreover microgrid can also reduce the load on the network by eliminating the impasse in meeting electricity needs and help repair network in case of errors[3]. Implementation of microgrid system will also help improve the reduction of emissions and the threat of climate change.

Microgrid development done by many countries since microgrid offers many advantages such as better power quality and more environmentally friendly. Moreover the economic potential that may still be used from this system is the opportunity to utilize the waste heat from the engine generator using a combined heat and power (CHP). Application of this system with RES as an alternative generation system in the future. Surely this system requires the operating mechanism and a sophisticated control system to make the finger with a reliable and efficient, and it can all be met by the microgrid[4].

## II. ARCHITECTURE OF MICROGRID

Microgrid system operate at a low voltage distribution, and has several distributed energy resources. Microgrid system also has the ability to operate connected to the grid (on grid) or disconnected to the grid (off grid/islanded) [5].

The microgrid structure consists of several types of distributed energy sources (DER) such as solar panels, wind turbines, microturbine, thermal power plant each in the form of distributed generation (DG), including energy reserves from battery (Distributed Storage/DS).



(a)

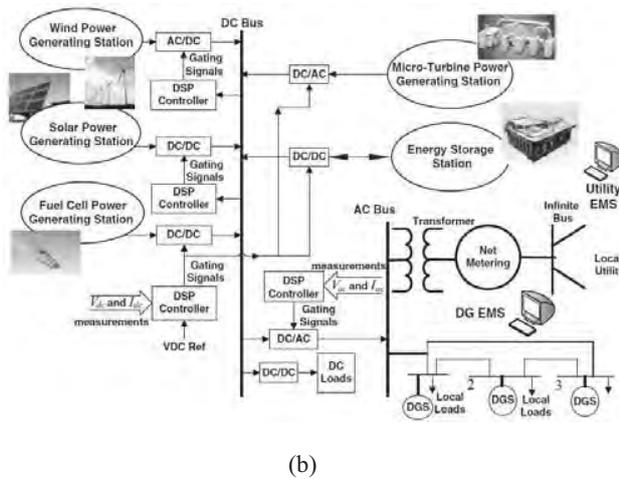


Figure 1. Architecture of Microgrid (a) AC microgrid (b) DC microgrid

Microgrid electrical connection points that connected to the low voltage network in the PCC (point of common coupling) that connected to the DG, DS and loads, which consist of several types of loads such as residential, commercial buildings, campuses and industrial complexes. As shown in Figure 1, architecture of microgrid organized as AC microgrid (AC bus) or DC microgrid (DC bus) or combine of both [6].

### III. TECHNOLOGY OF MICROGRID

Operation of microgrid system can not be separated from technologies that support from each part that make up the microgrid system, as the source of energy (distributed generation), energy storage, interconnect switches and microgrid control system. Technologies in energy sources distributed generation include the utilization of renewable energy sources such as photovoltaic, wind turbines, and fuel cells. Several power systems improve efficiency by implementing the use of flue gas using CHP technology (combined heat and power) as microturbine, figure 2.



Figure 2. Microturbine

Technologies in energy storage microgrid systems which include battery, super capacitor and flywheels. Energy storage in microgrid system is used among others to:

- Stabilization of the microgrid system in the face of fluctuating energy sources and load changes.
- Enables load sharing operation in microgrid system.
- Reduce the loads spikes and electrical interference
- Backup energy source

Switch interconnection technology in microgrid system utilizing digital technology using Digital Signal Processor (DSP) and equipped with communication devices, while meeting the IEEE 1574 standard network interconnection. To improve the response speed semiconductor switch used technologies such as thyristors and IGBT, Figure 3.

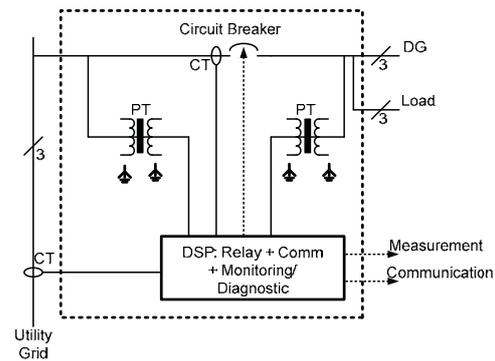


Figure 3. A schematic diagram of circuit breaker on connection to the grid

Control system technologies in microgrid can be grouped in two modes of operation are connected to the network mode and isolated mode (islanding). The control system is intended to regulate the stability of microgrid operation particularly in frequency and voltage to maintain stability in face of changes in load and interconnection with other networks. The control system is applied to power converter technology in regulating active and reactive power supply, applying droop control and frequency control [7].

### IV. CONTROL AND MANAGEMENT OF MICROGRID

Control system in microgrid contrast to conventional power systems, this is due to several reasons, among others:

- Steady state and dynamic characteristics of microgrid different from conventional plants
- microgrid possesses inherent unbalanced load due to one phase loads
- The supply of power from microgrid can come from uncontrolled sources such as wind
- The role of energy storage is very large in the control mechanisms used
- microgrid accommodate disconnection and connection mechanisms to maintain expenses during its operating
- microgrid requires initial requirements of power quality or service preferences for certain types of loads

TABLE I. SEVERAL TYPES OF MECHANISMS CONTROL USED IN DER

	Main Energy Sources	Interface/inversion	Power Flow Control
DG conventional	reciprocating engine small hydro Wind Turbin fixed speed	synchronous generator induction generator	AVR Control and Governor (+P,±Q) stall or pitch control of turbine (+P,-Q)
DG Non conventional	Wind Turbin variabel speed Microturbine	Power electronics converters (conversion AC-DC-AC)	Turbine speed control and DC link voltage control (+P,±Q)
	Solar Panel Fuel cell	Power electronics converters (conversion DC-DC-AC)	MPPT Control and DC link voltage control (+P,±Q)
Long time storage (DS)	battery storage	Power electronics converters (conversion DC-DC-AC)	state of charge and / or control output voltage / frequency (±P/±Q)
Short time storage (DS)	Flywheel	Power electronics converters (conversion AC-DC-AC)	state of charge (±P,±Q)
	Super Capacitor	Power electronics converters	Speed control (±P,±Q)

As described previously microgrid consists of DER configuration, loads with classified characteristics and management control systems and microgrid. DER may include distributed generation (Distributed Generation/DG) or distributed storage systems (Distributed Storage/DS). Diagram of DG on the microgrid system consists of primary energy sources, media interface and interconnect switches. A DS can be a major energy source for the DG. Moreover main energy source can be generated using a rotary machine /spinning and generating device that consists of power electronics converters.Both provide concepts, strategies and characteristics of different controls. Moreover control strategy and operation of interconnect system, as well as energy/power management used largely determined the type of DER technologies in use, the type of load demand and the expected operating scenarios. Several types of control mechanisms used in DER described in Table I.

In context of power flow control DER units can be grouped into unit dispatchable energy (power output can be regulated) and non-dispatchable (power output can not be adjusted). In dispatchable energy unit output power setting is set externally using supervisory control such as AVR, while for non-dispatchable energy unit output power settings based on the maximum power that can be generated using MPPT concept. A non-dispatchable energy units can be converted into dispatchable energy units using additional energy storage systems and power electronic circuit converter dc-de-ac. In addition to provide faster response electronic converters also able to limit short circuit contribution not less than 200% from current capability and to prevent damage due to currents, figure 4.

Stability of microgrid operation was also obtained by setting the loads connected to the network, especially on non-critical loads. Critical loads more attention than the other loads that are not critical. Settings done in several ways including termination control loads in order to maintain the stability of the voltage and frequency. The distinction between loads service, improved power quality and reliability for certain expenses.

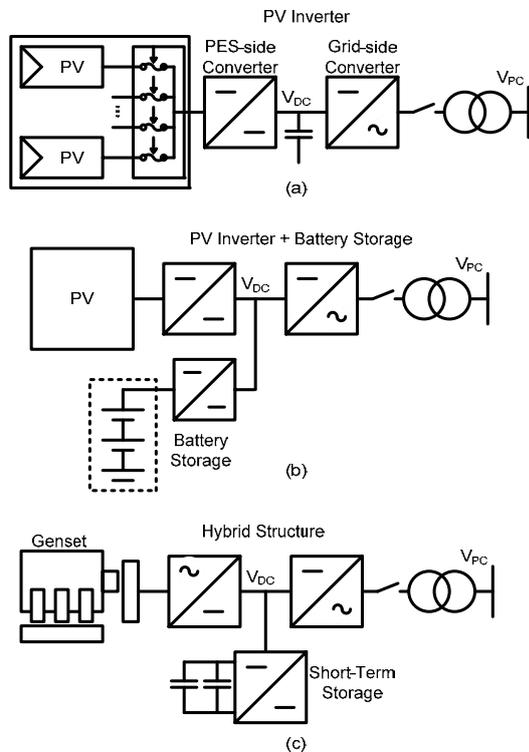


Figure 4. Configuration of non dispatchable (a) and dispatchable (b) and (c)

Control Method of microgrid

The aim control mechanisms of microgrid is to regulate voltage and frequency, as well as reactive and active power output, to fit the setting. Microgrid control strategies can be grouped into several alternative control as shown in table II.

TABLE II. CLASSIFICATION OF DER UNIT CONTROL METHOD

Control method	Grid following control	Grid forming control
Non-interactive control method	Power Export (with/without MPPT)	Voltage and frequency control
Interactive control method	Power dispatch real and reactive power support	Load sharing (droop control)

In non-interactive control strategies, output power settings carried out independently while at interactive control strategies output power setting performed as command from control unit. Each control strategy is divided into grid-following and grid-forming control. In grid-following control, settings power output including voltage and frequency are determined by the microgrid. Setting output active power and reactive power can use a synchronization

control strategy framework "dq0". In this control strategy current in each phase is used as an input to determine PWM voltage that will regulate power output. Magnitude of input current is transformed into massive d axis and q axis which then transformed into  $V_{abc}$  voltage magnitude. Mechanisms of active and reactive power dispatch by an energy management system to perform optimization strategy based on potential energy profile. Moreover setting output power is also determined by load profile, Figure 5.

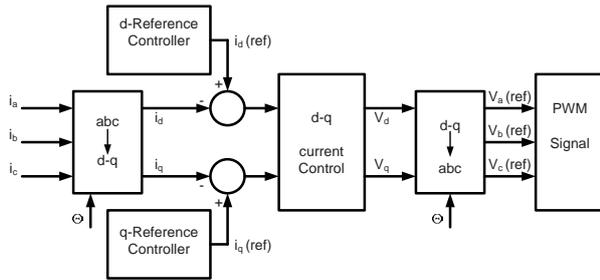


Figure 5. dq control on DER unit inverter

In grid-forming control power settings, including output voltage and frequency, by DER units and will be followed by another DER units. DER units that implement grid-forming should have a greater energy potential. Droop control strategies made using voltage and frequency droop control. Determination of allowable output power according to droop characteristics given parameters, as shown in figure 6,

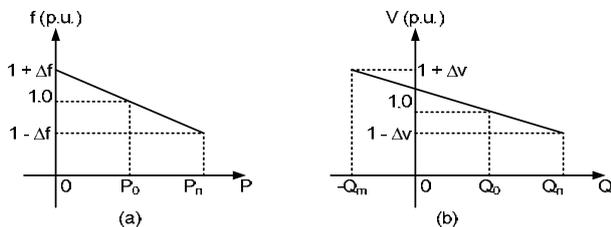


Figure 6. DER unit droop diagram on grid-forming control

Amount change in voltage and frequency of droop characteristics are used as input to dq transformation in order to determine amount of active and reactive power output. To ensure microgrid operation mechanism works as expected then the operation of each DER unit must be coordinated properly for it required method of supervisory control strategy microgrid operation. Microgrid operation supervisory control strategies can be centralized or decentralized [8].

#### Managing control of microgrid

On centralized supervisory control strategy, amount of power output from each LC (Local Control) is determined by MCC (Microgrid Control Center) based on input (bidding) production capacity owned by each LC. MCC based on inputs of LC and operating policy that covers current energy market prices, estimates needs and production as well as consideration of infrastructure conditions other microgrid,

determine LC operations include setting LC production capacity. The amount of loads to be served and amount of market price for energy optimization of LC in determining bidding further production capacity to MCC.

In decentralized supervisory control strategies each LC has ability to determine operating autonomy of energy production that will be generated by LC. The main purpose of control strategy in each LC is not aimed at increasing financial income but rather to overall performance of microgrid. So at each LC already has economic parameters, environmental conditions/ potential energy (weather) and the estimated load. One method of control that can be applied to this system is using Multi Agent System (MAS). MAS is a evolution form of classical control of distributed control systems with the ability to control large and complex entity. The main feature of MAS is the ability to incorporate elements of intelligence in each local control (LC). Configuration of MAS system on a microgrid as shown in figure 7.

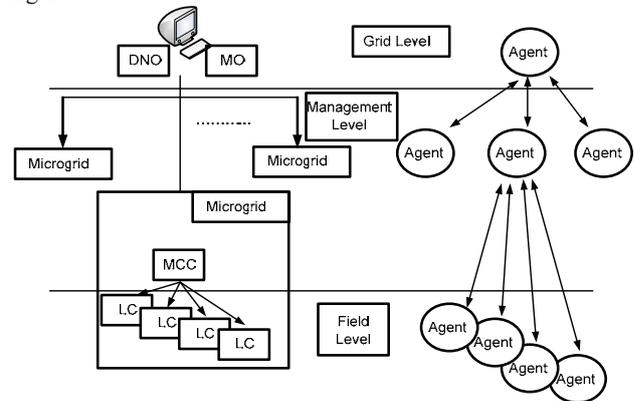


Figure 7. Multi Agent System configuration on microgrid

In the centralized and decentralized systems both require reliable data communications facilities. Data communication network can be radio, telephone or power line carrier. Through this communication networks microgrid operation mechanism arranged between each DER unit or the main control system in form of energy management system applications.

#### V. TECHNICAL CHALLENGES ON MICROGRID

As a new paradigm of power systems, implementation of microgrid still face many obstacles. Less understanding about microgrid and unfavorable government policies become an obstacle in applying microgrid technology. In general, in addition can be applied as a solution to electricity in remote areas, microgrid technology can also be used as electrical solutions such as urban residential complexes, offices, schools and others. In which implementation of microgrid technology will provide advantage compared if have to build a new transmission and distribution network. Advantages and disadvantages in applying microgrid technology among others [9]:

*Microgrid Advantages*

- Microgrid, have ability, during a utility grid disturbance, to separate and isolate itself from the utility seamlessly with little or no disruption to the loads within the Microgrid.
- In peak load periods microgrid can prevents utility grid failure by reducing the load on the grid.
- Microgrid have environmental benefits made possible by use low or zero emission generators.
- In microgrid to increasing energy efficiency, the use of both electricity and heat is permitted to get closer the generator to user.
- Microgrid can act to mitigate the electricity costs to its users by generating some or all of its electricity needs.

*Microgrid Disadvantages*

- In microgrid, that must be considered and controlled voltage, frequency and power quality parameters to acceptable standards whilst the power and energy balance is maintained.
- Electrical energy needs to be stored in battery banks thus requiring more space and maintenance.
- The difficulty of resynchronization with the utility grid.
- Microgrid protection is one of the most important challenges facing the implementation of Microgrids.
- Issues such as standby charges and net metering may pose obstacles for Microgrid.
- Interconnection standards needs to be developed to ensure consistency. IEEE P1547, a standard proposed by Institute of Electrical and Electronics Engineers may end up filling the void.

*Future Direction On Microgrid Research*

Future direction which require further investigation in the context of microgrid research are [10]:

- To investigate full-scale development, field demonstration, experimental performance evaluation of frequency and voltage control methods under various operation modes
- Transition between grid connected and islanded modes on interaction phenomena between distribution generation and high penetration of distributed generation
- Analysis the issue of black starting in an unbalanced system on the control, protection and power quality
- Transformation of microgrid system today into the intelligent, robust energy delivery system in the future by providing significant reliability and security benefits.

*VI. MICROGRID DEVELOPMENT USING GTI*

Microgrid systems can be implemented using grid tie inverter (GTI). The weakness of this system is when there is no grid, the system can not work because GTI will work if there is a power from grid that is used as a reference of GTI operation. microgrid trials using GTI have been conducted in laboratory.

In this experiment, PV source simulated with variable DC source. a set of Configuration tests looks like in figure 8

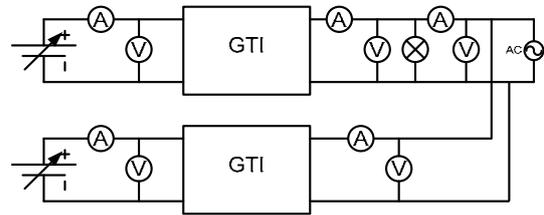
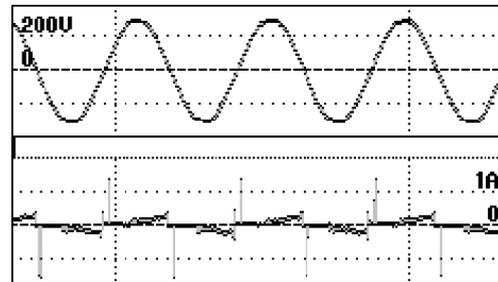


Figure 8. Microgrid system using GTI

In this trial used 2 pieces of GTI and a local load. Measurements were taken to see the distribution of power flow of each GTI and power flow from PLN in meeting needs of power required by load.



Gambar 9. GTI output voltage on grid condition

The measurement results of GTI output voltage shown in Figure 9. The form of GTI output voltage in accordance with PLN. Power measurements performed on each output of inverter, load and line to PLN. The measurement begins by activating the GTI without being connected to the PLN, characterized by value of PLN power = 0W as shown in table III.

TABLE III. POWER FLOW IN MICROGRID SYSTEM

$P_{GTI1}$ (W)	$P_{GTI2}$ (W)	$P_L$ (W)	$P_{pln}$ (W)
0	0	0	0
122	0	170	55
120	40	170	14
120	40	0	-158
0	0	0	0

From the data presented can be seen that when there is no supply from PLN then both the GTI does not generate power to the load. When GTI 1 (PGTI1) supplied power to load and GTI 2 (PGTI2) has not been issued, then power to load (PL) supplied by GTI 1 and PLN (PPLN). When GTI2 start generating power then the power of the PLN decreases proportional to the input power of GTI2. When there is no power supplied to load (load disconnected) power of both GTI supplied to PLN. Minus sign indicates direction of power flow towards PLN grid. When the source of PLN disconnected (isolated/islanding), as seen in last data table, PLN power = 0W, then both the GTI no output power again. The measurement results show that the number of power

does not show balance of power, this can caused each power output measurements performed using different tools.

### VII. CONCLUSION

Microgrid system is an alternative electricity network that can be used to meet the electricity needs of the future. In the microgrid system consists of multiple power sources, which can use renewable energy sources. Microgrid system works autonomously so it requires a complex control system to regulate the operation of microgrid.

Implementation of microgrid can be done using the inverter GTI. Microgrid with GTI can transferring power to/from grid. Power transfer can occur from GTI to grid when GTI has power excess and grid supplying power to GTI when GTI power shortage. Power sharing between parallel GTI based on input power of each of GTI, if there is shortage of power will be supplied from grid.

### REFERENCES

- [1] Ph. Degobert, S. Kreuawan and X. Guillaud "Micro-grid powered by photovoltaic and micro turbine", ICREPQ'06, 2006
- [2] R. Lasseter, A. Akhil, C. Marnay, J. Stephens, J. Dagle, R. Guttromson, A. Sakis Meliopoulos, R. Yinger, and J. Eto, "Integration of Distributed Energy Resources – The MicroGrid Concept". CERTS MicroGrid Review Feb 2002.
- [3] Anestis. G. Anastasiadis, Antonis. G. Tsikalakis, dan Nikos. D.Hatziargyriou, "Environmental Benefits From DG Operation When Network Losses are Taken Into Account", Distres Conference 11-12 December 2009 Nicosia Cyprus
- [4] Nikos Hatziargyriou, Hiroshi Asano, Reza Iravani, dan Chris Marnay. "Microgrid, An Overview of Ongoing Research, Development, and Demonstration Projects", *IEEE power & energy magazine*, july/august 2007
- [5] Wilsun Xu, Konrad Mauch, and Sylvain Martel, "An Assessment of Distributed Generation Islanding Detection Methods and Issues for Canada", CETC-Varennes 2004-074 (TR) 411-INVERT
- [6] Ali Keyhani, Mohammad N. Marwali, and Min Dai, "Integration Of Green And Renewable Energy In Electric Power Systems", John Wiley & Sons, 2010
- [7] Benjamin Kroposki, Ro-bert Lasseter, Toshifumi Ise, Satoshi Morozumi, Stavros Papathanassiou and Nikos Hatziargyriou, "Making microgrids work", *IEEE power & energy magazine*, IEEE 2008
- [8] Aris L. Dimeas, dan Nikos D. Hatziargyriou, "Operation of a Multiagent System for Microgrid Control", *IEEE TRANSACTIONS ON POWER SYSTEMS*, VOL. 20, NO. 3, AUGUST 2005
- [9] Shahab Ahmad Khan, Reshadat Ali, and SharibHussain, "Introduction to microgrid", 2010
- [10] A. A. Salam, A. Mohamed and M. A. Hannan, "Technical Challenges On Microgrids" *ARNP Journal of Engineering and Applied Sciences*, VOL. 3, NO. 6, DECEMBER 2008, ISSN 1819-6608

# Modeling the Magnet Electric Power Planning as the Alternative Energy

Doddy Irawan

Faculty of Engineering  
 University of Muhammadiyah Pontianak  
 Pontianak, Indonesia

Mobile Phone:+628157924936, Fax : (0561)764571  
 E-mail : dodi.unmuhpnk@gmail.com

Gusti Syabillah Muhammad

University of Muhammadiyah Pontianak  
 Pontianak, Indonesia

Mobile Phone:+6285386662896, Fax : (0561)764571  
 E-mail: gustisyabillah@yahoo.co.id

**Abstract** – Neodymium magnets are permanent magnets, which have high strength. Magnets can exert a force push or repel as powerful motor. The method in this study through the stages in the preparation of materials and research tools. Magnet is used N42 grade neodymium magnet with a diameter of 12.5 mm, thickness 1.5 mm thick composed of six pieces so that the whole 9 mm. In the attached magnet stator magnets are 48 pieces divided in 2 rows with the north pole facing into, and the magnet attached dictator a divided by 44 pieces also in the second row with the north pole facing out. The position of the stator magnet attached at an angle of 25° facing perpendicular magnetic rotor with 5 mm distance between the poles. Houses magnet drilled at an angle of 25° as deep as 9 mm, to install as many as 40 holes magnet is divided into 2 rows aligned with the row spacing of 15 mm. The results obtained by the occurrence of a failure in the magnetic shield systems to reduce the magnetic field, so it has been done in the selection of formulation shield Co-netic AA-Alloy, with the hypothesis magnet motor will work with power of 0.173 kW, torque of 1.81 Nm and motor rotation speed of 911 rpm.

**Keywords:** Magnet Neodymium, energy, power, torque, rotation speed

## 1. Introduction

### 1.1 Background

Electrical energy demand in Indonesia is needed, and the government should subsidize the operation so that the community can be met. In Indonesia is still very lacking supplies of energy resources, so that frequent electric power crisis that occurs mainly remote and isolated areas. Magnetic power generator is one of the ideas of alternative energy development, to maximize the potential energy that can be used as well as the fuel and mining. A large investment, but operating costs are very small, a power advantage is. By utilizing the energy of the magnetic poles repel without additional charge at each operation. Achievement of the preservation of nature can also be maintained as independent power against the pollution.

### 1.2 Objectives of Research

This magnetic power is assumed to be working optimally, without limitation too focused on the potential energy

required in its performance, because it relies on magnets repel force used. The power plant is expected to be helpful in terms of saving of minerals that are getting reduced due to excessive use of energy needed to obtain. The plant also preserve nature a clean, safe and comfortable without pollution, waste, noise, and other adverse effects.

In the village is not like the city of the electrical energy needs could be met, in villages sometimes do not work as a result electricity is not an unqualified company to always supply the electricity provider, so the policy was taken as a precaution. In anticipation long before the current energy crisis is to use water and wind. As the potential energy that can not be discharged, but the conditions and other support remains a limitation, not always where there is a large flow of water and there was always a strong wind pressure velocity, so this step can only be done in certain areas only, differently to magnets that can perform operations without the need to worry about where that does not support. In addressing these conditions, the researchers wanted to test the specimens will be obtained and the values of the necessary steps in planning a magnetic power generator. So that the future results of this study are expected to greatly help both in terms of science, the economy, and especially in the field of energy.

## 2. Magnetic

Neodymium magnet made from an alloy of neodymium, iron, and boron to form Nd<sub>2</sub>Fe<sub>14</sub>B tetragonal crystalline structure has a very high magneto crystalline uniaxial anisotropy (H<sub>A</sub> ~ 7 tesla). These compounds provide the potential to have high coercivity (resistance to be demagnetized). This compound also has a high saturation magnetization (J<sub>S</sub> ~ 1.6 Tesla or 16 kg). Therefore, the maximum energy density comparable to J<sub>s2</sub> magnetic phase has the potential to store a large amount of magnetic energy (~ 512 kJ/m<sup>3</sup> BH<sub>max</sub> or 64 MG · Oe). Unit poles in the system are MKS Ampere meter, symbol m and q as well as for electrical charge. If at any point we place a power pole m 'of magnetic thin and long, while at another point as far as r of m' well we put m a power pole the interaction style both poles are:



Figure 1 : The interaction of the two poles Style

$$F = \frac{\mu_0}{4\pi} \frac{m m'}{r^2} \quad (1)$$

Where:

F = force of attraction / repel force in newton

R = distance in meters

$m_1$  and  $m_2$  strong magnetic poles in Ampere-meter.

$\mu_0$  = permeability of vacuum.

$$\text{Value} \quad \frac{4\pi}{\mu_0} = 10^7 \quad \text{Wb/A.m}$$

(2)

This formula is the same as the interaction of two electric charge formula proposed by Coulomb.

If B is the magnetic induction wire cutting, the force experienced by the wire is  $F = 2\pi I B r$ , if  $2\pi r$  is the length of the wire windings. Flow of radius r there with the induction field of  $B = \mu_0 I / 2r$ , so that the power poles U experiencing a force of  $F = m B'$

$$F = \frac{m \mu_0 I}{2r} \quad (3)$$

Both styles in the last equation is the interaction force between the poles of a magnet with current N on the circuit, so that:

$$2\pi I B r = \frac{m \mu_0 I}{2r} \quad (4)$$

or

$$B = \frac{\mu_0 m}{4\pi r^2} \quad (5)$$

Magnetic induction is induced by the magnetic poles of the magnet poles so far r. Comparison of magnetic induction B with permeability of vacuum  $\mu_0$   $H = B / \mu_0$ ,  $\mu_0 = 12,5 \times 10^{-7}$ . Called the magnetic intensity of the room is empty, so the intensity of the generated magnetic pole strength m to r point extent of the poles are:

$$H = \frac{1}{4\pi} \frac{m}{r^2} \quad (6)$$

If B is measured dalam Wb/m<sup>2</sup> unit, the magnetic intensity H in Amp/m. Comparison between the power poles with cross-sectional area is called the power of the magnetization, as well as the charge per unit area is called the charge density.

$$J = \frac{m}{A} \quad (7)$$

Known as magnetic flux ( $\Phi_B$ ), which is the result of the projection of the magnetic field in all extents, penetrate. Magnetic field flux ( $\Phi_B$ ) that penetrates the area  $d\vec{S}$  is zero. This is due to a net magnetic charge magnetic dipole is zero so the number of lines entering the B value as the path out of the area it. This means the overall magnetic field magnetic flux is:

$$\Phi = B \cdot A \quad (8)$$

Where:

$\Phi$  = magnetic flux

A = area (surface) copy

B = strong magnetic field or magnetic

## 2.1 Style That Works On Portable Power Magnet Motor Mechanism

### 2.1.1 Rotation Kinematics

In Motion Straight subject, we know some scale, such as velocity, displacement and acceleration. Called angle because the rotational motion of each particle on a rigid body moving in a circle and take a certain angle. Quantities are also called angular velocity, angular acceleration and angular displacement.

When the disc rotates, each part of the disc moving at a different pace. Point near the axis (S), moving more slowly than the point located at the edge of the disc, however, because the rate of each point alias every part of the disc is different. However, when a point located on the edge of doing a full rotation, then the point near the axis also did a full turn. If discs do one lap, then all parts of the disc that also did one round.

### 2.1.2 Displacement Angle

In rotational motion, the easiest way is to measure angles using radians. Radian can be expressed in degrees, and vice versa. A full circle = 360°. Arc length around the circle =  $2\pi r$ . Thus:

$$\theta = \frac{l}{r} = \frac{2\pi r}{r} = 2\pi \text{ rad} \quad (9)$$

To help demonstrate the change in the position of rotational motion, set an imaginary line as a reference point to see the change in location of the position. When the disc rotates, a point which at first coincides with the reference line moves through an angle  $\theta$  l along the arc so far. A point is said to do the rounds as far as one radian if the length l = length r. In other words, if  $l = r$ , then  $\theta = 1$  radian. Mathematically, the angle  $\theta$  is expressed as follows (in radians):

$$\theta = \frac{l}{r} \quad (10)$$

where:

r = radius,

l = length of arc

$\theta$  = Angular displacement

### 2.1.3 Corner speed

If speed is the ratio of the displacement and the lapse of time, it is the ratio of the angular velocity and the angular displacement interval.

### 2.1.4 Average angle speed

The position angle is measured from the reference line. At the time  $t_1$ , part the wheels are marked with dotted lines in the position so far  $\theta_1$  from reference line. At time  $t_2$ , the wheels are marked with dotted lines in the position of the reference line as far  $\theta_2$  from line. Difference between  $\theta_2$  and  $\theta_1$  an angular displacement ( $\Delta\theta$ ). Mathematically average angular velocity is expressed as follows:

$$\omega = \frac{\theta_2 - \theta_1}{t_2 - t_1} = \frac{\Delta\theta}{\Delta t} \quad (11)$$

Where:

$\omega$  = angular velocity

t = time taken

$\Delta\theta$  = delta theta or angular displacement

$\Delta t$  = time interval or period

### 2.1.5 Average acceleration angle

Mathematically, the average angular acceleration is defined as follows:

$$a = \frac{\omega_2 - \omega_1}{t_2 - t_1} = \frac{\Delta\omega}{\Delta t} \quad (12)$$

where :

$a$  = average angular acceleration

$\omega_2$  = final angular velocity

$\omega_1$  = initial angular velocity

### 2.1.6 Frequency

The equation that connects between the frequency and the angular velocity is described as follows:

$$\omega = \frac{2\pi}{\Delta t} \quad (13)$$

Because  $\Delta t = 1/f$ , the angular velocity equation can be written as:

$$\omega = 2\pi f \text{ or } f = \frac{\omega}{2\pi} \quad (14)$$

where

$f$  = frequency (hertz)

### 2.1.7 Period

The period is the time it takes to do one lap

$$\Delta t = \frac{1}{f} = \frac{1}{\omega/2\pi} = \frac{2\pi}{\omega} \quad (15)$$

### 2.1.8 Relations between Linear Speed and Velocity Angle

When the disc rotates during the time interval  $\Delta t$ , the point of A cover corner as far as  $\Delta\theta$ , along the arc  $\Delta l$ . A point linear velocity direction given by the arrow to the end. Large linear velocity is:

$$v = \frac{\Delta l}{\Delta t} \quad (16)$$

because  $\theta = \frac{l}{r} \rightarrow l = r\theta$ , then the above equation can be written as:

$$v = \frac{\Delta l}{\Delta t} = r \frac{\Delta\theta}{\Delta t} = r\omega \quad (17)$$

The following equation expressing the relation between the tangential acceleration with angular acceleration.

$$a = \frac{v_2 - v_1}{t_2 - t_1} = \frac{\Delta v}{\Delta t} = r \frac{\Delta\omega}{\Delta t} = ra \quad (18)$$

### 2.1.9 Torque or moment of force

Newton's Second Law, that a body can move straight to a certain acceleration when given style. Changes in velocity = acceleration. The greater the force applied, the greater the acceleration of motion of an object. Mathematically, the relationship between torque to angular acceleration expressed as follows:

$$a \propto Fr \propto \tau \quad (19)$$

description :

$a$  = acceleration angle

$\propto$  = comparable

$F$  = force

$r$  = radius

$\tau$  = torque

### Big torque

Torque is the product of the force  $F$  and sleeve style  $l$ . Mathematically, the torque is formulated as follows:

$$\tau = Fl \rightarrow l = r \sin \theta = r F \sin \theta \quad (20)$$

description :

$\tau$  = torque and moment of force

$F$  = force

$L$  = sleeve style

### 3. Research methodology

The magnets used are grade N42 neodymium magnets with a diameter of 25.4 mm, 25.4 mm thick. In the magnet rotor magnet mounted as many as 30 pieces, 1 row with the north pole facing into, and the magnet-attached distator as many as 34 pieces, 1 row with the north pole facing out. The position of the stator magnet attached at an angle of 25°, facing perpendicular magnetic rotor. Planned home magnet rotor has a diameter of 360 mm with a thickness of 35.4 mm made that does not have an influence on the magnetic field, in order to eliminate the influence of the resistance in the future as well as other effects.

Hold the magnet or drilled with a variety of angles, to attach the magnet by 30 holes divided into rows of slits. Similarly to the stator magnet, only differentiated diameter, number of holes and the drill angle holes to adjust the rotor magnet. In the process works, rotor positioned at the beginning of the side, will be shifted towards the position of the stator, which is supported by a retaining bolt as well as sliding sab.

After shifting toward rotor stator, rotor magnet is in or distator, will face each other and provide a repulsive force refused to move the stator is connected to the shaft. Varied angles before seen performance comparisons occur. In a shift towards rotor stator hub is planned to be a component of slip, with the rotary system as well as on the clutch was still attached to the stator grinding machines hand.

### 3.1 Test tools

The shape and construction of the test apparatus is shown in the following figure:

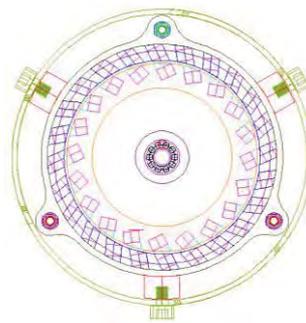


Fig 2 instrument testing looks ahead

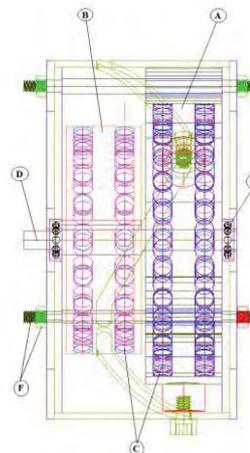


Fig 3 instrument testing looks aside

A: The house magnet stator, B: House magnet rotor, C: Magnet, D: Axis, E: Bearing / bearings, F: Bolts and nuts retaining

#### 4. Analysis and Discussion

Has been taken into account and planned for portable power magnet motors of performance, torque, rpm, power up component-supporting components, but on the ground the motor may not work as expected, with the review that the components of the magnetic material made of teflon, with a diameter of holes made of 12.5 mm with a depth of 9 mm, with a total hole / hold as many as 40 pieces in 2 rows of rotor, and the composition of each magnet is attached at an angle of 25 ° right upright faces in 48 holes in 2 rows on the stator, the distance between 5 mm, and the north pole is a pole of mutual dealing.

##### 4.1 Calculation of Magnetic Shielding And Planning

###### 4.1.1 Calculation Results:

magnetic data

Magnetic induction (B) = 0.1599 Wb/m<sup>2</sup> = 1599 Gauss

Strong magnetic field (m) = 39.978 amp.m

The intensity of the magnetic

(H) = 127920 amp/m = 1606.6315 Oersted

Magnetic flux (Φ) = 1.962 Wb

Magnet diameter (d) = 12.5 mm = 0.49213 in

data Shield

Co-netic AA-Alloy

The maximum magnetic induction (B<sub>max</sub>) = 7500 Gauss

Magnetic coercivity (H<sub>c</sub>) = 0.015 Oersted

Netic S3-6 Alloy

The maximum magnetic induction (B<sub>max</sub>) = 21 000 Gauss

Magnetic coercivity (H<sub>c</sub>) = 1.0 Oersted

###### 4.1.2 Magnet Shield Plan.

Based on the data above, the calculated thickness and damping material owned by comparing material Co-netic AA-Alloy and Alloy netic S3-6, so it can be selected to suit the needs. Planning With Material Co-netic AA-Alloy

Counting thick magnetic shield (t) can be found by the equation:

$$t = \frac{1,25 \cdot d \cdot H}{B_{max}} \quad (21)$$

Having acquired a thick shield, the shield can be searched damping (A) by a magnetic force, by the equation:

$$A = \frac{\mu \cdot t}{d} \quad (22)$$

Magnetic flux density is obtained by comparing the style of the magnetic field has shield calculated by the equation:

$$B = \frac{H}{A} \quad (23)$$

From the calculation results obtained:

Shielding Co-netic AA-Alloy

Shield thickness (t) 0.13 in, the damping rate (A) 36189.63 and the remaining influence of magnetic force intensity (B) 0.044 gauss.

Netic shield S3-6-Alloy

Shield thickness (t) in 0.047, the level of attenuation (A) 147.08 and the residual effect of the intensity of the magnetic force (B) 10.92 gauss. It can be concluded that material suitable for use on portable power magnet motors is the shield of the type Co-netic AA-Alloy, due to the influence of a magnetic shield once fitted are assumed to reduce the magnetic force very well, but the thickness of the field size on the market only in 0014, in 0020, 0.025 in, 0.030 in, 0.040 in, 0.050 in and 0.062 in, so based on the information stretcher, whichever is the thickest in the 0.062 to take into account the damping rate of return.

Planning with Co-netic material Alloy AA-size 0.062 in

Measured values for the remaining influence of the intensity of the magnetic force is small enough so that the magnets on the rotor and stator are expected to work optimally as desired. Because of the reduced resistance force, although of little value, still the necessity of calculating whether these changes are affecting the performance of the rotor and the stator, the returns obtained by the calculation of the force experienced.

###### 4.1.3 Calculation of Influence Remaining Prisoners Of Style Magnet

Consider the case that occurred due to force prisoners so that the rotor cannot rotate or does not move, which means that the force between repulsion and prisoners alike than or equal to zero. It can be concluded that the calculation can then be calculated on the basis of the failure.

Calculating the effect of magnetic force prisoners obtained from the equation:

$$F_{working} = m \times B_{working} \quad (24)$$

$$F_{resistance} = m \times B_{resistance} \quad (25)$$

$$F = F_{working} - F_{resistance} \quad (26)$$

#### 5. conclusion

From the measurement results based on the equations and literature obtained in simulation planning power magnet has specification power (P) 0173 kw, torque (τ) 1.81 Nm, rotation speed (n) 911 rpm. For the election to choose the magnetic shield material that has a high level of permeability to obtain maximum damping, but the thickness and material used in the planning should be adapted to the product in the market, as well as in the selection of the bearing, in order to facilitate the work. In this plan still need measurements of the magnet to be used that will be very helpful if you are using an accurate measuring tool, especially in the calculation of static magnets. On subsequent research, it is necessary variation to variable angle position magnet mounted on the rotor, so the comparison of power, torque and rpm of the angle formed can be seen clearly performance.

#### REFERENCES

- [1] Drs. Tobing, D. L, Teori Medan – FEJS 4433/3 SKS/Modul 1-5. DEPDIBUD, Universitas Terbuka, 1986.
- [2] Drive, Thomas, Literature Design Magnetic Shield. Bensenville, U.S.A. Magnetic Shield Corp
- [3] Hariadi, Ichwan, “Dasar-Dasar Magnetisme”. Jakarta, Erlangga, 1996
- [4] Muchsin, Ismail. ST.MT, Elemen Mesin II, Pusat Pengembangan Bahan Ajar, Universitas Muhammadiyah. Bandung, 2003
- [5] Priyambodo, Tri Kuntoro & Bambang Eka Murdaka Eka Jati, Fisika Dasar. Yogyakarta, ANDI, 2009
- [6] Sastra, Suparno M, Excellent With AutoCAD 2007. Jakarta, Alex Media Komputindo, 2007
- [7] Sularso & Suga, kiyokatsu, “Dasar Perencanaan Dan Pemilihan Elemen Mensin. Jakarta”, Pradya Paramita, 2008
- [8] Zuhail, “Dasar Teknik Tenaga Listrik Dan Elektronika Daya”. Jakarta, Gramedia, 1988

## Formation of Fluorine Doped Tin Oxide Nanorods as the Front Electrode in Dye Sensitized Solar Cells

D. Liyanage<sup>a</sup>, K. Murakami<sup>b</sup>

<sup>a</sup>Graduate school of science and technology  
Shizuoka university, Hamamatsu, Japan.  
E-mail : f5045027@ipc.shizuoka.ac.jp

<sup>b</sup>Research Institute of Electronics  
Shizuoka university Hamamatsu, Japan  
Tel & Fax: +81-(0)53-478-1329  
E-mail : rskmura@ipc.shizuoka.ac.jp

Dye sensitized solar cells, as an alternative for fossil fuel, has gain a reasonable interest among researchers because of its low cost of production and environmental friendliness. Although the efficiency of Dye sensitized solar cells (DSSCs) reaches 11~12%, various attempts have been still taken to improve the efficiency. The conventional fluorine doped tin oxide (FTO) layer used in DSSCs is a flat transparent thin film.

In this research, the FTO nanorods were fabricated to be used as the front electrode as shown in Fig.1. Rather than the conventional flat FTO film, the nanorods will have a comparatively large surface area. The high area of TiO<sub>2</sub>-FTO interface leads more charge collection and less charge recombination in the TiO<sub>2</sub> film due to a fast charge transportation through the FTO. The nanorods also could work as a charge-collecting probe inside the TiO<sub>2</sub> film, so that the effective path length that an excited electron has to travel before reaches the FTO can be shortened. In addition, because of the low resistance in FTO, the overall internal resistance of the cell will be decreased.

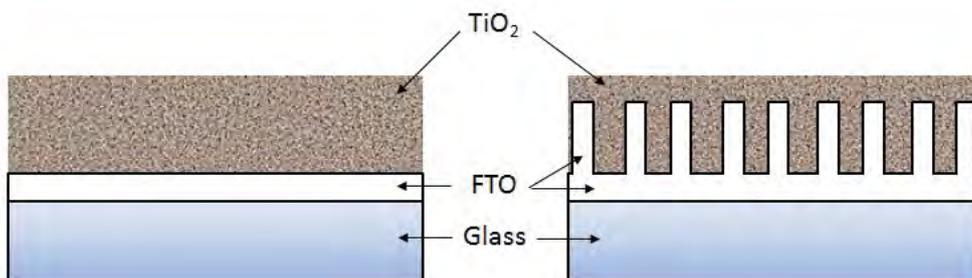


Figure 1: FTO thin films used in DSSC; conventional structure (left), new structure using nanorods (right)

To fabricate the FTO nanorods film, a solution mixture of SnCl<sub>4</sub>.5H<sub>2</sub>O and NH<sub>4</sub>F is sprayed on to a plain glass at 500°C using a specially designed and improved spray pyrolysis deposition apparatus. An ultra-fine mist is injected into a closed chamber, in which the heated substrate is kept. The spraying is done in 8 different spraying durations (15, 30, 45, 60, 75, 90, 105 and 120 min) and the transmittance, conductivity and morphology of the film are characterized.

The conditions for the well aligned FTO nanorods with higher conductivity and transmittance must be optimized before utilizing the films in DSSCs. For that, the spray duration, precursor solution concentrations, temperature, spray pressure and other physical parameters have to be altered and studied further.

Finally, it is expected that the FTO nanorods films could give a high efficiency for DSSCs comparing with those made with conventional FTO thin films.

### Keywords

Fluorine doped tin oxide, spray pyrolysis deposition, nanorods, thin films, dye sensitized solar cells.

# Development of Whole Body Motion Imitation in Humanoid Robot

Wisnu Indrajit

Electrical Engineering Department,  
University of Indonesia  
Depok, Indonesia  
wisnu.indrajit@ui.ac.id

Abdul Muis

Electrical Engineering Department,  
University of Indonesia  
Depok, Indonesia  
muis@ee.ac.id

**Abstract**—To be able to interact with humans, robot made as much as possible in order to have similar movement to human. Imitation Learning or often called Motion Capture is one of the humanoid robot control techniques with human as an actor and the robot as an agent who will imitate the movement of the actor. This method offers flexibility and ease to modify robot system. This paper explores the method of designing whole body imitation in Humanoid Robot. Robot motion was controlled by Joint Space Control with reference motion captured by natural human motion through Microsoft Kinect. The motions are also preserved in database for later used on robot motion generation and teaching as well. Finally, the effectiveness of the proposed method is illustrated by the experiment of imitating Indonesia Traditional Dances motion using humanoid robot with 18 DOF.

**Keywords**—Inverse Kinematic, Imitation, Kinect, Dynamixel, Humanoid Robot

## I. INTRODUCTION

The roboticist always trying to get the robot to approach the form and abilities like human, so that the robot can interact with human as well. Humanoid robots are without question a hot topic in research today. Humanoid robots may prove to be the ideal robot design to interact with people [1]. The most challenging problem in humanoid robot development is joint trajectory control. There are some ways to generate humanoid robot motion. For industrial need, robot motion is generated though complex computation code to achieve high precision. This is done in off-line mode through engineering software. Other method uses straightforward approach. Here, the operator drive robot to certain pose either by moving manipulator tool-tip with hand or remotely. Once the desired pose achieved, the current pose is saved to memory. However, these methods are time consuming especially for long-duration motion. Each pose may takes in minutes. Thus, these methods are not effective for more than hundred poses. In spite of that, an easy and quick approach is by imitating an object motion to robot with sensing device, or often called motion capture [5]. There have been numerous efforts for motion imitation either by using position sensitive detector (PSD) or by using stereo camera. Unfortunately, initial preparation is required such as mounting detector on object along with cabling or calibrating camera position for each measurement.

Programming by demonstration, or also known as imitation learning or motion capture is an answer to a problem how to control humanoid robot joints. This method offers flexibility and easy modification of the robot control. Humans as the actor would make a move, and then the robot as an agent will perform the movements performed by humans. Imitation is the best way to make the robots do some humanlike motion. The system is very useful to train the robot to make movements and in the future can be used to create a natural human-like motion of humanoid robot motion that can do housekeeping, dangerous work, and even entertain humans. Human motion imitation also can be used to record some traditional dance. The need for traditional dance preservation especially in Indonesia is unavoidable. There have been numerous claims on National traditional dances by other country while teenagers are starting to loose appetite in learning national cultures such as traditional dance. For that purpose, there have been national robot competitions on national dancing performance since three years ago. Here, the dancing should be carried out by humanoid robots since this kind of robot is more similar to human being. Also, interesting challenge in humanoid robot is how to design trajectory control for each joint. Obviously, the robot should have generated motion in memory.

Previous researches on robotic imitation have been done among others by Nakaoka research group to perform Japanese traditional dances by imitate motion to robot [7]. Imitation process has done by used 8 cameras to obtain three-dimensional information of 30 points on the actor body. Another imitation research is also done through markless tracking by Marc Rosanes to imitate the human arm movement on the Bioloid robot with TOF (Time of Flight) capture device Camera: Swiss Ranger 3000 [8]. Nevertheless, motion capture devices such as multi-camera capture or stereo camera are still expensive and have difficult algorithms to tracking human motion.

In this paper, realistic motion imitation by capturing human motion by markless method through Kinect is proposed. Kinect that usually used along with Xbox games has a stereo camera system. With certain library, the captured human pose is translated to quaternion form of each human joints. This is

done naturally without marking human body. Robot Operating System (ROS) used as work platform in this research. In the same time, the 18DOF humanoid robot imitates human motion. In addition, the extracted human motion is preserved in database for later used on robot motion generation and teaching as well. In this paper, only the upper part of humanoid robot is used. Moreover, to achieve realistic motion, the operation is made in rate 20Hz, which is close for human eye that has ability to see up to 25Hz.

## II. PROPOSED METHOD

There are three steps for doing imitation learning in this paper. First, we did human tracking to get important skeleton vectors. Second is mapping human motion to robot, joint position and velocity control. Finally, designed database motion, and then extract database to repeated movements that have been made.

### A. Human Tracking

Microsoft Kinect is used as capturing device to get human joint positions data. Microsoft Kinect is an accessory for Microsoft's Xbox 360 platform. Kinect is motion sensing unit device that was developed to interpret human gestures. It has sensors connected to a motorized pivot based. This device has a RGB camera, depth sensor, and multi-array microphone. With these sensors, Kinect can provide the ability to capture full-body 3D motion, facial recognition and voice recognition. Kinect has a good performance, small dimensions, and open source libraries that are able to make Kinect used on multiple OS platforms (Windows, Linux, and Mac), and also kinect is cheaper than other capture device. In this paper, human motion will be captured using kinect with markless method. With the skeleton tracking software from the Open NI, three-dimensional vectors of the joints in humans are achieved.



Fig. 1. Skeleton Tracking Node

To track the human skeleton, `openni_tracker` node from `stack openni_kinect` in Robot Operating System (ROS) is employed. This node will provide three-dimensional vector of 15 points on the human body. To perform tracking, someone needs to stand up and do "surrender" pose in front kinect (raise both hands). After the tracking process calibrated done, the `openni_tracker` node will publish 15 vectors which representing position of 15 main joints from the tracked body. Here is calibration pose picture and 15 vectors which `openni_tracker` published from this node.

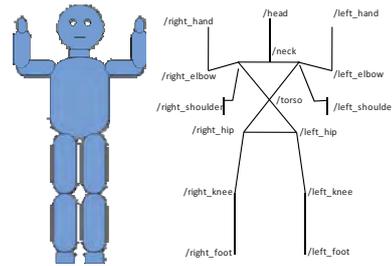


Fig. 2. Calibration Pose and Vectors Published by `openni_tracker`

### B. Mapping Human Motion

In mapping process, firstly, kinematics model of the robot must be identified which used to find the inverse kinematic solution of the model later. The used model robot consists of two arms with each arm consists of four degrees of freedom and two legs which consist 5 DOF in each leg. Humanoid robot model (each joint at 0°) and joint configuration of the robot model is shown in the figure below.

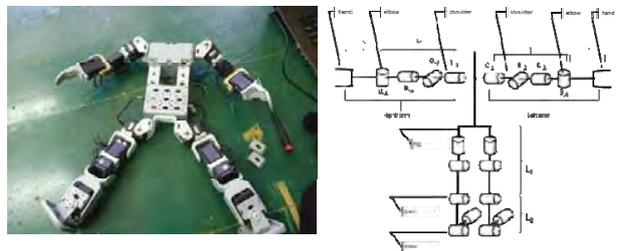


Fig. 3. Robot Model and Joint Configuration

Dynamixel AX-12 used as joint actuator in the robot. The advantages of using this actuator is feedback position, speed, voltage, temperature, and load. Here is Dynamixel AX-12 configuration movements and position constraint in the robot:

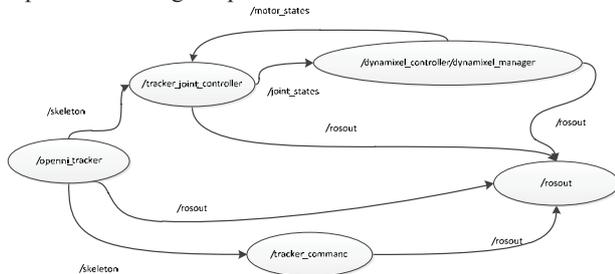
TABLE I. DYNAMIXEL AX-12 CONFIGURATION MOVEMENTS AND POSITION CONSTRAINT IN THE ROBOT

Right Body		
ID	Movement	Constraint
1	Flexion-Extension Shoulder	-90° to 90°
3	Abduction-Adduction Shoulder	-90° to 90°
5	Hand Internal Rotation	-90° to 90°
7	Flexion-Extension Elbow	-90° to 0°
9	Hip Yaw Rotation	-150° to 150°
11	Hip Pitch Rotation	-89.06° to 90°
13	Flexion-Extension Knee	8.20° to 143.26°
15	Ankle Pitch Rotation	-26° to 102.25°
17	Ankle Raw Rotation	-19.92° to 21.09°

Left Body		
ID	Movement	Constraint
2	Flexion-Extension Shoulder	-90° to 90°
4	Abduction-Adduction Shoulder	-90° to 90°
6	Hand Internal Rotation	-90° to 90°
8	Flexion-Extension Elbow	0° to 90°
10	Hip Yaw Rotation	-150° to 150°
12	Hip Pitch Rotation	-89.06° to 90°

14	Flexion-Extension Knee	-143.26° to -8.20°
16	Ankle Pitch Rotation	-102.25° to 26°
18	Ankle Raw Rotation	-19.92° to 21.09°

The complete process of real time imitation in ROS node is shown in following figure, ellipse shapes is node (process in ROS) and between two nodes, there is a topic which represents message or packet data:



First, /openni\_tracker node send /skeleton topic which contain 3D position of human joints. The position of human joints are computed in /tracker\_joint\_controller to generate the angular position and speed for dynamixel motor with inverse kinematic transformation. The /joint\_states topic contain data of position and speed which computed before. After that, we send the topic to dynamixel and dynamixel will give position feedback. Speed control Block diagram is shown in the following figure.

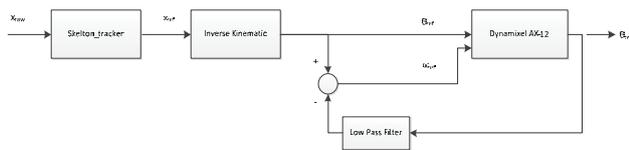


Fig. 4. Position and Speed Control Diagram

### C. Record Database Motion

Motion database is needed in order the robot can be able to repeat the results of imitation motions. In this paper, human motion is saved in a .csv extension by writing in the following format.

time	$\theta_1$	$\theta_2$	...	$\theta_{18}$
Goal Position				

secs.nsecs

Fig. 5. Motion Database Format

With that format, less memory is saved because there is no need to keep the speed memory of each joint. Velocity of each joint can be derived from the subtraction of the current and previous angle position divide by time difference.

### III. RESULT

The result of the real time imitation is a good, mapping algorithm with inverse kinematic show the robot can imitate human motion, and has conducted multi-solution anticipation of weakness in the method of inverse kinematic mapping

process. The video of the dance imitation result can be seen in this url: <http://www.youtube.com/watch?v=qIWyny3vqds>. Balancing method is still in development so that when doing imitation it still required hanger. Real time imitation process with Microsoft Kinect performed at frequency of 20 Hz.



Fig. 6. Real Time Dance Imitation Result

### IV. CONCLUSION

A real time motion imitation is realized in this paper. The imitation is done by capturing motion through Kinect and mapping the motion to robot's arms and legs. At the same time the motion also can be recorded in database motion. By tuning Robot Operating System, the proposed method has been validated in rate of 20Hz which is close to human eye ability. Here, the ROS package that has been developed, successfully solve the challenges of the imitation process as well humanoid robot capable of performing database extraction and storage and motion that has been done by humans.

### ACKNOWLEDGMENT

This work is part of Autonomous Control Electronics (ACONICS) Research Group Topics, Department of Electrical Engineering University of Indonesia.

### REFERENCES

- [1] Parul Gupta, Vineet Tirth, R.K. Srivastava. "Futuristic Humanoid Robots: An Overview." First International Conference on Industrial and Information Systems. Sri Lanka: IEEE, 2006. 247-254.
- [2] M.Z. Al-Faiz, MIEEE. "Analytical Solution for Anthropomorphic Limbs Model, (IK of Human Arm)." 2009 IEEE Symposium on Industrial Electronics and Applications (ISIEA 2009). Kuala Lumpur, 2009. 684-689.
- [3] K Saenko, S. Karayev, Y. Jia. "Practical 3-D Object Detection using Category and Instance Level Appearance Models." *International Conference on Intelligent Robots and Systems*. 2011.
- [4] R, Zhang, and Wang Y. "Research and Implementation from Point Cloud to 3D Model." *Second International Conference on Computer Modeling and Simulation*. 2010.
- [5] Shon, A.P. *Robotic Imitation from Human Machine Capture using Gaussian Process*. University of Washington, 2010.
- [6] Craig, John J. *Introduction to Robotics: Mechanics and Control*. USA: Addison Wesley Longman, 1989.
- [7] Nakaoka, Shinichiro. *Generating Whole Body Motions for a Biped Robd from Captured Human Dances*. Master Thesis, Tokyo: University of Tokyo, 2003.
- [8] Siscart, Marc Rosanes. *Algorithms and Graphic Interface Design to Control and Teach a Humanoid Robot Through Human Imitation*. Master Thesis, Catalunya: Universitat Politecnica de Catalunya, 2011.

# Comparative Analysis the Usage of Prepaid and Postpaid KWH Metre

Syamsuri<sup>a</sup>, Herlina<sup>b</sup>, Taufik Akbar<sup>c</sup>  
 Faculty of Engineering  
 University of Sriwijaya  
 Inderalaya, South Sumatera Indonesia  
 syamsurizaini@@ft.unsri.ac.id  
 herlinawahab@yahoo.com

**Abstract**— Prepaid electricity which is using prepaid digital kWh metre is one of the programs of PT PLN to enhance the quality of their services. They make these programs to avoid errors reading the meter, the uncertainty of the Bills, arrears and disconnection. The problems occurred in the consumer side is whether prepaid electricity consumption more efficient than postpaid electricity consumption. In this research we perform the measurement of electric energy consumption using postpaid and prepaid kWh meter with the same load and the same time, so that we able to know which is more efficient. The measurements performed on 1300 VA, R1 customers with 4 types of load (resistive load 500 Watts and 1000 watts, household expenses 407 Watts and 1235 watt), testing was carried out for 6 hours per day, 6 days per week for 1 month. The research result obtained from measurement and calculation of energy consumption. Technically at the time and the same loads, prepaid kWh meter more efficiently than postpaid kWh meters. Economically, according to TDL 2010, for consumption under 52 kWh kWh Meter prepaid more efficient, whereas for consumption above 52 kWh showed similar results.

**Keywords** :Pre paid electricity, Post paid electricity, Pre paid kWh meters, Post Paid kWh meters.

## I. INTRODUCTION

Electricity has become a fundamental requirement for a wide range of human activities, which are used for a variety of functions in the future. Electricity reliance would make man its existence. PLN was aware of society's reliance on electricity, so continue to conduct various studies to improve the quality of service by offering a variety of service programs. Forms of innovation created by PT. PLN is by issuing prepaid electricity program. The Program has issued prepaid electricity since 2008, prepaid electricity has the advantage that electricity use is more restrained, with no termination penalties, not fines imposed delays, there is no fixed monthly fees and so on. Additionally prepaid electricity created in order to avoid any incident read meter, erratic utility bills, the delinquent accounts, and any disconnection on electricity postpaid. With this program the community invited to better appreciate the existence of electric power and wiser in consuming electricity. Now the question is whether the use of prepaid electricity can be the solution of the existing problems at the moment? Is it true that prepaid electricity more efficient than postpaid

electricity? Therefore the authors conducted a study to analyze the comparative measurement of the electric energy with postpaid and prepaid meters kWh kWh meters with a load and the same time in the laboratory of State Polytechnic of Sriwijaya.

## II. THEORY

### A. Power<sup>[1]</sup>

Electric power is the amount of energy per unit of time, where work is in progress or the work done the Union time. From this definition, then the electrical power (P) can be formulated:

$$P = W / t \quad (1)$$

$$P = V \cdot I \cdot t / t \quad (2)$$

$$P = I^2 \cdot R \quad (3)$$

Whereas Power (P, Watt or Joule/detik), Electrical Energy (W, Joules), time (t, second), voltage (V, Volt), Resistance (R, Ohm).

### B. Electrical Energy<sup>[2]</sup>

Electrical energy is the ability to generate electricity. Electrical energy is represented by w. Where as the formulation is used to determine the electrical energy is:

$$W = Q \cdot V \quad (4)$$

$$W = (I \cdot t) \cdot V \quad (5)$$

$$W = V \cdot I \cdot t \quad (6)$$

Whereas Electric charge (Q, Coulomb)

### C. Current<sup>[3]</sup>

Current, depicted with the symbol i (derived from the French word: intensite), defined as the change of velocity with respect to time charge. Or, other sense is the charge flows in a unit of time. So, the current that is actually moving charge. As long as this charge is moving it will pop up the flow, but when the charge is stationary then the flow will also be lost. The charge will move if there's energy out that affected it. The charge is the smallest unit of an atom or a subsection of the atom. In the modern atomic theory, stated that atoms consist of a nucleus of particles (protons are positively charged (+)

and neutrons are neutral) surrounded by loads of electrons (-). So, is normally electrically neutral atoms.

The charge consisted of two types i.e. positive charge and the negative charge. Electric current direction in line with the direction a positive charge and the opposite direction with a flow of electrons. A particle can be a positive charge when it loses an electron, and a negative charge when accepts electrons from other particles.

Coulomb is the basic unit of the International System of Units (SI) is used to measure the electric charge. Mathematically, the current defined:

$$i = \frac{dq}{dt} \quad (7)$$

Symbol: Q = a constant charge, q = electric charge

#### D. Voltage<sup>[3]</sup>

Voltage or often called potential difference, is the work done for a charge of one coulomb moves from one terminal to another terminal. Or, in other words, if a charge of one coulomb is driven or moved, there is a potential difference on either Terminal.

#### E. Measurement<sup>[4]</sup>

The measurement is determination of quantity, dimensions, or capacity, usually against a standard or unit of measurement. In the study of measurement known a few terms, among other things:

- The instrument is measuring instrument for determining the value of a quantity or quantities or variables.
- Precision is a price closest to a reading of an instrument approach the true value of the measured variable.
- Precision is a measure of the ability to measure results that are similar.
- Sensitivity is a comparison between the output signal or instrument responses to changes in input or variables that are measured.
- Resolution is the change in the value of the smallest measured which instruments will give a response or a response.
- Error is the deviation of the measured variable price (value) which is actually

Measurement of electrical quantities no one produces perfect precision. Need to know the actual cause of the sensitivity and the occurrence of errors of measurement Errors in measurement can be classified into three types, namely: Error –common mistakes, Systematic error mistakes Random Errors Are Not Intentional.

### III. METHODOLOGY

The measurement of electric energy in kWh meters postpaid and prepaid using a measuring instrument of Power and Harmonics Analyzer. The measurement was carried out in

the laboratory of electrical engineering State Polytechnic Sriwijaya Palembang. The comparative testing of electrical energy in both postpaid and prepaid kWh meter is done with 4 different types of loads for 1 month and each load test performed within 6 hours per day for 6 days. Testing process performed with 4 different types of loads each week, namely:

1. The first week, the resistive load 5 incandescent lamps with a total power of 500 Watt.
2. The second week, the resistive load 10 pieces of incandescent lamps with a total power of 1000 Watts.
3. The third week, the load of household consisting of energy-efficient lighting, TV, fan, refrigerator, and water pumps with a total power of 407 Watts.
4. The fourth week, the load of household consisting of incandescent bulbs, television, fan, fridge, and water pump with a total power of 1235 Watts.

#### A. Measurement Equipment

##### Power and Harmonics Analyzer

Power Harmonics Analyzer is a combination of several functions measurement of electrical such as voltage, current, active power, reactive power, power factor, frequency, all power, and the other harmonics in one device. Power Harmonic Analyzer 6830 used to measure the current (total, phase motors and metal), voltage (total, ph-ph and ph-neutral), frequency, power factor (total and per phase), power/phase (active, reactive and apparent), total power (active, reactive and apparent), energy (active, reactive and apparent), THD (currents and voltages).

##### Analogue KWH Meter (Postpaid)<sup>[6]</sup>

kWh meter PLN postpaid used to calculate the power consumption of consumer kWh meter is analogous to the power of 1300 VA. This tool works using magnetic induction method in which a magnetic field to move the dish is made of aluminum. The rotation will move counter shows the number of digits as his kWh. The disc rotation will move counter shows the number of digits as his kWh

Kwh meter is a device used to measure the large power consumption by consumers. This tool is very common in the community. The main part of a kWh meter is, the coil voltage, the coil current, aluminum disc, fixed magnet whose task of induction aluminum disc to neutralize the magnetic field and mechanical gear that records the amount of rotation of the aluminum disc.

This tool works by using method of induction of the magnetic field in which the magnetic field moving the aluminum disc. The disc rotation will move the counter digits as the number of kWh display

##### Digital KWH Meter (Prepaid) 2R<sup>[7]</sup>

Prepaid kWh meters type of Star 2S-2R DDSY23S with a power of 1300 VA is the latest service from PLN with a range

of advantages in regulating the use of electric energy through the Prepaid Meters (CDM).

The electricity will be streamed to households (load), it first flowed through the MCB who serves as the current delimiter is at once in case of short circuit protection. Then streamed into kWh Meters which functions to calculate the energy used. This prepaid system using a special Meters kWh with keypad and have sensors to detect electrical energy used with impulse output of the lights flicker.

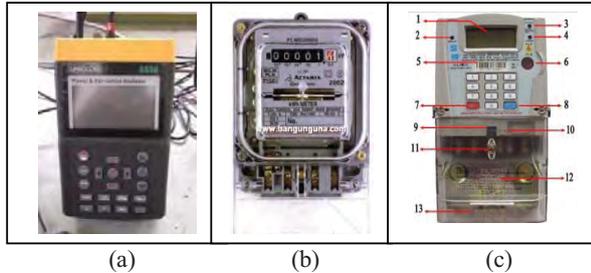


Figure 1. (a) Power and Harmonics Analyzer 6830, (b) analogue kWh meter, (c) Digital kWh Meter

### B. Load Measurement

Comparison of measurement of power on postpaid and prepaid meters kWh using a simulated series of module 1 simple phase consisting of load incandescent lighting (purely resistive), energy saving lights, water pump, TV, refrigerator and fan.

TABLE I. LIST OF LOAD

No.	Type of Load	Specification	Cos φ	Number	Power
1.	Incandescent lighting	100W/220V	1	10 pcs	1000W
2.	Energy Efficient lighting	18W/220V	0,64	4 pcs	72 W
2.	Water pumps	125W/220V	0,46	1 pcs	125W
3.	TV	70W/220V	0,53	1 pcs	70 W
4.	Refrigerator	90W/220V	0,81	1 pcs	90 W
5.	Fan	50W/220V	1	1 pcs	50 W

## IV. DISCUSSION

### A. Comparative Analysis of Measurement Results and Calculations

Comparison of the test results of electrical energy on average per hour within 6 hours for 6 days for each load on postpaid and prepaid kWh meter, obtained electric energy comparison on average for 6 days as follows :

TABLE II. COMPARING THE RESULTS OF MEASUREMENTS AND CALCULATIONS OF ELECTRICAL ENERGY PER HOUR

Type of Load	Type of Metre	Energy Used
--------------	---------------	-------------

		Measurement Result	Calculation Result
500 Watt (a pure resistive load)	Pospaid	0,446 kWh	0,4488 kWh
	Prepaid	0,443 kWh	0,4461 kWh
	<b>Difference</b>	<b>0,003 kWh</b>	<b>0,0027 kWh</b>
1000 Watt (a pure resistive load)	Pospaid	0,874 kWh	0,8758 kWh
	Prepaid	0,871 kWh	0,8723 kWh
	<b>Difference</b>	<b>0,003 kWh</b>	<b>0,0035 kWh</b>
407 Watt (Load of household)	Pospaid	0,380 kWh	0,4699 kWh
	Prepaid	0,376 kWh	0,4668 kWh
	<b>Difference</b>	<b>0,004 kWh</b>	<b>0,0031 kWh</b>
1235 Watt (Load of household)	Pospaid	1,101 kWh	1,1351 kWh
	Prepaid	1,088 kWh	1,1327 kWh
	<b>Difference</b>	<b>0,013 kWh</b>	<b>0,0024 kWh</b>

Technically, the use of electrical energy in kWh meter postpaid and prepaid using the same load and the same time, energy consumption electricity kWh meter postpaid larger or faster than electrical energy consumption spent electric energy in prepaid kWh meter. Each of kWh Meter have different working principles, where in principle work on postpaid kWh meters have a coil inductance, which had resulted in consequential kWh meters more quickly heat so it's more quickly spend electrical energy. whereas Prepaid kWh meters just an electronic device with keypad keys which has sensors to detect electrical energy used with impulse output of the lights flicker. Thus in technical measurements prepaid kWh meters more efficient than postpaid kWh meter.

### B. Economic Analysis

From the results of calculations performed in accordance TDL 2010, Rp 790 for 1300 VA. Then can be calculated economically postpaid and prepaid electricity.

TABLE III. THE ECONOMICAL CALCULATION RESULTS OF PREPAID AND POSTPAID ELECTRICITY

Usage (kWh)	Amount of Postpaid Electricity bills	Amount of Prepaid Electricity Bills
49	Rp 41,080	Rp 38,710
50	Rp 41,080	Rp 39,500
51	Rp 41,080	Rp 40,290
52	Rp 41,080	Rp 41,080
53	Rp 41,870	Rp 41,870
54	Rp 42,660	Rp 42,660
55	Rp 43,450	Rp 43,450

Customers of R1 1300 VA according to TDL 2010, total electricity bill for prepaid than postpaid more efficient for use of <52 kWh and it is same for the use of ≥ 52 kWh. For calculation of postpaid tariff, electric energy consumption limits enforced minimum is 40 hours. When taking electrical energy under 40 hours, for the calculation of the rates will still be counted 40 hours of usage. While prepaid tariffs, electrical energy consumption is calculated according to the amount consumed, do not impose minimum limit the consumption of electrical energy. postpaid Bill for not including VAT and the

use of street lighting. While the bills for prepaid is already included VAT and the use of street lighting.

### CONCLUSION

From the results of measurements and calculations for R1 customers 1300 VA technically, electric energy consumption in postpaid and prepaid kWh meter with the same and the same time, prepaid kWh meters are more efficient than postpaid kWh meters. While economically, for the consumption of electrical energy under 52 kWh prepaid kWh meter more efficient than postpaid kWh meters. for usage above 52 kWh will both alike.

The advantages and disadvantages of Prepaid Electricity and Postpaid Electricity are as follows.

- Prepaid Electricity, has advantages over the postpaid electricity, energy prices: kWh "ALONE" (without the cost burden), no minimum account limit, the registrar meter no need to record the number of usage, there is no potential for arrears, and most importantly, the customer able to manage and control the use of electricity to be more efficient in a month. The disadvantage if the usage limit is over then the power turns off immediately no matter the time of day or night, you are using electricity or not it is being considered by the consumer to change the way electricity consumption by using electricity vouchers.
- Postpaid Electric, Has the disadvantage compared to prepaid ie, price of energy: additional kWh cost burden (power 450 and 900 VA), is limited to the "minimum bill" (40 hours minimum), need to recording kWh rate, potential delinquent "big enough". While the advantages are electrical disconnection the connection manually.

### REFERENCES

- [1] Sutrisno, Tr., "Measurement of Power unused at residen In Village of Talang Putri". Palembang : Politeknik Negeri Sriwijaya, 2011.
- [2] A.J. Watkins, R.K. Parton, "Electrical Installation Calculations", Volume 1, Jakarta : Erlangga, 2004.
- [3] Ramdhani, Mohamad. "Electrical circuit". Jakarta : Erlangga, 2008.
- [4] Muzakir, Ahmad. "Comparison of Measurement Electrical Power Measurement Using Digital and Analog Gauges". Palembang : Politeknik Negeri Sriwijaya, 2011.
- [5] Manual Book, "Power and Harmonics Analyzer 6830"
- [6] Siburian, Espol. "Designing Prepaid KWH Meter With System Microcontroller Based on AVR ATmega8535". Medan : USU, 2010.
- [7] <http://www.pln.co.id/ntb/?p=108>. [Online], accessed at 7 April 2012
- [8] Simatupang, Roli. "Analysis of Centralized Working kWh metre to get Saving kWh". Palembang : PT. PLN (Persero) 2010.
- [9] Siahaan, Ricky Hisar. "Comparative Measurement of 3 Phase electric Power Using 3 Phase kWh Metre". Skripsi Palembang : Politeknik Negeri Sriwijaya. 2008.
- [10] <http://www.pln.co.id/ntb/?p=108>. [Online], diakses pada 7 April 2012
- [11] PT.PLN (Persero). "kWh Meter Prabayar STAR DDSY23S 2S-2R". Manual Book
- [12] PT.PLN (Persero). "Listrik Prabayar". Manual Book

# An Implanted Dipole Antenna for RFID-Based Patient Monitoring System

<sup>1</sup>Dony Canisius Sirait, <sup>1</sup>Basari, <sup>1</sup>Fitri Yuli Zulkifli, <sup>1</sup>Eko Tjipto Rahardjo

<sup>1</sup>Antenna Propagation and Microwave Research Group (AMRG), Department of Electrical Engineering,  
 Faculty of Engineering, Universitas Indonesia, Kampus Baru UI, Depok 16424  
 canisius\_donra@yahoo.com, basyarie@eng.ui.ac.id, yuli@eng.ui.ac.id, eko@eng.ui.ac.id

**Abstract**— Radio Frequency Identification (RFID) is one of the developed technologies, which is used in several applications, including for medical field applications. For patient monitoring purpose, the RFID system is consisted of a medical tag that is implanted into the human body and a reader unit that is installed away from the human either in proximity or far away from the human body. By this communication system, it can reduce medical error, the risk of the tag being lost, and can be used for uncooperative patient. The monitoring device will be connected to the existing network (wireless LAN and so on) allowing to provide the mobility of patient, the physicians or caregivers can get easily patient's medical information without spending a lot of time via such a network connection. In this study, it will propose a tiny dipole antenna for RFID tag that will be implanted into the body following it is enclosed by a silica glass to reduce the radiation effects on the human body. The antenna is numerically simulated by using a human arm model in the frequency of 924 MHz according to the RFID band allocation in Indonesia. This study also investigates two other different surrounding environment of the antenna in order to precisely understand about the antenna characteristics, i.e. antenna placed in free space and enclosed in silica glass material. Each environment gives effects on the antenna's resonant frequency including its bandwidth. Following the simulation, the antenna is fabricated and validated by the basic measurement. This paper will show the current results of the antenna characteristics in free space environment in order to validate its basic manner. The antenna is relatively very small dimension compared to the band wavelength with good performances in S parameter, sufficient bandwidth, and omnidirectional radiation pattern.

**Keywords**— Implanted dipole antenna, medical tag, patient monitoring system, RFID, short range communication

## I. INTRODUCTION

Patient monitoring system in the hospital still uses a conventional monitoring, where nurse or doctor needs to go to the patient's room to examine and check the current physical condition of the patient. This condition is quite impractical if the number of available medical personnel is fewer than the number of patients in the hospital. In order to overcome such a drawback, an automated monitoring system that is able to instantaneously display the state of the patient's physical condition.

The concept of the monitoring system will allow for monitoring the patient's condition without the patient itself coming to the nurse's room. Currently, most of hospitals in Indonesia have applied a cable-based monitoring system. Along with the current wireless technology especially the RFID (Radio Frequency Identification) system, most of cable-

based application systems tend to shift into wireless-based technology, in order to ease the equipment's installation and reduce its cost. The RFID is a tremendously adopted wireless technology in very wide applications that uses radio frequency to send data from a device called RFID tag, which is placed on the object, and will be recognized by a reader or recipient for the purpose of identification or tracking the object [1].

The development of wireless technology for health sector today has greatly attracted both academic and industrial researchers as the needs of the world (especially in developed countries) and associated with rising health care costs and the demand for hospital resources [2].

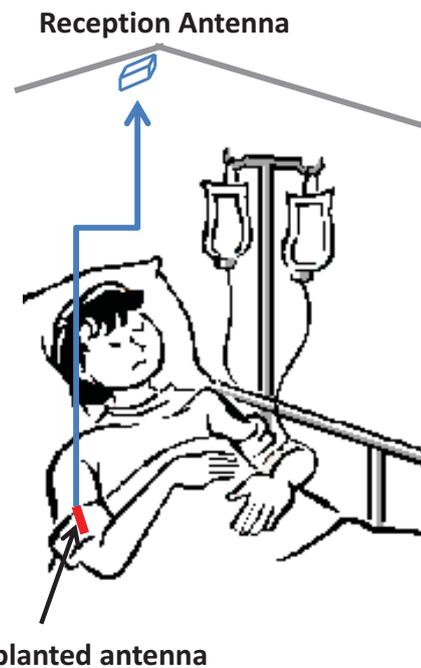


Fig. 1. An example of monitoring system of the patients in hospital.

One of the technologies with interestedly studied is the RFID technology, which offers a promising solution in building health care with wireless technology [3] and has a potential point to reduce medical errors and improve the quality of life of the patients in hospitals [4]. Figure 1 shows an example of RFID application for patient's monitoring system. Most of antennas researches for medical applications still focus on hyperthermia for cancer treatment and diagnostics on physical parameters of a patient [5], even though currently some researchers has been interested to study

on antennas for medical communication. In the past, the RFID technology is usually used by planting a tag on animal's body. However, current developments have allowed for putting a RFID tag or implantation in the human body [6]. The use of tags in the body (not the outside of the body) is aimed to reduce the risk of losing the tag and yet it looks suitable for patients who are less willingness to cooperate with the doctor [7].

Earlier RFID technology typically uses low frequency, since it has no signal attenuation and less significant effect to the human body. However, the existing system is limited to have a short distance coverage and very low data transmission rate. In order to overcome these drawbacks, UHF frequency band (Ultra High Frequency) is sometimes used to have the possibility of further transmission distances, higher data rate although the damping (loss) is greater, especially in the layers inside the human body because the nature of the material body man is very lossy [8]. Currently, some of RFID tags are widely designed for medical applications in the form of loop antennas, which work at frequencies 402–405 MHz to determine the effect of a human head to the signal transmission frequency. Another tag is also designed for transmitting patient data such as temperature, blood pressure, heart rate, and so on in real time operation. The tag antenna works at frequencies 951 – 956 MHz implanted in the human upper arm model [5]. However, this operating frequency band is not recommended to use in Indonesia, since the regulation of Indonesia government recommends to use RFID frequency at 923 – 925 MHz [9]. In addition the use of the frequency 923 MHz is intended to reduce the effects of SAR in the human body. In this paper, it will be proposed a RFID tag antenna operates at frequency of 923 – 925 MHz aiming at patient monitoring system.

## II. ANTENNA CONFIGURATION

The configuration and dimension of the proposed antenna is shown in Fig. 2. The antenna is fabricated by using a copper wire that is folded in such a way it will be appropriate design for 50 ohm-port. The antenna element (without silica glass cover) is made by the size of 33.3 mm × 1.8 mm × 1.8 mm (L × D × H). The antenna will be implanted in the human body at the upper arm, which the arm model is represented by three layers consist of skin, fat and muscle. The antenna is implanted at the position between the skin and fat layer. The thickness of skin, fat and muscle layers is 2 mm, 4 mm and 54 mm, respectively [10]. Each layer electrical property is shown in Table 1. Hence, by this design it is expected to establish communication in range of 10 m coverage as predicted in link budget [10]. The fabricated antenna is shown in Fig. 3.

TABLE 1: ELECTRICAL PROPERTIES OF TISSUES AT 924 MHz

Tissue	Electrical Properties	
	Permittivity	Conductivity
Skin	41.284523	0.874705
Fat	5.458249	0.051615
Muscle	56.824448	1.004436

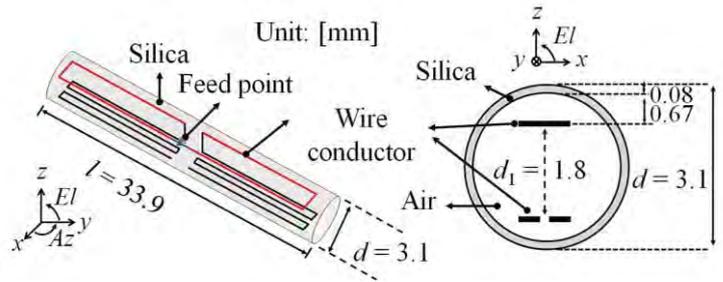


Fig. 2. A proposed antenna's structure



Fig. 3. Fabricated Antenna

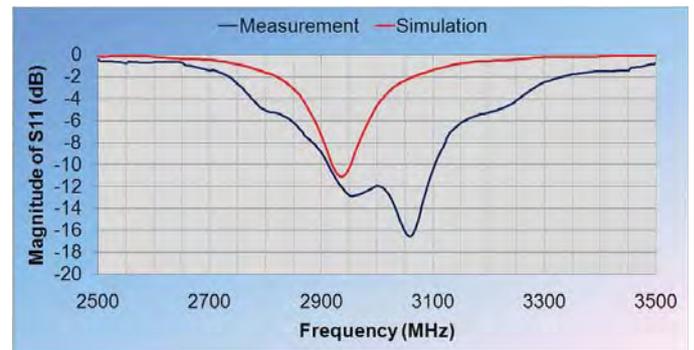
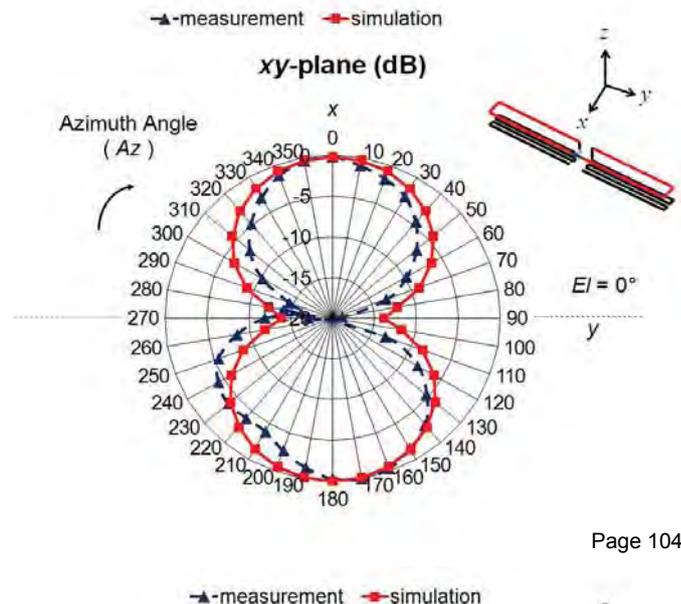


Fig. 4. S11 performance



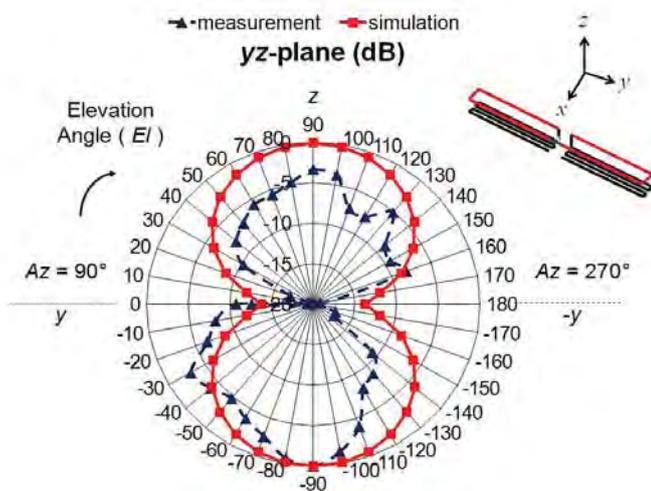


Fig. 5. Radiation pattern characteristics of the antenna

### III. MEASUREMENT RESULTS

The fabricated antenna is validated by measuring basic characteristics such as coefficient reflection and radiation pattern. In present validation, the antenna is measured in free space environment, where at least it can be known the basic performance of the antenna before it will be inserted in the phantom model or animal tissue.

In accordance to the measurement results, it can be seen that the fabricated antenna has large enough bandwidth from 2915 – 3100 MHz in the standard of  $S_{11} \leq -10$  dB, which is very sufficient bandwidth. The result agrees with the simulation result as shown in Fig. 4.. In addition, the radiation pattern of the antenna is evaluated in three different planes, namely  $xy$ -,  $yz$ - and  $xz$ -plane. In comparison to the simulation results, the measured radiation pattern meets the simulation at the resonant frequency 2.94 GHz as shown in Fig. 5. Moreover, the antenna has omnidirectional pattern in H-plane and 8-number shape as the basic pattern of the electric dipole antenna.

### IV. CONCLUSION

In this study, we have proposed a tiny dipole antenna for RFID tag that will be implanted into the body following it is enclosed by a silica glass to reduce the radiation effects on the human body. The antenna is numerically simulated by using a human arm model in the frequency of 924 MHz. The distance

between the tag and reader is expected by 10 m with the minimum gain of the antenna is -30 dBi. Then, the antenna is simulated using the finite integration technique (FIT) software in three different conditions; those are when the antenna is implanted, when it is enclosed in silica glass, and in free space environment, in order to understand the antenna characteristics in each given condition. The dimension of the antenna is  $33.3 \times 1.8 \times 1.8$  mm<sup>3</sup> at operating frequency 924 MHz with very sufficient bandwidth. When the antenna is enclosed in silica the resonant frequency is shifted to the frequency 2.69 GHz and it becomes 2.94 GHz in free space condition. In this paper, the antenna's characteristic is evaluated in free space environment in order to validate its basic manner. The antenna is fabricated and measured in anechoic chamber including the reflection coefficient and radiation pattern to validate the simulation results. The antenna has good coefficient reflection, sufficient bandwidth, and omnidirectional radiation pattern as it is expected in the simulation.

### ACKNOWLEDGMENT

This work was supported in part by Program Desentralisasi DIKTI - Riset Unggulan Perguruan Tinggi Skema Riset Madya Universitas Indonesia (RM-UI) 2013, Universitas Indonesia.

### REFERENCES

- [1] RFID – Opportunities for mobile telecommunications services. Available at <http://www.itu.int/ITU-T/techwatch/RFID: A Brief Technology Analysis>. Available at [www.rfidconsultation.eu/docs/ficheiros/](http://www.rfidconsultation.eu/docs/ficheiros/).
- [2] Y. Hao and R. Foster, "Wireless body sensor networks for health-monitoring applications," *Physiol. Meas.*, vol. 29, pp. R27–R56, Nov. 2008.
- [3] C.J. Li, L. Liu, S. Chen, C.C. Wu, C. H. Huang, and X.M. Chen, "Mobile healthcare service system using RFID," *Proceedings of 2004 IEEE Int. Conf. Netw. Sens. Control*, vol. 2, pp. 1014–1019.
- [4] H.Y. Lin, M. Takahashi, K. Saito, K. Ito, "Development of UHF Implanted RFID Antenna for Medical/Health-care Applications," *Proceedings of XXXth URSI IEEE General Assembly and Scientific Symposium 2011*, Istanbul, pp.1 – 4, August 2011.
- [5] C.H. Durney and M.F. Iskander, "Antennas for medical applications," in *Antenna Handbook*, Y. T. Lo and S.W. Lee, Eds. New York: *Van Nostrand Reinhold*, 1988, ch. 24.
- [6] A. Masters and K. Michael, "Human-centric applications of RFID implants: The usability contexts of control, convenience and care," *Proceedings of the 2nd IEEE Intl. Workshop Mobile Commerce Services*, pp. 32–41, 2005.
- [7] A. Sani, M. Rajab, R. Foster, Y. Hao, "Antennas and propagation of implanted RFIDs for pervasive healthcare applications," *Proceedings of the IEEE*, vol 98, no. 9, pp. 1648 – 1655, Sep. 2010.
- [8] G. Marrocco, "RFID antennas for the UHF remote monitoring of human subjects," *IEEE Trans. Antennas Propag.*, vol. 55, no. 6, part 2, pp. 1862–1870, Jun. 2007.
- [9] Peraturan Direktur Jenderal Pos dan Telekomunikasi Nomor 221/DIRJEN/2007. Available at <http://web.postel.go.id:81/index.php?0401=&key=0&cari=221#>
- [10] Basari, D.C. Sirait, F.Y. Zulkifli, and E.T. Rahardjo, "Simple Folded Dipole Antenna for Medical Implant Communications at 900 MHz Band," *Proceedings of 2012 IEEE Asia Pacific Microwave Conference (APMC 2012)*, Kaohsiung, Taiwan, 4–7 Dec. 2012.
- [11] D. Panescu, "Emerging Technologies [wireless communication systems for implantable medical devices]," *IEEE Engineering in Med. & Bio. Mag.*, vol. 27, no. 2, pp. 96–101, 2008.

# The Modified Alternator 115/208 Volt, 400 Hz, 15 KVA on Fokker-27 Aircraft, At SKADRON 2<sup>nd</sup>

Ainil Syafitri

Department of Electrical Engineering  
 University of Pancasila  
 South Jakarta, Indonesia  
 fitri1976@yahoo.com

Munnik Haryanti, Ali Ngimron

Department of Engineering  
 Suryadarma University  
 East Jakarta, Indonesia  
 munikbgr@yahoo.com

**Abstract**— The Fokker-27 remains one of logistics and military transport aircraft to the Indonesian Air Force. With age and life-time aircraft components, the components have been and often damaged during the flight. One of the important equipment is the alternator Fokker 115/208 Volt 400 Hz 15 KVA generating power.

This paper was discussed, about first our research on the alternator, and performed at the Air Squadron 2, this is done one of which is due by the Fokker Industry. Alternator type in Fokker 27, is not produced anymore, given the alternator and its function as a supplier of electricity, converting DC voltage into AC and as a voltage divider is used to keep the generator excitation and round on the Fokker 27 be a constant and airworthy.

The result showed that the alternator Fokker 27 with 15KVA power, with small dimensions, can be used 12 KVA at 0.9 lagging power factor as alternative substitutes and have similar characteristics to the alternator Fokker 27, and now the stage is made up paper being conducted routine flight air force in particular at SKADRON 2nd.

**Keywords** Electricity on the Fokker 27, alternator, voltage regulator

## I. INTRODUCTION

Indonesia is an archipelago with numbers of islands, it has considerable natural potential of developing countries. To preserve and defend the territory of Indonesian from the threat of the other countries, so we need a strong military component.

The Air Force as one of the major elements of the military who have the task of carrying out air defense to protect the territory of Indonesia and also provide support for rapid transit assistance in addressing the situation of natural disasters in Indonesian.

We need aircraft with maintained well condition, so when the Air Force have assignment they able for move quickly and then have the high mobility, especially to reach the long distances areas that have in a rapid relatively. The one entity that is in the Air Force is the Air Squadron 2 as a union that supports the assignment routinely done every day. Currently Air Squadron 2 only has 6 units Fokker 27 (F27) whit the highest mobility, so we need a good condition of the aircraft and ready to perform their duties

It is necessary for both routine maintenance aircraft structures, engines, avionics and electrical systems. In electrical systems Fokker 27 aircraft see figure 1, one of the most important tools is the Alternator 115/208 Volt 400 Hz 12 KVA generating power.

Altenator is electricity supplier for avionics equipment or other equipment on the aircraft in large numbers. Because the alternator is vital quite in generating electrical power for the aircraft, care and maintenance is very important because the aircraft will not fly without a power supply. Due to financial constraints that exist today for financing and maintenance should be conducted as well as how to analyze the performance of the alternator to the other electronic devices that use the life or alternator in a long time.



Figure1. Fokker F-27 aircraft owned by the Air Force

## II. ELECTRICAL

### A. Electrical In Fokker -27

In order to know the alternator as a backup power source, it first has to be discussed on electricity on Fokker-27, as follows:

The Electrical power from the AC bus Foker-27 aircraft supplied by three different sources is:

- a. The twin engine driven were voltage 208 volts, 3 phase, variable frequency alternator that produces electrical power for heating main. The alternator is not used by parallel, but independently operated.
- b. The twin main inverters, which is controlled by a DC motor, with the supply of 115 volts, 3 phase, a static

inverter frequency of 400 Hz are essential for the operation of the battery installed aircraft.

- c. The Twin power converter is supplied electricity at 115 volts, 400 Hz, single phase AC power for lighting equipment.

Alternator is 208 Volt AC generator brushless type that has a voltage 120/208 volts and 3 phase, which produces 12 kVA, with a power factor of 0.9 lagging the speed range of 6700-10000 rpm (10000 - 15000 rpm engine). The frequency of the output voltage of 400 Hz at 8000 rpm (12000 rpm engine). Common voltage alternator output will be reduced on minimum speed, which amounted to 4020 rpm (6000 rpm engine).

The most high-efficiency fan was set at anti-drive or inlet end of the generator. Therefore, fan can operate more efficiently in the air more and more cold on inlet, than heated air from the engine.

Thermostat for overheat warning coupled with the objective of identifying a surplus generator winding temperature. The Usability of thermostat is normally open circuit, which closes when the winding temperature reaches a critical point, i.e.  $374 + 10^{\circ}$  Fah ( $190 \pm 6^{\circ}$  Cel). Contactors are used to operate THE OVERHEAT warning light on the top left panel.

Loads is not really a burden raktif, because it is not regulated supply frequency (unfegulated).

Supply is provided by twin alternators, which are designed to be used by the left hand and right hand. Each alternator is generated by the core control, control switches, assorted gauges and indicator lights as a warning if something goes wrong and the isolation transformer and circuit breaker 3 phase.

#### B. The electrical components and panels on Fokker27

The template is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin in this template measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

##### A. Alternator.

The Alternators used on aircraft Foker-27 Squadron Air 2 is a generator with voltage AC 120/208 Volt, 3 phase, 12 KVA, brushless assembly (no brush), installed on additional gearbox connected to the machine. Alternator is relatively mild when compared with the alternator in general with the same capacity (the alternator is low weight about 158 kg). This unit basically consists of three parts, that is a permanent magnet generator (PMG), an exciter generator, and a main generator. PMG produces power for the control system. Generator exciter produces a regular supply excitation to the main generator, which produce 3 phase AC output for

equipment that uses voltage 208 volts. In addition the unit is produced with an overheat thermostat.

##### B. The unit control

Control units are equipped with a transistor placed in the cargo compartment ceiling front right. This unit produces alternators with Voltage 'regulation and overvoltage protection. Internal power supply for the control unit is obtained from the PMG. Switch OVERVOLTAGE placed on maintenance and comes with a test panel to examine circuit voltages (over voltage circuit).

##### C. The switch control.

The Switch ON / OFF was a single pole alternator that is provided on the panel above the head to the left. This switch controls the internal power supply of the control unit.

###### a. Circuit Breaker 3 phase

Channel charger alternator is protected with a current 50 amperes per phase, using 3 phase circuit breaker. Circuit breaker is organized into additional gearbox of the engine compartment connected.

###### b. Isolation Transformer.

The Isolation transformer was provided to protect the voltage levels of the control unit using circuits of the wave (surge) of the busbar voltage. The transformer is wye-to-wye, same by changing the ratio of assembly which consists of a series to release capacitance resistance earthed neutral point to where the alternator is connected. The transformer is placed near the control unit.

The danger indicators of Fokker-27, can be caused by several reasons, that is:

###### a. The Alternator couldn't be operated

The Blinker indicating that the alternator INOP (not working) is a red indicator "press to test" that is placed on a panel at the top left. The panel is controlled by a relay inoperative alternator which is positioned on the AC voltage of 208 Volt.

###### b. Overheat

The Alarm is indicated by a red light. HEAT "press to test" warning light (light hazard) is positioned on the upper left. The panel is operated by the alternator overheat thermostat.

###### c. Over voltages

The Warning of the danger is provided by the magnetic indicator, placed on test and maintenance panel, and is controlled by the control unit overvoltage circuit. Under normal conditions, the indicator will look black but with the condition that excessive voltage, red indicator will appear on the glass.

D. Gauges located on the instrument panel are :

- a. Voltmeter  
 The Rating alternator is 120 volts line-to-neutral (L-N) and 208 volt line-to-line (L-L), the alternator main terminal. In circumstances where the voltage drop on the line until the filler (feeder lines), this terminal generates a voltage of 115 Volt L-N and 200 Volt L-L to regulasi point. The Potential point 115 Volt L-L monitored by a voltmeter, one for each alternator. Twin Voltmeter is placed on the left side panel.
- b. Amperemeter (Ammeter)  
 Load current from the alternator is monitored by Ammeter which is positioned on the top left. They used to be connected to a double pole, twin position switch, arranged near by Ammeters. Position switches spiked TOTAL description, and POWER UNIT. In this position, TOTAL, Ammeter in series with the situation of the current transformer connected to phase A of the output circuit of the alternator. At the position of POWER UNIT, Ammeter connected in series with a current transformer input circuit de-icing of the power unit. TOTAL current transformer placed on the panel at 208 volts AC.
- c. Test Point  
 Test point prepared on the maintenance and test panel to monitor line-to neutral and phase-to-phase voltage output of the alternator.
- d. Alternator Load Distribution.  
 Each alternator was located separate load. Alternator was operated independently of one another and in the event of failure of one of the alternator, the alternator the other can not be used to supply the load fails (a faulty alternator load from / failure).



Figure 2. (A) Panel cabin without a pilot



(b) The Pilot position at Fokker-27

III. CALCULATION AND ANALYZING OF FOKKER 27 MACHINES POWER AND ENERGY CALCULATIONS

A. Power of single machine

Power = 1835 Hp; if 1 HP= 746 watt, so the power of machine is = 1835 x 746 watt = 1369 kW

B. Energy for a single machine

the formula :  $P = Q/T$  (1)  
 with : P = power (watt)  
 Q = energy (kWh)  
 T = time (hour)

The energy produced by the engine is :  
 $Q = P \times T = 1369 \text{ kW} \times 1 \text{ hour} = 1369 \text{ kWh}$

C. Fuel usage

Specification Fuel Consumption (SFC) = 0,728 lb/HP/h  
 The fuels for single engine = 1835 x 0,728 = 1335,88

The Assumptions distance Surabaya and Jakarta ± 900km. The time required is 2.5 hours. The fuels for twin machines per-hour is 666 x 2 = 1332 liters/hour, so for 2.5 hours is used as fuel:

Total Consumption = Fuel consumption per hour x time (2)  
 = 1332 x 2,5 = 3330 liters for distance 900 km.

So consumption per kilometer is:  
 Consumption = Total consumption / Distance  
 = 3330 / 900 = 3,7 liters/km

#### D. The mileage of aircraft

Tank capacity is owned 5000 liters. So Foker-27 aircraft to fly the farthest distance is :

$$\text{Distance} = \text{Tank Capacity} / \text{Consumption every kilometers.} \\ = 5000 / 3,7 = 1351 \text{ km} \quad (3)$$

With flying time :

$$\text{Flying Time} = \text{Tank Capacity} / \text{Consumption every kilometers.} \\ = 5000 / 1332 = 3,75 \text{ hours} \quad (4)$$

#### E. Alternator frequency calculation

$$\text{From formula: } f = p.n / 60 \quad (5)$$

With :  $f$  = frekwensi (Hz)  
 $p$  = the number of pairs of poles  
 $n$  = speed of rotation (rpm)

Because alternator has 6 poles and the machine is 8000 rpm, the frequency of the alternator generated :

$$f = 3 \times 8000 / 60 = 400 \text{ Hz}$$

#### F. Speed Alternator

a. The ratio of engine speed versus alternator are:

$$\text{Engine : Alternator} = 1 : 0,672 ; \text{ so, if the engine speed is } 12,000 \text{ rpm, then :} \\ \text{Rotation of Alternator} = 12000 \times 0,672 = 8064 \text{ rpm}$$

b. Torque than the engine alternator is

$$\text{Engine torque} = \text{power} / (2\pi \times \text{rotation} / 60) \quad (6) \\ = 1369 \text{ kW} / (2\pi \times 12000 / 60) \\ = 1089,4 \text{ N} \\ \text{Alternator torque} = (12 \text{ VA} / 0,9) / (2\pi \times 8064 / 60) \\ = 15,79 \text{ N} \\ \text{Engine alternator} = 1089,4 : 15,79$$

So which is used to drive alternator for:

$$= (15,79 / 1089,4) \times 100\% = 1,45\%$$

$$\text{Power used} = 1,45 \times 1369 \text{ kW} = 19,85 \text{ kW}$$

The above calculation in accordance with the installed generator capacity, to 12 kVA.

#### G. Battery

The batteries used are nickel-cadmium batteries with a capacity of 40 Ah. Charging required is 140% of capacity rating 5 hours so, the charging current is needed:

$$I_{\text{charge}} = \text{Capacity (Ah)} / \text{time} \quad (7) \\ = 40 \text{ Ah} / 5 \text{ hour} = 8 \text{ Ampere}$$

$$\text{So, to achieve 140 \%, than: } 140\% \text{ Capacity} = 140\% \times 40 \text{ Ah} \\ = 56 \text{ Ah}$$

The time required for charging is

$$T = 140\% \text{ Capacity} / I_{\text{charge}} \quad (8) \\ = 56 \text{ Ah} / 8 \text{ A} \\ = 7 \text{ h}$$

#### H. Power and efficiency inverter

a. Generated power inverter is:

$$P = V \times I \quad (9)$$

with :  $P$  = Power (VA)  
 $V$  = Tension (Volt)  
 $I$  = Flow (ampere)

For phase I, the power generated :

$$P_{\text{in}} = 27,5 \times 106 = 2915 \text{ VA} \\ P_{\text{out}} = 115 \times 13,1 = 1506,5 \text{ VA}$$

With an efficiency of :

$$\eta = P_{\text{out}} / P_{\text{in}} \times 100\% \quad (10) \\ = 1506,5 / 2915 \times 100\% \\ = 51,68\%$$

b. Power to 3 phase

Generated power: The current generated by phase 3 phase selector is 9.1 A, the current flows are:

$$I = \sqrt{3} \times I_{\text{phasa}} = 15,76$$

For the third phase, the power generated:

$$P_{\text{in}} = 27,5 \times 116 = 3190 \text{ VA} \\ P_{\text{out}} = 115 \times 15,76 = 1812,4 \text{ VA}$$

With an efficiency of:

$$\eta = P_{\text{out}} / P_{\text{in}} \times 100\% \\ = 1812,4 / 3190 \times 100\% = 56,8\%$$

#### I. Expense analysis

Alternator used on Foker-27 aircraft at the Air Squadron 2 was used for:

Heating equipment (heating), covering is:

- Extra Cockpit Heating = 5,5 Ampere
- Windshield De-Icing = 7,5 Ampere
- Power de-icing unit consisting of :
  - Air Intake Continuous = 3,5 Ampere
  - Air Intake Cycle = 19,7 Ampere
  - Propeller Blade dan Spinning Cycle = 24,2 Ampere

Load rating safety is used attached to the equipment. To load Air Intake Cycle and Propeller blade alternately stated, so for the calculation of the largest taken Propeller Blade.

a. Total current used is 40,7 A.

b. Maximum current is generated alternator

$$P = \sqrt{3} \cdot V \cdot I$$

$$I = 12000 / (\sqrt{3} \times 208) = 33,3 \text{ A}$$

In this analysis, it appears that the alternator is used is not sufficient when compared with the load attached. The difference is due to differences in the burden of manual list maintenance (Maintenance Manual) and manual repairs / maintenance (Overhaul Manual) because at the Air Squadron

2 used Foker-27 aircraft with the old type altenator (12 KVA), while the Handbook is used has been revised by the Vendor (the company that made the plane) concerned (15 KVA). In this case, should the Air Squadron 2 change or modify the aircraft used, However as the aircraft used are considered to meet the eligibility standards flying, then the modification is still not necessary see figure 3 about specification Fokker F-27 Indonesian Air Force.



Figure 3. Specifications of the Fokker 27

#### IV. CONCLUSION

From the calculation and analysis of the performance of Alternator 115/208 Volt, 400 Hz, 12 KVA aircraft Fokker-27 on Air Squadron 2, it can be summed up as follows :

1. Altenator used on Fokker-27 aircraft Air Squadron 2 is minimized with a large enough power (12 kVA). This can be achieved with a high frequency (400 Hz), in order to get a small physical size.
2. Altenator used should be 15 kVA (corresponding maintenance manual). Altenator used now 12 kVA at 0.9 lagging power factor is time modified in accordance with

the new load to improve the performance of the aircraft.

#### REFERENCES

- [1] Anonim, "Induction Motors", TECO Electric Motor, 1998.
- [2] Berahim, Hamzah Ir. *Teknik Tenaga Listrik*, Andi Offset, Yogyakarta 1996.
- [3] **Charles I. Hubert**, *Preventive Maintenance of Electrical Equipment*, Glencoe, McMillan / Mc Graw-Hill, New York 1996.
- [4] Eismen, Thomas K, *Aircraft Electricity & Electronics*, Mc Graw-Hill Mernational Editotis, Fifth edition, California 1994.
- [5] Tumbelaka, Hanny, "Dasar Konversi Energi" Elektronics Jakarta 2000
- [6] Kroes, Michael J an Wild, Homas W, "Aircraft Powerplants, Glencoe Aviation Technology Series", MC Graw Hill 1995
- [7] Moelyono W. Nono, "Pengantar Sistem Distribusi Tenaga Listrik", Jakarta 1999
- [8] Rashid H. Muhammad, *Elektronika Daya Jilid 1*, PT Prenhallindo, Jakarta 1993
- [9] Teng (Ce), Amrasaes, FSslaet, Pallet, EHJ," *Aircraft Electrical Systems*", John Wiley & Sons, Inc, New York 2000.
- [10] Tirtoatmodjo, Rahardjo, Dr, "Penggerak Mula", Bina rupa Aksara, Jakarta 1996

# Radiation Pattern Characterization of Single Patch Spiral Resonator (SR) Structure Using Linear Array Approach

Mochamad Yunus<sup>1</sup>, Fitri Yuli Zulkifli<sup>2</sup>, Eko Tjipto Rahardjo<sup>3</sup>

<sup>1,2,3</sup>Antenna and Microwave Research Group, Electrical Engineering Department, Faculty of Engineering,  
 Universitas Indonesia, Depok 16424, Indonesia  
 Tel : (021) 7270011 ext 51. Fax : (021) 7270077

<sup>1</sup>email : [mochyunus@yahoo.com](mailto:mochyunus@yahoo.com), <sup>2</sup>email : [yuli@eng.ui.ac.id](mailto:yuli@eng.ui.ac.id), <sup>3</sup>email : [eko@eng.ui.ac.id](mailto:eko@eng.ui.ac.id)

**Abstract** – Spiral resonator (SR) structure is used in many microstrip antenna design due to its unique properties, such as negative permeability value as an artificial magnetic inclusion. This paper present the formulation of the radiation pattern of the microstrip antenna with single patch SR shaped structure using linear array model of  $n$  nonisotropic similar point sources. The linear array is assumed by modeling of each stripline of the spiral with length  $l$  and width  $w$  as a nonisotropic point source. The result of this approach is compared to the simulation result through CST software and it shows the similarity between both results for the same  $N$ . Moreover, with both  $w$  and  $s$  are constant; the radiation level tends to increase with the increasement of  $N$ .

**Keywords** : *Spiral Resonator; Radiation Pattern; Linear Array Approach*

## I. INTRODUCTION

Mobile communication needs portable device with characteristics such as compact, light and small size. To achieve this requirement, many research on size reduction of microstrip antenna has been conducted such as [1]–[2]. Commonly, the dimensional miniaturization of the microstrip antenna has been done by using the high permittivity substrate. However, if the high permittivity substrate is used to design microstrip antenna, this will increase the surface wave which will impact to the reduction of gain, efficiency, and bandwidth parameters. To solve these problems, the negative permeability or Miu Negative (MNG) material is used to design the microstrip antenna. MNG material has unique properties, such as no wave absorption or transmission in this material, so that it is suitable used to miniaturize the microstrip antenna dimension. Generally, the MNG microstructure is shaped as split ring resonator (SRR) or spiral resonator (SR), both are the artificial magnetic inclusion [3]–[4]. The SR structure is better than the SRR due to dimensional reduction. Bilotti [5]–[6] has presented the lumped element model to calculate the  $R$ ,  $L$ ,  $C$  calculation of SRR and SR structures and give the  $L$ ,  $C$ , and resonance frequency values to the variation of the spiral turn number  $N$ . However, these model can not be used to calculate and predict the radiation pattern. Therefore, this paper discusses the formulation of the

radiation pattern of the microstrip antenna with single patch SR shaped structure as linear array approach.

## II. SR LOOP PLANAR STRUCTURE

To derive the radiation pattern formulation, consider the single patch SR structure with  $N$  loop as shown in Fig. 1(a). This structure is assumed as a planar loop that has a continuous path. The single patch SR structure is a square loop with the length of each stripline  $l_n$ , where  $n$  is the number of stripline as nonisotropic similar point sources,  $N$  is total amount of the spiral turn,  $w$  is the stripline width, and  $s$  is a gap between stripline. Therefore, using  $N$  variation and  $w$ ,  $s$ , and inner radius parameters that defined constant, the different length of each stripline due to inward turning of spiral can be calculated. For the linearly array model,  $s$  is assumed to be equally distant. For further analysis, the planar loop as shown in Fig. 1(a) can be assumed geometrically as linear arrays of  $n$  nonisotropic similar point sources at the  $X$ - $Z$  or  $Y$ - $Z$  plane and the vector addition of  $E$  field as shown in Fig. 1(b) and Fig. 1(c), respectively. The length of stripline at the  $X$ - $Z$  plane can be calculated as  $l_1 = 5(w + s)$ ,  $l_2 = 3(w + s)$ ,  $l_3 = (w + s)$ ,  $l_4 = l_3 + (w + s)$ ,  $l_5 = l_4 + 2(w + s)$ ,  $l_6 = l_5 + 2(w + s)$ ; while at the  $Y$ - $Z$  plane one is  $l_1 = 6(w + s)$ ,  $l_2 = 4(w + s)$ ,  $l_3 = 2(w + s)$ ,  $l_4 = l_3 + (w + s)$ ,  $l_5 = l_4 + 2(w + s)$ ,  $l_6 = l_5 + (w + s)$ .

Consider to substitute the slot line [7] with the stripline, the radiation pattern can be formulated as

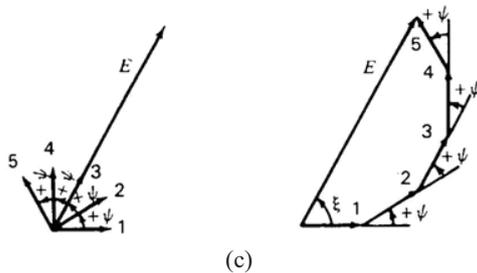
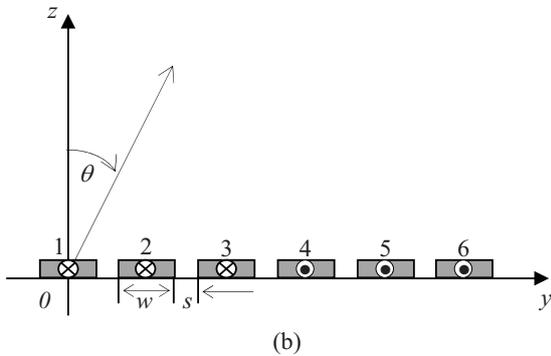
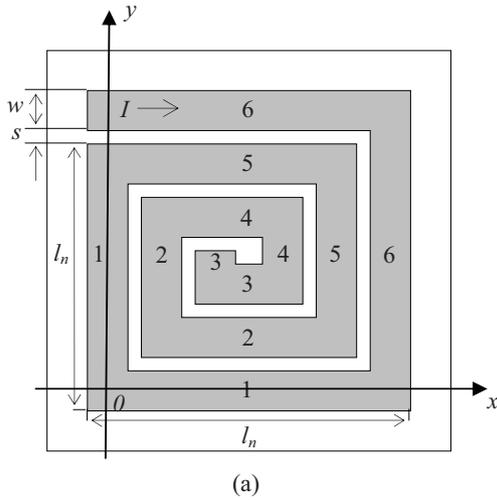
$$E_\theta = I_0 \frac{\sin\left[\left(\frac{2\pi l}{\lambda}\right)\cos(\theta)\right]}{\left(\frac{2\pi l_1}{\lambda}\right)\cos(\theta)} ; \quad (1)$$

$$E_\theta = I_0 \frac{\sin\left[\left(\frac{2\pi w}{\lambda}\right)\cos(\phi)\right]}{\left(\frac{2\pi w_1}{\lambda}\right)\cos(\phi)}$$

If the (1) is applied to Fig. 1, then the  $n^{\text{th}}$  stripline  $E$  is :

$$E_{\phi 0n} = I_0 \frac{\sin\left[\left(\frac{2\pi}{\lambda} \frac{l_n}{2}\right) \cos(\theta)\right]}{\left(\frac{2\pi}{\lambda} \frac{l_n}{2}\right) \cos(\theta)} ;$$

$$E_{\theta 0n} = I_0 \frac{\sin\left[\left(\frac{2\pi}{\lambda} \frac{w_n}{2}\right) \cos(\phi)\right]}{\left(\frac{2\pi}{\lambda} \frac{w_n}{2}\right) \cos(\phi)}$$



**Fig. 1** (a) Single Patch SR Structure as a Continuous Loop ( $N=3$ ,  $w=3$  mm,  $s=1$  mm, inner radius 1 mm); (b) Linear Array of Six Nonisotropic Similar Point Sources for X-Z or Y-Z Plane; (c) Vector Addition of  $E$  Field for  $n=5$  [8]

According to the electric current direction at each stripline, the electric current at the 1<sup>st</sup> up to 3<sup>rd</sup> striplines are opposite with the electric current at the 4<sup>th</sup> up to 6<sup>th</sup> striplines. If the electric current at the 4<sup>th</sup> up to 6<sup>th</sup> striplines are positive, then the electric current at the 1<sup>st</sup> up to 3<sup>rd</sup> striplines are negative.

(2) The radiation pattern of each nonisotropic point source can be formulated :

$$E_{\phi n} = -E_{\phi 0n} e^{j(n-1)\psi} ; 1 \leq n \leq N ;$$

$$E_{\phi n} = +E_{\phi 0n} e^{j(n-1)\psi} ; N < n \leq 2N$$

(3)

$$E_{\theta n} = -E_{\theta 0n} e^{j(n-1)\psi} ; 1 \leq n \leq N ;$$

$$E_{\theta n} = +E_{\theta 0n} e^{j(n-1)\psi} ; N < n \leq 2N$$

where :

$$\psi = \frac{2\pi d}{\lambda} \sin \theta ; d = s = 0.5 \text{ mm} ; N \geq 2$$

(4)

The radiation pattern of linear array of nonisotropic similar point sources is the product of the pattern of the individual source and the pattern of linear array of isotropic point sources, having the same locations, relative amplitudes and phases as the nonisotropic point sources. The individual nonisotropic source or antenna may be of finite size but can be considered as a point source situated at the point in the antenna to which phase is referred. Therefore, the total radiation pattern of the single patch SR structure can be formulated :

$$E_{\phi,SR} = -\sum_{n=1}^N E_{\phi n} + \sum_{n>N}^{2N} E_{\phi n} ;$$

(5)

$$E_{\theta,SR} = -\sum_{n=1}^N E_{\theta n} + \sum_{n>N}^{2N} E_{\theta n}$$

If the (2) to (4) are applied to the (5), and by splitting its real and imaginary parts, then the radiation pattern of  $E_{\phi,SR}$  and  $E_{\theta,SR}$  can be solved.

### III. RESULTS AND DISCUSSION

For the comparison of the radiation pattern between the simulation and the linear array approach, the microstrip antenna with single patch SR structure is designed at FR4 substrate with thickness 1.6 mm,  $\epsilon_r = 4.3$  and  $\mu_r = 1$ . The microstrip antenna is designed without the ground plane for both the simulation and linear array approach. The single patch SR characteristic due to the variation of  $w$  and  $s$  parameters through CST simulation is shown in Table 1 and Fig. 2. The parameter variation of  $w$  and  $s$  shows similar radiation pattern, with a slight difference of amplitude level of the  $E$  field.

TABLE I. SINGLE PATCH SR CHARACTERISTICS USING CST SIMULATOR WITH  $w$  AND  $s$  VARIATIONS

Parameters	Single Patch SR, $N = 3$							
	$w=3$	$s=1$	$w=3$	$s=2$	$w=2$	$s=3$	$w=2.5$	$s=2.5$
Freq (GHz)	2.325		2.175		2.400		2.290	
$S_{11}$ (dB)	-23		-25		-25		-25	
BW (MHz)	150		181		251		215	
$E$ (V/m)	4.3		4.1		4.5		3.8	
Pattern	Similar							

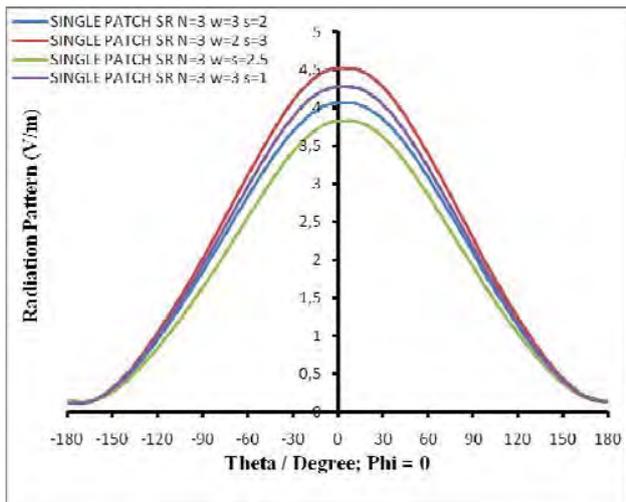
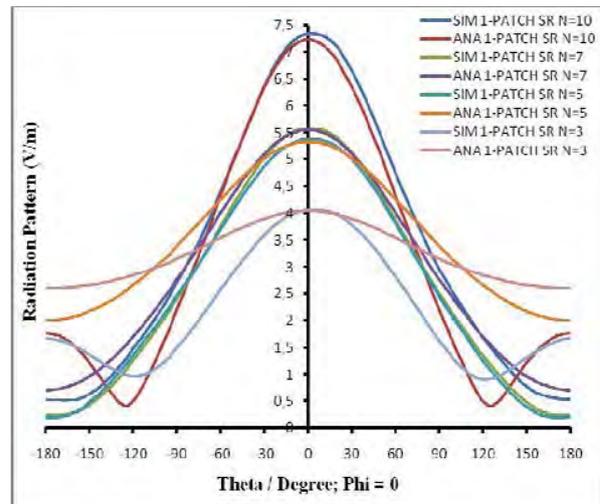


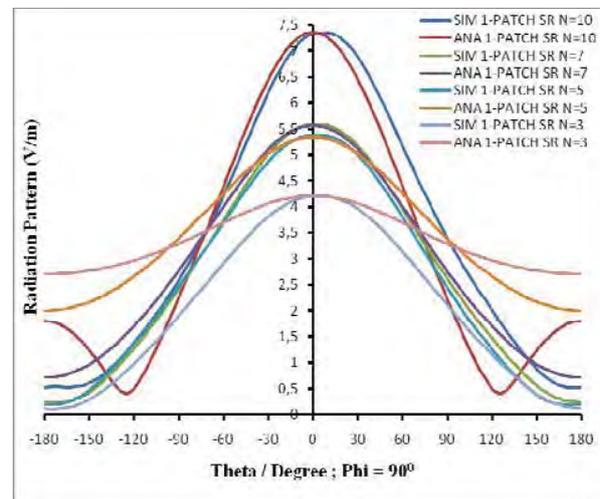
Fig. 2 Radiation Pattern of Single Patch SR with  $w$  and  $s$  Variation Using CST Simulation

Figure 3 shows the radiation pattern for  $w = 3$  mm and  $s = 1$  mm. The radiation pattern is obtained by using CST simulation and linear array approach from (5). The simulation results using CST software are compared to the achieved result of the absolute values from linear array approach as shown in Fig. 3 (a) for  $X$ - $Z$  plane and Fig. 3 (b) for  $Y$ - $Z$  plane. The radiation pattern using linear array approach has the similarity with the radiation pattern using the CST simulation for the same  $N$  at boresight direction. The radiation level tends to increase with the increment of  $N$  for both approaches. The difference at the sidelobes occur due to the different method between CST simulation and linear array approach. The radiation pattern simulated with CST Studio Suite uses the finite difference time domain (FDTD) with finite integration technique (FIT) algorithm and cartesian mesh but with much improved PBA (perfect boundary approximation), whereas the calculation of the radiation pattern proposed uses the linear array of point source method. Table 2 shows the difference value of the side lobe level between CST simulation and linear array approach from  $\pm 90^\circ$  to  $\pm 180^\circ$ . From Table 2, the minimum average value difference occurs for  $N = 7$ . Therefore with the increment of  $N$ , it does not show a more accurate sidelobe level of radiation pattern. Thus, the proposed linear array approach can be used as an alternative method to solve

the radiation pattern problem of the microstrip antenna with single patch spiral resonator structure.



(a)



(b)

Fig. 3 Comparison of Radiation Pattern Between Linear Array Approach and Simulation Results: (a)  $X$ - $Z$  Plane; (b)  $Y$ - $Z$  Plane

TABLE II. LEVEL DIFFERENCE OF RADIATION PATTERN BETWEEN CST SIMULATION AND LINEAR ARRAY APPROACH

Theta/ Degree	Level Difference of Radiation Pattern			
	$N = 3$	$N = 5$	$N = 7$	$N = 10$
$\pm 180$	2.5967	1.8013	0.4705	1.2794
$\pm 170$	2.6058	1.8159	0.4976	1.2096
$\pm 160$	2.5779	1.7890	0.5380	1.0098
$\pm 150$	2.4850	1.6969	0.5392	0.6346
$\pm 140$	2.3473	1.5707	0.5079	0.0730
$\pm 130$	2.1811	1.4333	0.4666	0.5689
$\pm 120$	1.9969	1.2973	0.4281	0.8762
$\pm 110$	1.8018	1.1685	0.3973	0.7611
$\pm 100$	1.6007	1.0473	0.3738	0.5562
$\pm 90$	1.3964	0.9305	0.3539	0.3377
Average Value Difference	2.1590	1.4551	0.4573	0.7306

#### IV. CONCLUSIONS

The radiation pattern characteristics of single patch SR structure have been studied using linear array approach synthesis. The computation results have been verified by simulation using CST Microwave Studio which shows good agreement. Therefore, this approach can be used as the alternative method to provide field pattern.

#### ACKNOWLEDGMENT

The authors would like to thank Universitas Indonesia for partially support of this work under Hibah Riset Utama UI 2012, under contract number : 1606/H2.R12/HK P05.00/2012. The authors would also like to thank to reviewers for their valuable comments and suggestions.

#### REFERENCES

- [1] E. T. Rahardjo, W. Yuswardi and F. Y. Zulkifli, "Size Reduction of Microstrip Antenna with CRLH-TL Metamaterial and Partial Ground Plane Techniques", 2012 Intern'l Symp. on Antennas and Propagation, October 29-November 2, 2012, Nagoya Japan
- [2] A. A. Fashi, M. Kamyab, and M. Barati, "a Novel Small Resonant Antenna Using the Meta-Materials Array", PIERS Proceedings, Moskow, Russia, August 18-21, 2010
- [3] V. L. John, "Antenna Engineering Handbook", Mc Graw Hill, Fourth Edition, 2007
- [4] N. Engheta, R. W. Ziolkowski, "Metamaterial : Physics and Engineering Explorations", IEEE Press, John Wiley & Sons Inc., 2006
- [5] F. Bilotti, A. Toscano, and L. Vegni, "Design Of Spiral And Multiple Split-Ring Resonators For The Realization Of Miniaturized Metamaterial Samples", IEEE Trans. On Antennas And Propagation, Vol. 55, No. 8, August 2007
- [6] F. Bilotti, A. Toscano, L. Vegni, K. Aydin, K. B. Alici, and E. Ozbay, "Equivalent-Circuit Models for the Design of Metamaterials Based on Artificial Magnetic Inclusions", IEEE Trans. On Microwave Theory And Techniques, Vol. 55, No. 12, December 2007
- [7] R. A. Sainati, "CAD of Microstrip Antennas for Wireless Applications", Artech House, Inc., Boston, London, 1996.
- [8] J. D. Krauss, "Antenna", Mc-Graw Hill, Inc., Intern'l. Edition, 1992.

# Multiple Slots Technique for Bandwidth Enhancement of Microstrip Rectangular Patch Antenna

Achmad Munir, Guntur Petrus, Hardi Nusantara  
School of Electrical Engineering and Informatics  
Institut Teknologi Bandung  
Bandung, Indonesia  
munir@ieee.org

**Abstract**—This paper discusses the investigation of bandwidth enhancement for microstrip rectangular patch antenna by putting up multiple slots etched on the patch. The technique is proposed in overcoming the nature characteristic of microstrip patch antenna which has narrowband bandwidth response. Here, the antenna is designed to work at center frequency around 1.6GHz for GPS application. The patch of antenna is fed by using a microstrip transmission line feeding network extended from a center pin of 50Ohm SMA connector. The number of slots etched on the patch is set to be 13 which are separated 3mm each other. The 13 slots which have different length for each are arranged in parallel with the feeding line. To shows the feasibility of proposed technique, the characteristics of microstrip patch antenna with multiple slots are compared to the conventional microstrip patch antenna. Both antennas are implemented using FR-4 Epoxy dielectric substrates with the dimension of 55mm x 80mm and the thickness of 1.6mm. From the characterization, although there are some slight differences of simulation and measurement results, in general the microstrip patch antenna with multiple slots demonstrates bandwidth enhancement up to 98.3% and 70.8% for simulated result and measured result, respectively.

**Keywords**— *Bandwidth enhancement, rectangular patch antenna, microstrip, multiple slots technique*

## I. INTRODUCTION

In recent years, numerous applications developed from patch array which is deployed by employing printed circuit board (PCB) have been widely implemented in wireless communication devices [1]-[3]. Due to the planar structure of patch array which is deployable on some dielectric substrate, the use of patch element and its array are becoming popular for practitioners involved in the design of RF components [3]-[4]. The applications include the use of microstrip patch antenna in various shapes also referred as patch antenna, which is developed based on microstrip technology. In addition to have the portability aspect, this type of antenna has some advantages such as easy to be incorporated with other planar structure, low cost in realization, and robust for the implementation on rigid surfaces [5]-[6]. Furthermore, the antenna is also able to be easily produced both in linear and circular polarizations, and has the capability to provide dual-band, multiband, and wideband frequency responses [7]-[8].

Unfortunately, the transverse dimension of microstrip patch antenna cannot be made arbitrarily short, since a regular patch antenna will have resonant frequency when its linear transverse dimension is of the order of one-half wavelength. Moreover, the microstrip antenna has also some disadvantages such as low gain, low efficiency, high loss, narrow bandwidth. Some efforts to overcome those disadvantages have been investigated numerically and experimentally. In [9]-[10], microstrip patch antennas with parasitic patch substrate have been proposed to improve the overall gain and bandwidth response. Hence, the similar attempt to enhance the bandwidth response has been conducted by employing parallel feeds to the L-probe coupled single layer patch antenna and metamaterials [11]-[12].

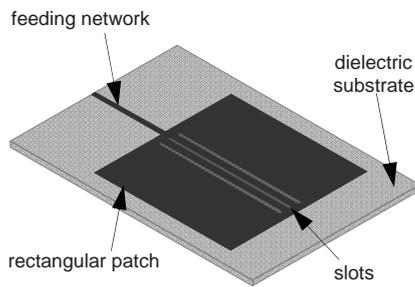
In connection with overcoming disadvantages of microstrip antenna especially for widening the bandwidth response, in this paper, the bandwidth enhancement is proposed by utilizing multiple slots technique over the patch of antenna. The antenna is designed to operate at frequency of 1.6GHz for GPS (Global Positioning System) application. Actually, the characteristic bandwidth of microstrip antenna which is naturally narrow is almost affected by the use of dielectric substrate with some relative permittivity. However, since the use of dielectric substrate for the deployment of patch antenna is unavoidable thing, therefore the possibility effort is by handling the patch through some treatments. Here, the rectangular type is used as the shape of patch as well as the shape of slot for investigation. Meanwhile, the permittivity of dielectric substrate used for the antenna deployment is 4.2 realized using an FR-4 Epoxy substrate. The antenna which has the dimension of 80mm length and 55mm width is fed by use of a microstrip transmission line feeding network which is extended from a center pin of 50Ohm SMA connector. Hence, the number of slots is set to be 13 which are separated 2mm each other. Before designing and characterizing the antenna, a theoretical background which explains the correlation between the slot and the bandwidth will be briefly introduced. Then the design of microstrip patch antennas with and without slots is described. Some basic parameters of antenna especially the bandwidth as the focus of investigation will be observed in which the design result will be compared and verified with the experimental measurement. Some discussion related to the characterization results will be presented consecutively.

---

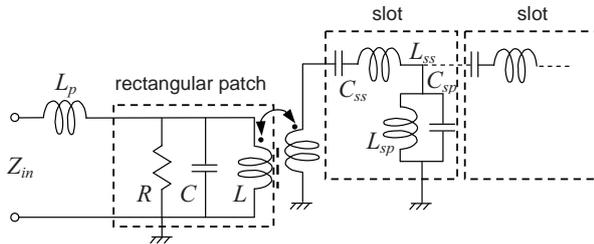
This work is partially supported by the Research Grant from ITB under the scheme program of Research and Innovation 2013.

## II. BRIEF THEORETICAL BACKGROUND

An approximation of equivalent circuit model for rectangular microstrip patch antenna with slots is illustrated in Fig. 1. The antenna is constructed of a ground plane at the bottom side of dielectric substrate and a radiating element, i.e. rectangular patch, connected to microstrip line feeding network at the top side. The feeding network uses a quarter-wavelength matching impedance to minimize the impedance mismatch between the impedance of connector and the impedance of rectangular patch contact point. The equivalent circuit model consists of  $L_p$  as the inductance of connector's probe and feeding network, and the  $RLC$  circuit as the approximately model of rectangular patch. Hence, each slot is approximately modeled by using a combination of  $L_{ss}C_{ss}$  series connected to another  $L_{sp}C_{sp}$  shunt which produces a characteristic of bandpass filter. The approximation model of slot is coupled to the rectangular patch through the patch inductor.



(a) rectangular microstrip patch antenna with slots



(b) approximation of equivalent circuit model

Fig. 1. Rectangular microstrip patch antenna with slots and its approximation of equivalent circuit model

From the equivalent circuit model, the resonant frequency of microstrip rectangular patch antenna without slots can be determined from the value of inductance ( $L$ ) and capacitance ( $C$ ) as expressed in (1). Hence the value of patch resistance ( $R$ ) influences to the quality factor and bandwidth of antenna. By providing a number of slots over the patch, as a consequence the resonant frequency is affected as the patch inductance changes. However, the effect can be elaborated to be synchronized by taking the shape of slot to be able resonates at the same resonant frequency.

$$f = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

The correlation of bandwidth (BW) and quality factor ( $Q$ ) of patch antenna are denoted in (2), where the bandwidth is defined for voltage standing wave ratio (VSWR) value  $< 2$ . By using the equivalent circuit model, the  $Q$  factor of patch antenna without slot can be determined as written in (3).

$$BW = \frac{1}{Q\sqrt{2}} \quad (2)$$

$$Q = \frac{R}{\omega_0 L} \quad (3)$$

In other term, the  $Q$  factor of patch antenna exists due to the conductor loss of patch ( $Q_c$ ) for the  $nm^{\text{th}}$  mode and the dielectric loss of substrate ( $Q_d$ ) as expressed in (4) [13].

$$Q = \frac{1}{\frac{1}{Q_c} + \frac{1}{Q_d}} = \frac{1}{\frac{2\beta_{nm}^2}{\omega\varepsilon_0\varepsilon_r h_d \sigma_c \delta_c (\beta_0 Z_0)^2} + \frac{\sigma_d}{\omega\varepsilon_0\varepsilon_r}} \quad (4)$$

where  $\varepsilon_r$ ,  $\sigma_d$  and  $h_d$  are parameters related to the dielectric substrate, i.e. relative permittivity, conductivity and thickness, respectively. Whilst,  $\sigma_c$  and  $\delta_c$  are patch conductivity and skin depth, respectively. Hence,  $\beta_0$ ,  $\beta_{nm}$ ,  $\omega$ , and  $Z_0$  are propagation constant at resonant frequency, propagation constant for  $nm^{\text{th}}$  mode, working radian frequency, and surface impedance of antenna, respectively.

Due to the presence of slots, the  $Q$  factor of patch antenna with slots in (3) decreases as the value of patch inductance increases. This can also be figured out that the existence of slots evokes the decrease of patch area which affect to the conductor loss of patch and the dielectric loss of substrate in (4), as a result the  $Q$  factor decreases. By the decrease of  $Q$  factor, therefore, the bandwidth (BW) of patch antenna in (2) increased accordingly.

## III. DESIGN AND CHARACTERIZATION

Figure 2 shows the illustration of rectangular microstrip patch antenna with and without slots which are designed on FR-4 Epoxy dielectric substrates with relative permittivity of 4.2 and thickness of 1.6mm. The antenna is designed to work around the resonant frequency of 1.6GHz for GPS application. Based on equations in [8], the patch dimension can be determined theoretically by including value of relative permittivity, fringing extension length and thickness of dielectric substrate in calculation. After some parametrical studies, the patch dimension takes the length of 44.5mm and the width of 45mm. The width of patch is slightly wider than the length to obtain the better bandwidth characteristic for some mode of resonance. Hence the total dimension of antenna including feeding network is 80mm length and 55mm width. The patch is then fed using microstrip transmission line as feeding network which is extended from a center pin of 50Ohm SMA connector. In addition to be a feeding network, microstrip transmission line also acts as matching impedance circuit between the impedance of connector and contact point of rectangular patch, therefore it takes a dimension of a quarter-wavelength with the width of 1.2mm.

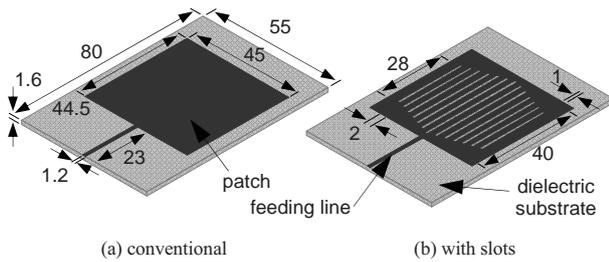


Fig. 2. Illustration of rectangular microstrip patch antennas (unit in mm)

For microstrip patch antenna with multiple slots, as shown in Fig. 2(b), the number of slots over the patch is set to be 13 which are separated 3mm each other from its center line. The 13 slots which are arranged in parallel with the feeding line have different length where the outer slot has 2mm shorter than each the inner consecutive slot. The longest and the shortest slots are 40mm and 28 mm, respectively. In the design, the patch of antenna, microstrip line feeding network and ground plane are made of copper metal with the thicknesses of 0.035mm. To obtain an accurate design, copper conductive loss with  $\sigma_c$  of  $5.8 \times 10^7$  S/m and the dielectric loss with  $\tan\delta$  of 0.02 are taken into account. Then, both designs of microstrip patch antenna are characterized numerically to obtain their characteristic responses.

The numerical characterization results of both antennas are depicted in Figs. 3-6 for reflection coefficient, VSWR, gain, and radiation pattern, respectively. From the coefficient reflection in Fig. 3, it shows that the center frequency of antenna with slots is shifted to higher frequency around 15MHz compared to the conventional antenna. Hence, the working bandwidth depicted in Fig. 4 for the antenna with slots at  $VSWR < 2$  is 692MHz which is wider 34.3MHz than the working bandwidth of conventional antenna, i.e. 34.9MHz. It could be noted that the working bandwidth of antenna with slots is almost 100% enhanced from the conventional one. Unfortunately the gain of antenna with slots is relatively lower for all frequency ranges. Whilst from Fig. 6, it is seen that the radiation pattern of both antennas is almost similar each other with slightly difference in the magnitude.

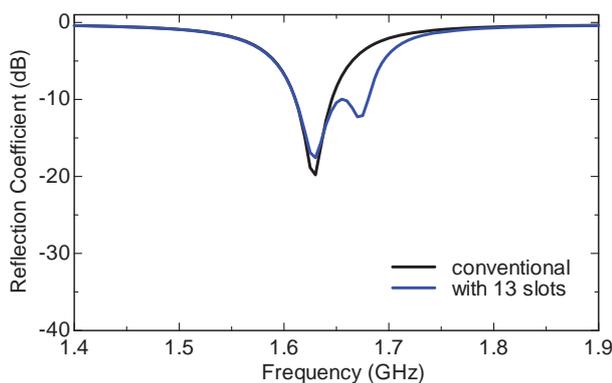


Fig. 3. Simulated results of reflection coefficient for both patch antennas

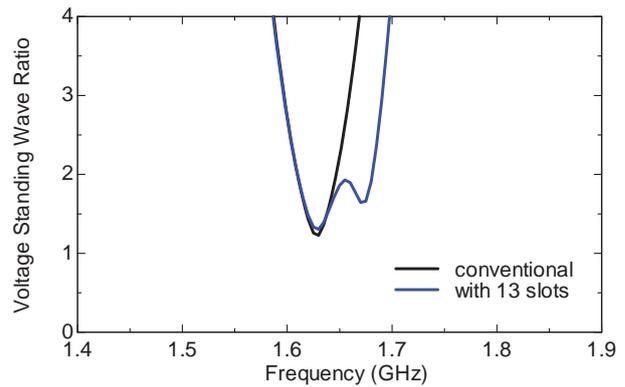


Fig. 4. Simulated results of VSWR for both patch antennas

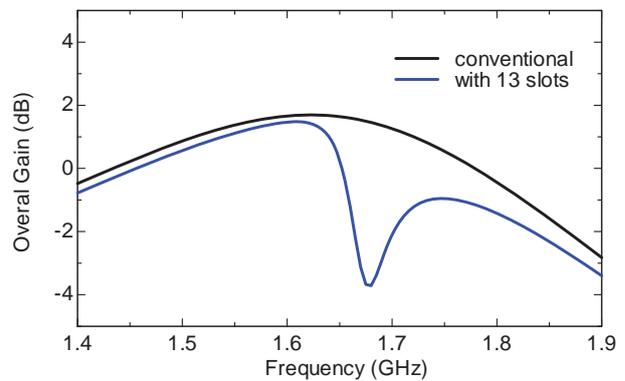


Fig. 5. Simulated results of gain for both patch antennas

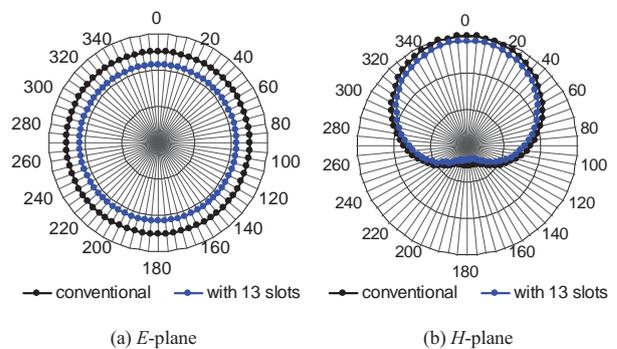


Fig. 6. Simulated results of radiation patterns for both patch antennas

#### IV. MEASUREMENT AND RESULTS COMPARISON

To verify the numerical characterization, hardware realizations of rectangular microstrip patch antennas without and with slots are carried out by fabricating the designed antennas on FR-4 Epoxy dielectric substrate through wet etching technique. Figure 7 shows a picture of fabricated patch antennas without slot (right) and with 13 slots (left) for experimental characterization.

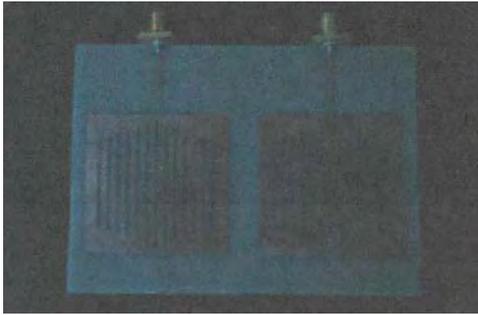


Fig. 7. Fabricated rectangular microstrip patch antennas for measurement; right is conventional patch antenna; left is patch antenna with 13 slots.

Figure 8 plots the measured reflection coefficient of both fabricated antennas with the numerical characterization results as comparison. It is seen that the both fabricated antennas have better characteristic responses than the design ones; however with the center frequencies are shifted less than 10MHz to the higher frequency. The difference is mostly evoked by the value of relative permittivity used in the numerical design which is slightly higher than the value in the measurement. The measured resonant frequency of patch antenna with slots is 1.642GHz which is higher 2MHz than the measured conventional patch antenna, i.e. 1.64GHz. The achievement of frequency shift is better than the numerical result of 15MHz. Nevertheless, the measured results of reflection coefficient have good agreements qualitatively with the simulation results for all frequency ranges.

Whilst from the measured VSWR results shown in Fig. 9, the measured working bandwidths also show the similar trend as the numerical results. The measured working bandwidth of patch antenna with slots for VSWR < 2 is 53.3MHz. This bandwidth is 22.1MHz wider than of the conventional patch antenna, i.e. 31.2MHz, so the bandwidth enhancement achieves 70.8%. In comparison with the numerical result, the measured bandwidth enhancement is smaller. This is probably affected by the inaccuracy of fabricated slots which have probably narrower dimension than the design one. As the narrower dimension of slot, the higher  $Q$  factor is produced; therefore the narrower bandwidth is obtained.

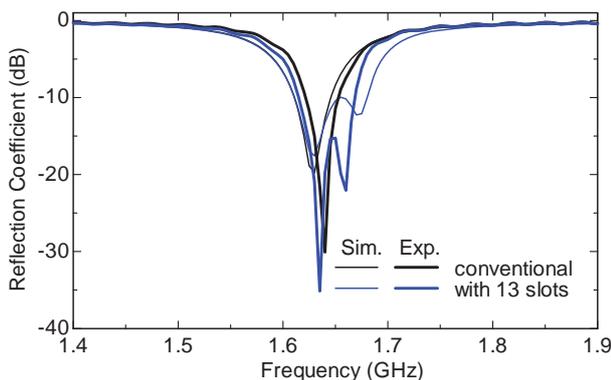


Fig. 8. Measured and simulated results of reflection coefficient for both patch antennas

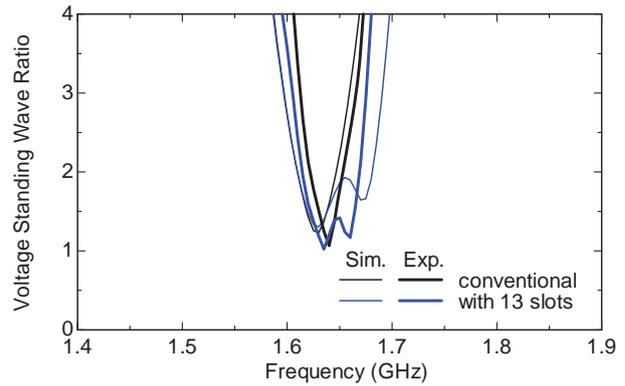


Fig. 9. Measured and simulated results of VSWR for both patch antennas

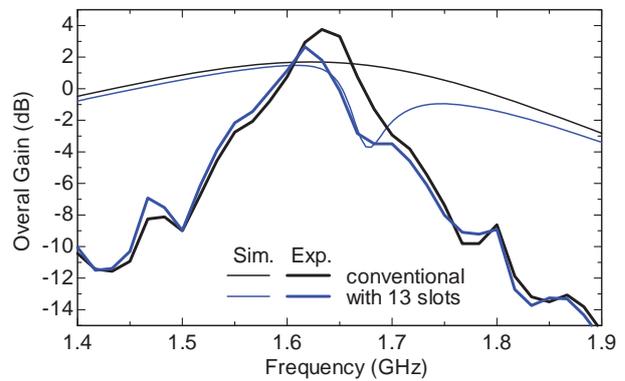


Fig. 10. Measured and simulated results of gain for both patch antennas

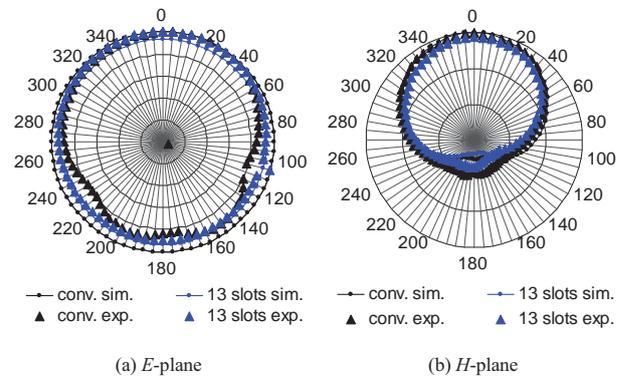


Fig. 11. Measured and simulated results of radiation patterns for both patch antennas

In the overall gain result as plotted in Fig. 10, it is seen that around resonant frequency, the measured gain for both antennas is higher than the numerical results, whereas in other frequency ranges are lower. Similar as the numerical result, the measured gain of patch antenna with slots is also lower, i.e. less than 2dB, around the resonant frequency and the higher frequency band compared to the conventional patch antenna, but at the lower frequency band the overall gain is higher.

Hence from Fig. 11, it can be understood that the utilization of slots over the patch of antenna has no effect significantly to the radiation pattern both for  $E$ -plane and  $H$ -plane. In spite of radiated power in some direction has distortion in the magnitude, however, both results for numerical and experimental characterizations show good agreements each other. This is an advantage of utilizing multiple slots technique which is usable to improve the working bandwidth of rectangular microstrip patch antenna.

#### V. CONCLUSIONS

The bandwidth enhancement of microstrip rectangular patch antenna by implementing multiple slots technique has been investigated numerically and experimentally. It has been successfully demonstrated by experimental characterization that the multiple slots, here was 13 slots, could improve the working bandwidth of conventional patch antenna up to 70.8% without affecting remarkably the resonant frequency, gain as well as the radiation pattern. Whilst from the numerical characterization, the bandwidth enhancement has achieved up to 98.3%. Although, there were some discrepancies in term of resonant frequency, bandwidth, gain, and radiation pattern between the numerical and the experimental characterizations, however, in general it could be concluded that the proposed technique has been successfully applied for bandwidth enhancement of rectangular microstrip patch antenna and should be implementable for other patch antenna shapes.

#### ACKNOWLEDGEMENT

The authors thank to Dr. Chairunnisa, School of Electrical Engineering and Informatics, Institut Teknologi Bandung (ITB) for the fruitful discussion and support.

#### REFERENCES

- [1] R. Caso, A.A. Serra, M. Pino, P. Nepa, and G. Manara, "A wideband slot-coupled stacked-patch array for wireless communications," *IEEE Antennas Wireless Propag. Lett.*, vol. 9, pp. 986–989, 2010.
- [2] W.M.A. Wahab, S.S. Naeini, and D. Busuioac, "Low cost microstrip patch antenna array using planar waveguide technology for emerging millimeter-wave wireless communication," *Proc. of 14<sup>th</sup> Int. Symp. on Antenna Technology and Applied Electromagnetics & the American Electromagnetics Conf. (ANTEM-AMEREM)*, pp 1-4, Jul. 2010.
- [3] A. Munir and Sutinah, "Numerical Characterization of Metamaterials-based Patch Antenna Array," *Proc. of 6<sup>th</sup> Int. Conf. on Telecommunication Systems, Services and Applications (TSSA) 2011 Proc.*, pp. 292-295, Oct. 2011.
- [4] K-S. Chin, H-T. Chang, J-A. Liu, H-C. Chiu, J.S. Fu, and S-H. Chao, "28-GHz patch antenna arrays with PCB and LTCC substrates," *Cross Strait Quad-Regional Radio Science and Wireless Technology Conference (CSQRWC)*, pp. 355 – 358, 2011.
- [5] J.R. James and P.S. Hall, *Handbook of microstrip antennas*, London: Peter Peregrines, 1989.
- [6] D.M. Pozar and D.H. Schaubert, *Microstrip antennas: The analysis and design of microstrip antennas and arrays*, New York: IEEE Press, 1995.
- [7] J.D. Kraus and R. J. Marhefka, *Antennas for all applications*, 3rd ed., New York: McGraw-Hill Inc., 2002.
- [8] C.A. Balanis, *Antenna theory, analysis and design*, 3rd ed., New Jersey: John Wiley & Sons Inc., 2005.
- [9] E. Nishiyama and M. Aikawa, "Wide-band and high-gain microstrip antenna with thick parasitic patch substrate," *Int. Symp. Antennas and Propagation Society*, pp. 273-276, 2004.
- [10] O. Shibata, H. Koyama, and T. Sawaya, "Small size, high gain and high F/B ratio patch antenna arranging parasitic element on the back," *Proc. of European Microwave Conf.*, pp. 1022-1025, 2007.
- [11] C-L. Mak, H. Wong and K-M. Luk, "High-gain and wide-band single-layer patch antenna for wireless communications," *IEEE Trans. on Vehicular Technology*, vol. 54, issue 1, pp. 33-40, 2005
- [12] A. Munir, Sutinah, and Chairunnisa, "Bandwidth enhancement and size reduction of WLAN patch antenna using metamaterials," *Proc. of 5<sup>th</sup> Indonesia Japan Joint Scientific Symp. (IJSS)*, pp. 329-332, Oct. 2012.
- [13] R.E. Collin, *Antennas and Radiowave Propagation*, Singapore, McGraw-Hill International Ed. 1985

# Lungs Patch Structures: Numerical Computation, Testing and Application

Elyas Palantei and Syafruddin Syarif  
 Telecommunication and Information Engineering  
 Department of Electrical Engineering  
 Faculty of Engineering, Universitas Hasanuddin  
 Makassar, Indonesia  
 E-mail: [elyas\\_palantei@unhas.ac.id](mailto:elyas_palantei@unhas.ac.id) ;  
[syafruddin.s@eng.unhas.ac.id](mailto:syafruddin.s@eng.unhas.ac.id)

Nadhifah Sakka, Andi Asmi Pratiwi, Bayu Topalaguna  
 and Zakiy Ubaid  
 Student Association of Electrical Engineering Department  
 Faculty of Engineering, Hasanuddin University, Makassar,  
 South Sulawesi, Indonesia  
 E-mail: [usil.suka@gmail.com](mailto:usil.suka@gmail.com), [bayu047@gmail.com](mailto:bayu047@gmail.com)

**Abstract**—The constructions of the novel and robust lungs antennas were examined. Several kinds of the lungs patch structure antennas were numerically computed, fabricated and tested. A number of the lungs antenna models were designed to be suitable for large varieties of modern wireless communication applications including mobile computing devices, GPS-SAR, LTE, detection and sensing networks, satellite communications, and other cellular mobile peripherals. In this paper, each designed antenna was evaluated through a certain corresponding resonant frequency, i.e. 1.2 GHz, 1.98 GHz and ISM band 2.4-2.5 GHz. The fabrication step was performed using a simple and straightforward method that commonly applied in printing a PCB. The most advantageous of the constructed antenna lied not only on its robust and unique electrical properties but it also has a compact and reconfigurable physical structure to meet the required technical specifications.

**Keywords**—Lungs patch structure, UAV, GPS-SAR, LTE, and biological inspired antenna

## I. INTRODUCTION

The high availability of such rapid data transfer provided through a microwave transmission media in the modern communication networks has boosted the popularity of wireless technologies access. This may also attract more consistent innovation and intensive development of antenna systems. The antenna has in fact emerged as a vital element on the wireless networking. Most wireless applications require miniaturization or improved performance. Thus, it is required an antenna that has excellent performance, easy installation and inexpensive costs. A patch antenna structure can meet such criteria. It has several advantages such as low profile and low cost of fabrication. Due to the compactness and resistance to extreme environments (ruggedness) its use in other fields such as in aerospace and satellite applications has received much attention. The radiator layer model of the patch antenna structure is commonly in the form of rectangles, squares, circles, ellipses and triangles [1-5].

In this study, the uncommon form of the radiating element, inspired from the actual life environment [4, 6-7], were constructed and examined. The new patch structure is so-called lungs antenna. The antenna models were constructed from the conventional patch forms including four elliptical and some rectangular patches. Benefits of this antenna

radiating layer includes capable of the compact construction and its easy way to be reconfigured to meet certain technical parameters such as return loss ( $S_{11}$ ), patterns, impedance bandwidth, VSWR and axial ratio. In addition, its electrical properties are very sensitive to change due to the alteration of various physical parameters such as the location of the RF input port, the length ( $L$ ) and the width ( $W$ ) of the RF-transmission line and the effective surface area of the radiator (see Figure 1). In construction, these parameters should be set appropriately and accurately in order to obtain the optimal performance.

This paper outlines several current researches and development of lungs antenna prototype intended to be deployed in various wireless communications. There are three areas of concern where the studies are focused. These include, for instance, the GPS-SAR antenna technology onboard an autonomous spacecraft, nanosatellite antenna system for the telemetry application, and LTE technology. However, not all the constructed lungs antennas of these applications will be fully presented and discussed in this paper, but only the designed antennas intended for GPS-SAR and LTE applications that will be extensively evaluated.

## II. ANTENNAS MODELING, TESTING AND EVALUATION

The radiating element of a typical lungs antenna model has been constructed through the addition and subtraction algorithms to the common patch radiating layer including some elliptical and rectangular forms during the numerical computing process using FEM-HFSS Version 13. Several models of lungs radiating element were created to meet a particular wireless application. The experimental evaluations were also performed to all antenna models. The descriptive discussions of the lungs antennas fundamental operation are presented in the following sub-sections.

As described in Figure 1, the lungs shape antenna consists of three layers, i.e. the top lungs shape conducting layer, the dielectric material, and the ground plane. The type of dielectric materials used to construct the antenna systems was the one has  $\epsilon_r$  4.4 (FR4-Epoxy) and the loss tangent 0.021 and the thickness  $h$  1.6 mm. In the construction of a single lungs structure, the ground plane and the dielectric substrate size were flexibly altered to meet a certain resonant frequency. For

exactly the same substrate material type and thickness, FR4-Epoxy (1.6 mm thickness) as for instance, the smaller the size of the ground plane and the dielectric layer tends to produce the higher resonant frequency. This, off course, directly relates to the intended wireless network application. However, the dimension of those lungs antenna elements will significantly increase while the array configuration is set-up. In order to design two lungs patch array from its initial single lungs patch structure the required size of the ground plane and dielectric, respectively, is almost double. The size comparison of the ground plane and dielectric substrate to configure the designed lungs array and its corresponding particular application is tabulated in Table I.

A single lungs patch antenna as depicted in Figures 1, 2 (a) and 2 (c) exploited the excellent advantages of the coaxial edge feeding technique to feed RF-power to the whole lungs alike radiating layer. As clearly visualized in the figures, a copper 50  $\Omega$  SMA connector was soldered exactly in the middle position at one edge side of a double layers PCB material. In the transmit mode, the RF-energy fed from this connector will be transported through the short transmission line of  $L$  length (see Figure 1). The wave power will be equally divided by the passive patch splitter structure [5] of  $W$  width before entering the two identical lungs conducting layers. These top conducting layers perform two functions i.e. transmitting and receiving of RF-wave. However, an opposite RF wave processing is performed as the antenna working in the receive mode.

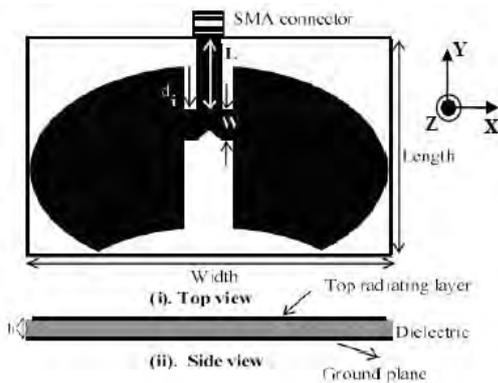


Fig. 1. Lungs shape antenna structure: (i) top view and (ii) side view

TABLE I: DIMENSION COMPARISON OF THE GROUND PLANE AND DIELECTRIC LAYER CONSTRUCTED IN AN ARRAY CONFIGURATION.

Typical Applications	Ground Plane and Dielectric Layer Size	
	Length (mm)	Width (mm)
Antenna array of 2.5 GHz nanosatellite telemetry [4]	93.52	160
Two elements array LTE 1.96 GHz	300	480
Two elements array GPS-SAR 1.2 GHz	280	495

In order to develop the antenna array for a particular application such as for the deployment in GPS-SAR, LTE and nanosatellite systems [4] an extensive optimization procedure

must be performed on the constructed lungs antenna structure to meet certain technical specifications. For instance, to produce the excellent axial ratio ( $AR$ ) 2.3 and 2.29 dB as previously tabulated in Table 2, three methods were applied on constructing the more powerful lungs patch array. First technique is by inserting a passive phase shifter [5] to a feeding line of the lungs linear array (see Figures 2 (b) and 2 (d)). The feeding port was set-up in the parallel configuration [1, 8]. Second technique adopted to achieve the required  $AR$ , the little conducting patch layer of the circle or circular form should be generated during the HFSS optimization process and used to subtract the two identical lungs patch structures. In practical, the size of the circle (or circular) patch form will determine the value of  $AR$  generated. The last technique is to optimize RF-port position along one edge side of the lungs patch structure (see Figure 2 (b)). With having those two axial ratio values it is guaranteed that the lungs antenna may work in the circular polarization property.

The electrical properties as outlined in Table II including  $S_{11}$ , impedance bandwidth,  $VSWR$ , axial ratio ( $AR$ ), beamwidth, and pattern were recorded at the antenna resonant frequency for each particular application. The 3D-patterns of the single element and the two elements of the constructed lungs antennas, both for GPS-SAR and LTE applications are illustratively presented in Figure 3. Based on those figures, it is clearly shown that gain and directivity of the optimized lungs array outperformed the single lungs design.

The reflection coefficient ( $S_{11}$ ) profiles of the constructed GPS-SAR and LTE-BTS antennas, both the simulated and measured  $S_{11}$ , are depicted in Figures 4 (a-b). All the measured  $S_{11}$  were recorded using VNA E5071C. From these figures, it has been shown that the constructed lungs antennas have met the required technical specifications working at certain frequency operation, i.e. 1.2 and 1.98 GHz, respectively. As tabulated in Table II, all the designed lungs antennas whether a single element or two elements array, are capable to generate the impedance bandwidth approximately 40 MHz to more than 100 MHz. While, the impedance matching are quite good where the  $VSWR$  achieved is from 1.05 to 2.

The  $S_{11}$  parameters of the designed GPS-SAR antenna are depicted in Figure 4.(a). Both the simulated and measured  $S_{11}$ , whether single lungs element or two lungs elements array, exhibited very close agreement within the intended operation frequency 1.2 GHz. The simulated single element of the lungs patch structure produces the impedance bandwidth of approximately 50 MHz while the two elements (both simulated and measured ones) exceed 100 MHz. Even though, the designed antenna is classified as the narrowband antenna (less than 8% bandwidth) however to fulfill such practical sensing, recording and transmitting the earth surface image or other environmental parameters (e.g. temperature, humidity, rain intensity and so on) from an UAV (unmanned aerial vehicle) to a ground station this available bandwidth is sufficiently enough.

The broader bandwidth of the designed lungs antennas for LTE-BTS 1.98 GHz application was obtained by configuring the single element of lungs patch structure into two elements array. The improvement of bandwidth achieved is more than 200%. The  $S_{11}$  profiles of the LTE-BTS antenna design is visualized in Figure 4.(b). Conceptually, the constructed antennas, both single element and array, provide the impedance bandwidth of 50 MHz and larger than 220 MHz, respectively. The bandwidth according to the measured  $S_{11}$  is approximately 80 MHz. However, this bandwidth will increase to more than 220 MHz while the 1.8 GHz and 2.2 GHz frequency operations are also considered.

### III. CONCLUSION

Various models of lungs patch antennas have been computed, optimized, manufactured and tested to meet the particular wireless communication applications including GPS-SAR onboard an automobile aircraft, LTE BTS terminal and nanosatellite system. The designed antennas provide the good performance in terms of the electrical properties such as *pattern*, *gain*,  $S_{11}$  and *axial ratio* as the physical parameters of the radiating elements set-up properly to meet certain technical requirements in modern wireless networks. In average, the constructed lungs patch antennas whether it is a single element or two elements array could provide the operation bandwidth from 40 MHz to 100 MHz, approximately. The gain and directivity profiles of lungs antenna configured in the array form are better than the single elements of lungs patch structure.

### ACKNOWLEDGMENT

This research activity is partially funded through the Riset Terapan Grant awarded from Ministry of Research and Technology (MENRISTEK), the Republic of Indonesia under the project of the 2012-2013 financial year. This also partially supported through Mandiri Research Grant funded from DIPA Faculty of Engineering, UNHAS 2012 financial year. The

authors would like to deliver our sincere thank to Mr. Danang Santoso and Mr. Ade Chandra for the generous helps and discussions to develop the previous investigated lungs patch antenna models to meet the intended wireless applications.

### REFERENCES

- [1] C. Balanis, "Antenna Theory: Analysis and Design," 3<sup>rd</sup> Edition, John Wiley & Sons Inc., 2005.
- [2] E. Palantei, D.V.Thiel and S.G. O'Keefe, "Rectangular Patch with Parasitic Folded Dipoles: A Reconfigurable Antenna," *IEEE International Workshop on Antenna Technology (IEEE iWAT) 2008: Small Antennas and Novel Metamaterials*, Chiba, Japan, 4-6 March 2008.
- [3] E. Palantei, R. M.Salehu, A. E. Putra, and A. Achmad, "Printed Microstrip Antennas (MSAs) Suitable for MS and BTS WiMAX Applications," *Proceedings of the 2nd Makassar International Conference on Electrical Engineering and Informatics (MICEEI) 2010*, Makassar Golden Hotel (MGH), Makassar, South Sulawesi, Indonesia, 27-28 October 2010, pp.42-45. On line available [14 February 2013] at [http://www.unhas.ac.id/miceei/miceei2010/ProceedingsMICEEI2010\\_Part\\_One.pdf](http://www.unhas.ac.id/miceei/miceei2010/ProceedingsMICEEI2010_Part_One.pdf)
- [4] E. Palantei, S. Syarif, B. Topalaguna and Z. Ubaid, "Four Elements Array of Lungs Shape Patch Antenna for Nanosatellite Telemetry," accepted for oral presentation on *IEEE International Symposium on Antennas and Propagation and USNC-URSI National Radio Science Meeting*, Hilton Orlando Lake Buena Vista, Lake Buena Vista, Florida, USA July 7-12, 2013.
- [5] E. Palantei, J.T. Sri Sumantyo, and K. Osa, "Rectangular Patches Array Utilized Coaxial Edge Feeding and 90° Phase Shifter for Achieving CP Property," *the SANE2011-IEICE Technical Report* Vol. 111, No. 239, pp.123-126, 2011.
- [6] Marco Briasco, Andrea F. Cattoni, Giacomo Oliveri, Marina Ottonello, Mirco Raffetto, and Carlo S. Regazzoni, "Antenna systems with embodied cognition for next generation wireless communications," *IEEE International Symposium on Antennas and Propagation Society*, 9-15 June 2007, Honolulu, Hawaii, USA, pp.1685-1688.
- [7] Noah J. Cowan, Emily J. Ma, Mark Cutkosky, and Robert J. Full, "A Biologically Inspired Passive Antenna for Steering Control of a Running Robot", *Springer Tracts in Advanced Robotics: Springer Berlin Heidelberg*, Vol.15, 2005, pp.541-550.
- [8] Jorge Sosa-Pedroza, Fabiola Martínez-Zúñiga and Mauro Enciso-Aguilar, "Planar Antennas For Satellite Communications," on line available [21 March 2013] at [www.intechopen.com](http://www.intechopen.com)

TABLE II: ELECTRICAL PROPERTIES OF THREE DIFFERENT LUNGS PATCH ANTENNA MODELS AND THE POTENTIAL APPLICATIONS.

Electrical Properties	Nanosatellite Application		GPS-SAR Application		LTE System	
	Number of Lungs Patch Element		Number of Lungs Patch Element		Number of Lungs Patch Element	
	Single	Two Elements	Single	Two Elements	Single	Two Elements
Reflection coefficient (dB)	- 14.36 (simulated)/ - 21.99 (measured)	-22.99 (simulated)/ -12.52 (measured)	-32.23 (simulated)/ -12.141 (measured)	-17.969 (simulated)/ -12.032 (measured)	-27.96 (simulated)/ -1.64 (measured)	-10.96 (simulated)/ -11.355 (measured)
Impedance bandwidth (MHz)	50 (simulated)/ 50 (measured)	53 (simulated)/ 53 (measured)	50 (simulated)/ 50 (measured)	>100 (simulated) >100(measured)	50 (simulated)/ 50 (measured)	>220 (simulated) / >220 (measured)
VSWR	< 2 (simulated)/ 1.17 (measured)	1.15 (simulated)/ 1.6 (measured)	1.05 simulated)/ 1.85 (measured)	1.29 (simulated) /1.69 (measured)	< 2 (simulated)/ 1.74 (measured)	1.86 (simulated)/ 1.721 (measured)
Axial Ratio (dB)	-	7.2 (simulated)	-	2.3 (simulated)	-	2.29 (simulated)
Beamwidth (°)	Approx. 120 (simulated)/ Approx. 80 (measured)	Approx. 70 (simulated)/ Approx. 80 (measured)	Approx. 90 (simulated)/ NA	Approx. 45 (simulated)/ NA	Approx. 55 (simulated)/ NA	Approx. 25 (simulated)/ NA
FTBR (dB)	Approx. 15 (simulated)/ Approx. 15 (measured)	Approx. 14 (simulated)/ Approx. 5 (measured)	Approx. 7 (simulated)/ NA	Approx. 10 (simulated)/ NA	Approx. 12 (simulated)/ NA	Approx. 14 (simulated)/ NA

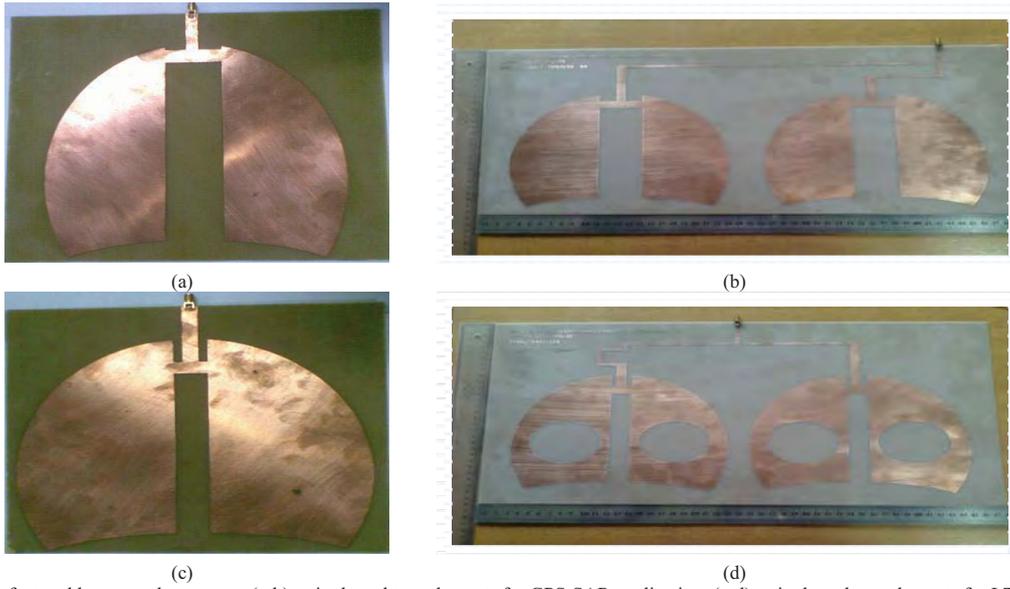


Fig. 2. The manufactured lungs patch antennas: (a-b) a single and two elements for GPS-SAR application; (c-d) a single and two elements for LTE application.

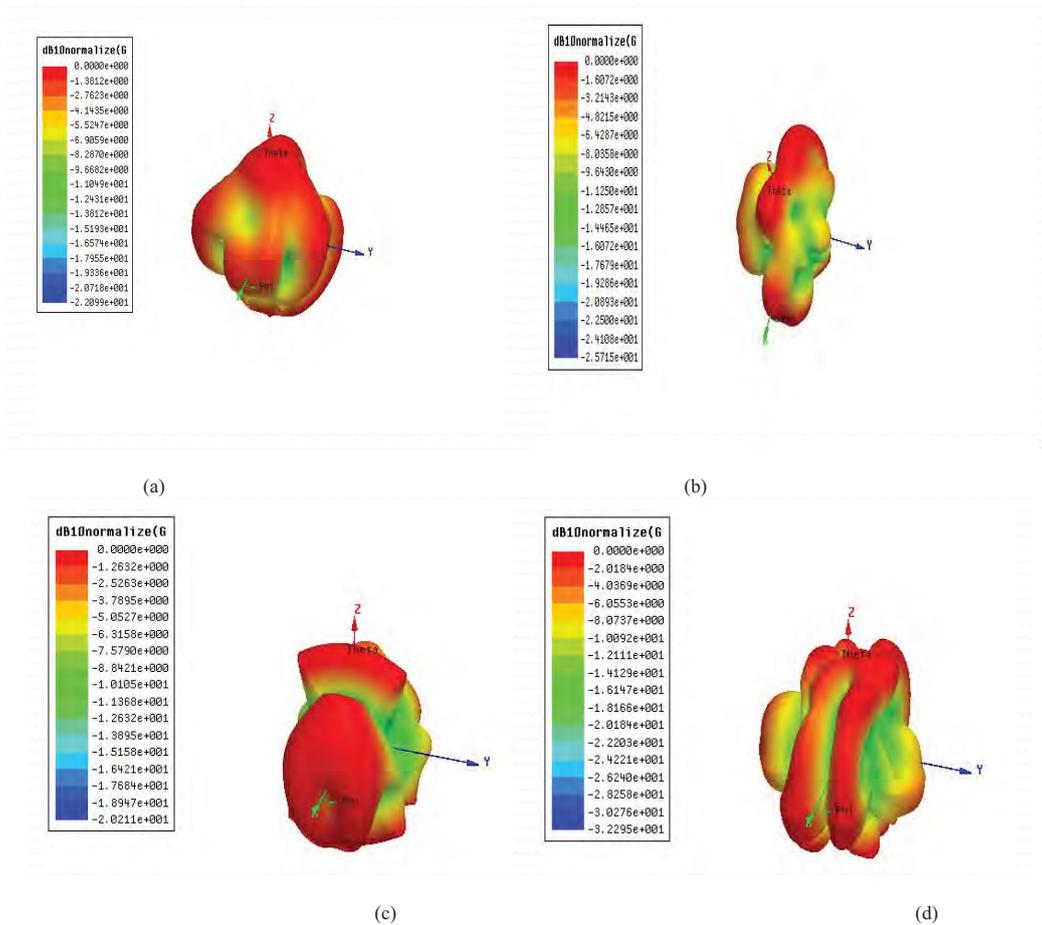


Fig.3. The 3D-patterns of the constructed lungs antennas: (a) a single lungs GPS-SAR antenna, (b) two elements array of lungs GPS-SAR antenna, (c) a single lungs LTE antenna, and (d) two elements array of lungs LTE antenna.

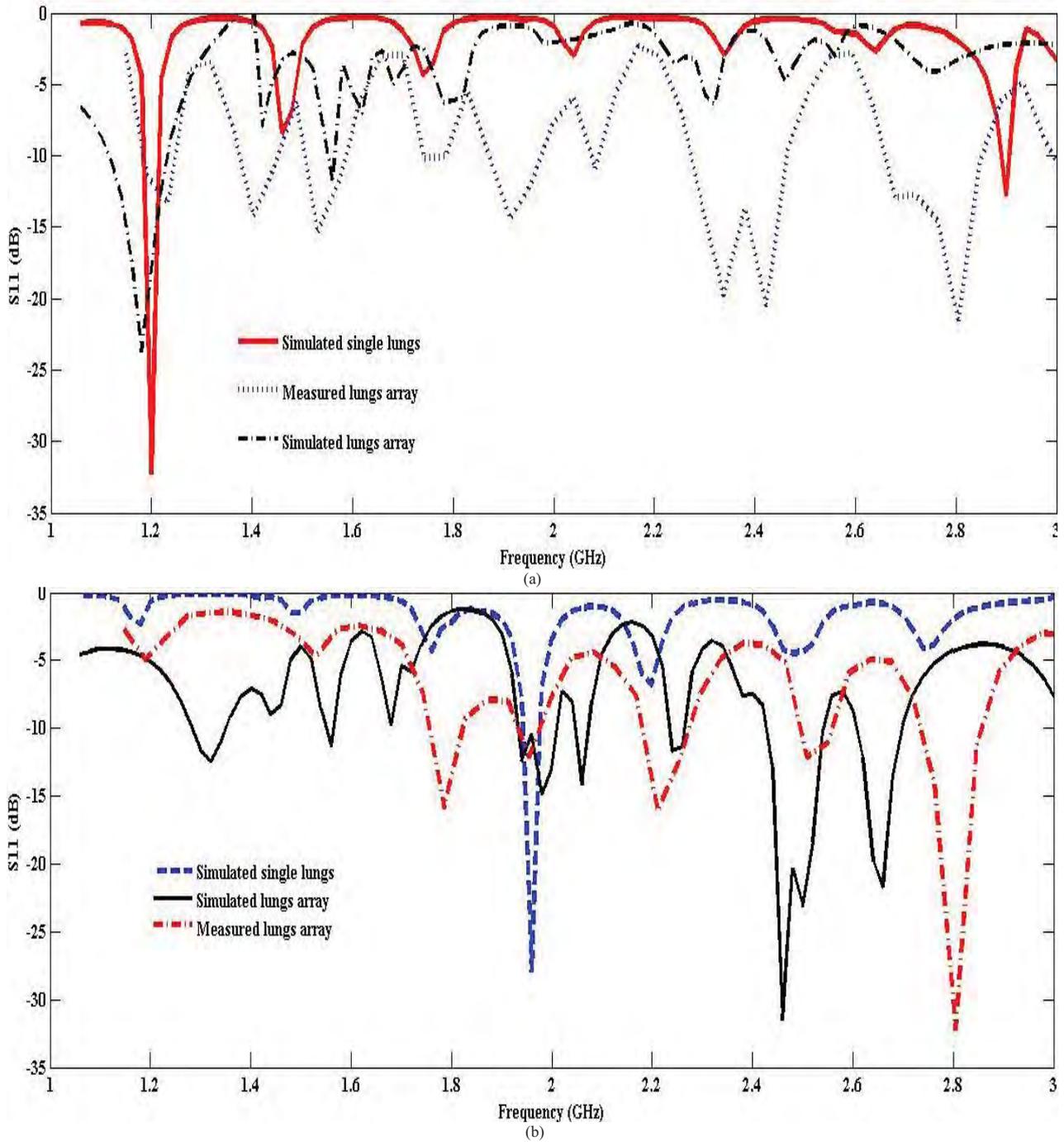


Fig.4. The reflection coefficient of the designed lungs antennas: (a) a GPS-SAR antenna 1.2 GHz, (b) a lungs LTE-BTS antenna 1.98 GHz.

# A Comparison of the Merits of Nuclear and Geothermal Energy in Indonesia

Phil Smith  
 Managing Director  
 Hoshin, Data Hoshin, Studio Hoshin  
 Manchester, UK

Consultant Director  
 PT Multi-Interdana  
 Jakarta, Indonesia

Visiting Scholar, VEPR  
 Vietnam National University  
 Hanoi, Vietnam  
 phil@hoshin.co.uk

**Abstract**—This paper considers the relative merits of nuclear to geothermal power, largely from an economic perspective, but also with references to environmental, social and political issues. Both nuclear and geothermal have the potential to produce large amounts of base electricity, necessitating well-developed grids. Both have very low operation and maintenance costs. But both have very high capital costs, and therefore interest rates have a major impact on their financial viability.

The current feed-in tariffs appear to suggest that investing in either is now attractive, but that the tariffs are so high they are likely to increase the cost of electricity (as they are significantly higher than domestic supply and most industrial tariffs). Although over the long term Indonesia may need to invest in both nuclear and geothermal, to meet its increasing demand for electricity, the model suggests that Indonesia should first focus on its geothermal resources.

Nevertheless, local opposition to nuclear probably means that geothermal will take precedence, for political rather than economic reasons. Long-term international investment in nuclear and geothermal will require the generous published feed-in tariffs to remain in force, as Indonesian public finances would be stretched to internally fund all of the necessary development.

The remoteness and limited electricity network development in much of eastern Indonesia means that despite generous feed-in tariffs, development of large scale generation schemes will be limited to those initiated by Government, curtailing the community and economic development of some of Indonesia's most deprived communities.

**Keywords**—Nuclear Energy, Geothermal Power; Indonesia; International Investors; Market Regulation

## I. INTRODUCTION

The National Electricity Development Plan [1] forecasts that by 2027 electricity demand will be 813,000GWh, with increases of 7-9% per annum. It also outlines plans for an additional 217GW of capacity; meaning that Indonesia needs to invest \$4-\$5bn per annum in generation plant and transmission infrastructure. Indonesia must diversify its energy sources [2] to avoid the ecological impact of investment in coal fired power stations and to avoid a trade debt crisis from imported oil and gas.

Indonesia has the largest geothermal energy capacity in the world (around 38% of the global resource), and therefore, this would appear to be an ideal option for Indonesia's diversification. 265 geothermal fields have been surveyed; although some are not close enough to electricity grids to be economical (nearly half of the capacity is located in remote areas of Sumatra). There is a plan to develop 19% of the

country's most suitable capacity, so that nearly 6GW will be available; and then to increase this to 9.5GW by 2025.

Pertamina, PLN and private sector investors have been identified for large scale development in Bali, Java, Sulawesi and Sumatra (Bali, and Java share a grid, which connects to the Sumatra grid). The Government and PLN will take a lead in other regions, where small scale development is planned [3]. However, even these plans look unambitious when compared with the Philippines where 27% of total energy is derived from geothermal [4].

\$12bn of investment is required to achieve the initial 6GW of geothermal generation, or \$30bn for the full 9.5GW, of which it is anticipated that 70%-80% will come from the private sector. The World Bank has pledged a \$300mn loan, with the potential for more from its Clean Technology Fund.

For private investors, the tender process is currently that the Government, or Local Government (as it is now their responsibility), conduct a preliminary survey and initial exploration activities to define the field. Private companies then conduct advanced exploration, a feasibility study, followed by exploitation and steam production activities. The private company that conducts the advanced exploration is expected to then supply the electricity. In the past, the company producing the steam and the company producing the electricity were different, creating commercial conflict and production co-ordination issues [5]. However, recent legislation makes it mandatory for them to be the same company. Nevertheless, the commercial reality is that exploration companies may not develop a field that others would wish to exploit, meaning that the exploration company and producer are not necessarily the same.

In 2012 the feed-in tariff for geothermal was increased to between \$0.10 and \$0.185 [6], depending on the voltage and location. These both reflect the difficulty in developing large scale infrastructure in eastern Indonesia and its shortages of electricity, especially low cost non-diesel generated electricity.

A possible alternative to geothermal would be to develop nuclear energy. Like geothermal it supplies base power, produces large quantities of electricity (far greater than the average geothermal field) and therefore requires high levels of capital investment. Both really require well-developed grid systems and are ill-suited to small scale development, meaning that Java, Sumatra and Bali are the most obvious areas for their development.

Indonesia began its nuclear activities in 1954 and had its first test reactor in 1965. It now has test reactors in Bandung,

Pasar Jumat and Serpong south of Jakarta, and Yogyakarta [7] Indonesia also has a cadre of nuclear professionals and technicians and well developed programmes for training nuclear professionals [8]. Although Permana [9] argues that these professionals may be poached by neighbouring countries such as Malaysia, Singapore, Thailand and Vietnam. Potential sites for civilian reactors to generate electricity include:

- Muria in Jawa Tengah;
- Kramatwatu-Bojonegara in Banten;
- Bangka in Bangka-Beitung;
- Banjarmasin in Kalimantan Barat (largely in response to a proposal to develop a reactor in neighboring Sarawak, Malaysia).

At this stage two 1,000MWe reactors are proposed for each site. Of these, the least contentious and therefore, the most likely to be built, is Bangka, although the entire program has been thrown into some doubt following the disaster in Fukushima, Japan. Feasibility studies will need to be finished on all sites, which are between 3 and 7 years before completion.

## II. METHODOLOGY

In order to compare the relative economic merits I have constructed a discounted internal rate of return model, similar to those that international investors would use when considering investing in large capital projects. For the model, cost and revenue data has been taken from a variety of sources. For nuclear these include:

- Energy Fair, [10];
- International Energy Agency, Nuclear Energy Agency and Organization for Economic Co-operation and Development, [11];
- World Nuclear Association, [12].

These have been used because they seem to be a little more independent than some sources. The costs of nuclear production is a highly contentious area, vendors claim exceptionally low costs and the vociferous anti-lobby claim much higher lifetime costs, when all issues are considered. The great variability in the costs identified in the various studies, is a part of the reason for this; with importance of the learning curve and economies of scale in nuclear energy developments.

The First of Kind (FOAKE) costs of developing and building a reactor are always high and known for substantive cost overruns [13]. In addition, early nuclear programs never run at anything like capacity with scheduling and transmission being constant problems for these programs. Nevertheless, China and Korea are showing that, the large scale development of a single reactor technology can dramatically reduce the levelized cost of electricity (LCOE).

For geothermal the cost data is less contested (although the learning curve and economies of scale are still important); sources include:

- Engineering and Consulting Firms Association, [14];
- Geotherm Ex Inc., [15];
- PT Castlerock Consulting, [16] [17];
- Sanyal, [18];
- Sanyal, et al. [19];
- SKM, [20];
- Smith, [21].

The main assumptions are analyzed in a spreadsheet model, these are:

TABLE I. COST ASSUMPTIONS USED IN SPREADSHEET MODEL (\$MN.)

<i>Nuclear</i>	<i>Costs Low</i>			<i>Costs High</i>		
	<i>1000e</i>	<i>1400e</i>	<i>2000e</i>	<i>1000e</i>	<i>1400e</i>	<i>2000e</i>
Capital Costs	1,000	1,400	2,000	4,000	5,600	8,000
Annual Operating Costs	29	40	57	40	56	80
Decommissioning Costs	52	73	104	400	560	800
<i>Geothermal</i>	<i>Costs Low</i>			<i>Costs High</i>		
	<i>20</i>	<i>50</i>	<i>100</i>	<i>20</i>	<i>50</i>	<i>100</i>
Capital Costs	43	61	111	74	102	146
Annual Operating Costs	0.4	1.0	2.0	0.6	1.5	3.0
Decommissioning Costs	0	0	0	0	0	0

Nuclear overnight costs (or capital costs) are generally expressed in \$/kWh (which is another source of cost variability as plants rarely run at full capacity), meaning that there is no apparent reduction for larger reactors. This is because the effects of the learning curve are more important than economies of scale. Although economies of scale do exist; lacking evidence of what this discount should be, I have had to apply a standard rate.

Geothermal fields and plant have a lifespan of around 25 to 30 years that I have applied to the high cost (25 years) and low cost model (30 years) respectively. Third plus generation nuclear plants are double these at 50 to 60 years. As this is a discounted internal rate of return model I have included discount rates of 12.5%. However, nuclear reactors often come with cheap or interest free loans from the vendor countries (as is the case for the Russia reactors proposed in Vietnam [22]). For income I have used the \$0.10 and \$0.185 per kWh, the current tariffs for geothermal, for both geothermal and nuclear development.

The low and high costs form the parameters for the model, along with low and high revenues. I then look at average costs, which of course over-simplifies the myriad of permutations which exist in the real world. The actual costs of developments will depend on many things, including the network availability and capacity, current energy mix and availability, the geography and geology of the site and the

profile of the demand. A detailed feasibility study is required to assess individual investments in either nuclear, or geothermal. This paper only attempts to provide a comparison of these two technologies for the purpose of supporting Indonesia's energy policy and decision making within the context of the policy.

### III. RESULTS

Given the \$/kWh standard costs for nuclear; it is difficult to directly compare costs and returns to geothermal plants of differing capacity. However, all permutations make a profit and therefore have a positive rate of internal return (see line labeled Discounted IRR in Table II). As this is a discounted model, the cost of capital has already been factored in, so any positive return represents a real profit. Nevertheless, my model suggests that geothermal appears to produce a higher rate of internal return than nuclear. Although of course, in some actual situations, a detailed feasibility may contradict this finding.

TABLE II. MODEL COSTS, REVENUE AND INTERNAL RATE OF RETURN (\$MN.)

Nuclear	Costs Low/Revenue High			Costs High/Revenue Low			
	MW	1000e	1400e	2000e	1000e	1400e	2000e
Capital		1,000	1,400	2,000	4,000	5,600	8,000
Interest		8,250	11,550	16,500	28,000	39,200	56,000
Operations and Maintenance		1,720	2,408	3,440	2,000	2,800	4,000
Decommissioning		52	73	104	400	560	800
Total Costs		10,022	14,031	20,044	30,400	42,560	60,800
Revenue		82,651	115,711	165,301	30,660	42,924	61,320
Discounted IRR		12.08	12.08	12.08	0.02	0.02	0.02
Geothermal	Costs Low/Revenue High			Costs High/Revenue Low			
	MW	20	50	100	20	50	100
Capital		43	61	111	74	102	146
Interest		188	266	485	278	383	548
Operations and Maintenance		12	30	60	15	38	75
Decommissioning		0	0	0	0	0	0
Total Costs		200	296	545	293	420	623
Revenue		788	1,969	3,938	355	887	1,971
Discounted IRR		9.82	18.82	20.75	0.85	4.45	8.67

Table II shows great variability in potential costs and revenues; therefore, we cannot be clear about much, in such a broad and simplified model. What is perhaps more important is the average costs and average revenue model in Table III.

The model shows that for all sizes of power plant geothermal produce a greater return than nuclear (see line

labeled Discounted IRR in Table III). In other words Indonesia should focus first on developing its geothermal resource before it's nuclear. Although over the long term it may need to invest in both (certainly in Java and Bali achieving a balance of sources is important in offsetting fluctuations in the relative costs of different generation technologies), but as much as possible, geothermal should be developed prior to nuclear.

The average cost model (in Table III) also makes clearer the likely attitude of international investors. It would appear to suggest that investors may be interested in building nuclear and geothermal plants in return for future revenues; although this may not really help to solve the electricity shortages in eastern Indonesia, where geothermal fields tend to be much smaller [23], offering lower returns (see line labeled Discounted IRR in Table III), populations are dispersed and grids are less developed.

TABLE III. MODEL COSTS, REVENUE AND INTERNAL RATE OF RETURN (\$MN.)

Average Costs and Revenue	Nuclear			Geothermal			
	MW	1000e	1400e	2000e	20	50	100
Capital		2,500	3,500	5,000	58	81	128
Interest		22,400	31,360	44,800	229	319	503
Operations and Maintenance		1,860	2,604	3,720	14	34	68
Decommissioning		226	316	452	0	0	0
Total Costs		24,486	34,280	48,972	243	353	571
Revenue		56,655	79,317	113,311	571	1,428	2,955
Discounted IRR		2.27	2.27	2.27	4.84	10.88	14.91

### IV. DISCUSSION

The model results show that both nuclear and geothermal have the potential to produce large amounts of base electricity. Both have very low operation and maintenance costs, largely because neither consumes large quantities of fuel (unlike for example coal, oil and gas fired power stations). Nevertheless, both have very high capital costs, and therefore the cost of capital, or appropriate discount rate, has a major impact on their financial viability.

Prices for uranium are forecast to increase due to limited supply and increasing demand, however, Indonesia's own resources are sufficient to supply all of its needs [24]. Even if it does need to import uranium and costs rise drastically, nuclear plants use so little that this would hardly place an impact on overall costs. The issue of energy security is probably more significant, which includes which countries' technology Indonesia will use and therefore which country it will be dependent on. This is true to a lesser extent for geothermal, with drilling and exploration being quite specialized and normally conducted by international oil and gas companies.

It could be argued that the most important economic consideration is that of the financial risk and who mitigates them? The massive variations in the internal rates of return between the low cost/high return and high costs/low return models point to the high level of risk of any endeavor for either the Indonesian Government, or international investors, in developing either nuclear, or geothermal, in Indonesia. There are a number of geological and technical factors which feed into this, but the model shows that discount rate (or capital cost) is the most important element of this (see line labeled interest in Tables II and III).

Chevron already has a program of geothermal development in Indonesia and Tata have expressed interest; this proves that international investors are prepared to invest in geothermal exploration and production. For nuclear, it is normal for the host country to bear a much higher proportion of the risk involved. Indeed, Indonesia, in common with many countries, wants to retain some control over its nuclear program. The escalating costs of nuclear mean that, even with access to cheap capital, Indonesia would be taking on a major financial risk, potentially impacting on future economic stability. Indeed a consortium of the German companies (E.ON and RWE) have recently pulled out of building three reactors in the UK [25], following escalating costs [26].

A major uncertainty for nuclear, is the cost of decommissioning [27]. In my model I have assumed fairly high costs for decommissioning (see line labeled decommissioning in Tables I, II and III), notwithstanding the fact that there still is no adequate technical solution for disposal of high level radioactive waste. It is likely that the countries supplying the technology will bear some of this risk, but it remains a major area of uncertainty [28]. For geothermal whilst there are some decommissioning costs, these are normally less than the scrap value of the plant.

There is the contested issue of safety, particularly in area with high seismic activity, which the recent disaster at Fukushima, in Japan, highlights. However, nuclear power has a strong safety record compared with many industries [29]. In addition, the third plus generation reactors, that are likely to be built in Indonesia, incorporate a number of safety features. Nevertheless, Alan Marshall [30], possibly xenophobically, casts doubt on Indonesia's ability to manage and maintain such potentially dangerous technology (contrary to the opinion of the International Atomic Energy Agency).

Both nuclear and geothermal are believed to have a small environmental impact (ignoring the issues of high grade radioactive waste), with their main environmental impact being in their construction and decommissioning. For large nuclear reactors the environmental impact of their construction and the transport of materials for their construction are huge. But then this is offset by the fact that nuclear reactors produce a large amount of clean electricity! Both nuclear and geothermal plants tend to be located in remote and often environmentally sensitive locations, requiring full AMDALs as a part of their feasibility stage. Again their construction and decommissioning is the main issue here, particularly in terms of disturbing the habitat of endangered plants and animals.

Within Indonesia there is a very vocal anti-nuclear lobby; which has not only protested against nuclear power, but also called for a resistance movement. For example, Nahdlatul Ulama declared a fatwa on nuclear power which they have found to be haram (Hindu groups in Bali have a similar objection to geothermal)! Undoubtedly, the powerful coal industry will support and possibly promote such dissent. Whilst this opposition may not derail Indonesia's nuclear program, it will certainly lead to further delays and favor geothermal development.

It could be argued that, there are too many uncertainties to reliably construct a comparison of nuclear to geothermal. Nevertheless, a simple comparison of the issues that I have identified (see Table IV) would appear to suggest that geothermal should be developed prior to the nuclear program. So whilst both are relatively cheap, my model suggests that geothermal is cheaper than nuclear, hence I have rated geothermal '++' and nuclear slightly less positively is rated at '+'. It is a similar position for energy security, with nuclear relying on overseas vendor technology and comes with greater financial risk, reflecting the greater uncertainties that come with it. In part, these uncertainties are due to the unknown decommissioning technologies and costs for nuclear (proving an assessment of '-'). Neither nuclear, nor geothermal have a major environmental impact, although by their nature do occupy a lot of land, often in environmentally sensitive areas. Perhaps, the most significant obstacle to nuclear is the anti-nuclear lobby in Indonesia, meaning that further geothermal development will occur long before any nuclear development.

TABLE IV. COMPARISON OF NUCLEAR TO GEOTHERMAL

	<i>Nuclear</i>	<i>Geothermal</i>
Cost per kWh	+	++
Energy Security	+	++
Reduced Financial Risk to Indonesia	+	++
Decommissioning and Safety	-	++
Environmental Impact	+	+
Internal Opposition	-	+

## V. CASE STUDIES

Neighboring France and Germany provide an interesting comparison in terms of their overall energy policies and commitments to nuclear power.

Concerned about energy security France has a long-standing commitment to nuclear power, indeed, France generates over three-quarters of its electricity from 58 nuclear reactors [31]. In addition, France is the world's largest net exporter of electricity due to the very low cost of generation (arising from the economies of scale and effects of the learning curve from investing in so many nuclear power plants). Whilst electricity is not as deregulated as in other EU countries, French consumers and industry do enjoy comparatively low prices. France also exports nuclear technology and fuel products. Geothermal heating systems and heat pumps are widely used in France and there are three geothermal fields in operation in France's overseas territories. However, geothermal development for electricity production has really not been exploited in France; given the strong policy steer towards nuclear and only recently have

exploration licenses been granted to exploit its significant potential.

Germany is home to a significant green lobby including a number of Alliance 90/Green Party politicians. Public sentiment was severely tested by the Fukushima disaster, resulting in a commitment to close all of Germany's nuclear power plants by 2020. Currently four-fifths of Germany's electricity comes from fossil fuels and nuclear, the Federal Government plans that within 40 years four-fifths will come from renewables [32]. Geothermal is being actively promoted within these renewables, but is currently very under-developed. Electricity prices are rising sharply to underpin this investment in new generation and transmission systems (smart grids) and consumption per capita is forecast to decline. The Federal Government believes that this will put Germany at the forefront of renewable technology, opening opportunities in major export markets and offsetting the decline of high energy consuming industries, such as chemicals. In addition, by reducing the reliance on imported fossil fuels, Germany will achieve greater energy security.

Despite very different strategies, both France and Germany show a high level of concern for energy security and are using energy policy to support industrial policy. As Indonesia matures, it will also need to consider energy much more strategically; with decisions over nuclear and geothermal taken on more than just cost.

## VI. CONCLUSION

International investment in nuclear and geothermal will require the generous published feed-in tariffs to remain in place, which almost certainly means increasing the price of electricity.

The main vendors that are likely to be considered for nuclear include those from Russia, Japan and Korea. Other potential vendor countries include the US and France, both of which are likely to charge far more for their technology than Russia, or Korea; although India may also enter the market with highly competitive reactors. Over the long term the learning curve and economies of scale would suggest that Indonesia should choose a particular reactor technology and stick with it, but which should it be?

The major vendors of geothermal drilling and production facilities are in the US, Australia and Germany; although Tata, of India, is also actively exploring opportunities in Indonesia. Whilst strong economies of scale exist, these are not really tied to the technology so it would be possible to use a number of vendors. Nevertheless, the issue on choice of vendor country for both nuclear and geothermal is as much an issue of international politics as it is economic! But perhaps the greatest issue Indonesia faces is internal opposition to nuclear; therefore, it is more likely that internal politics will dominate investment decisions, more so than the relative merits of the various technologies available for base electricity generation.

Finally, despite the generous feed-in tariffs, especially for eastern Indonesia, it is unlikely the much development will occur for domestic consumption, other than those initiated by Government, as a result of the difficulties and uncertainties

identified. This is an opportunity missed as I have previously argued [33] that providing electricity to the remote areas of eastern Indonesia would provide a significant boost to community and economic development.

## References

- [1] Ministry of Energy and Mineral Resources, The national electricity general plan (RUKN) 2008 —2027. Jakarta, Ministry of Energy and Mineral Resources, 2008.
- [2] International Energy Agency, Energy policy review of Indonesia. Paris, International Energy Agency, 2008.
- [3] Ministry of Energy and Mineral Resources, Master plan development of electricity 2010 -2014. Jakarta, Ministry of Energy and Mineral Resources, 2009.
- [4] de Wilde, A. Accelerating geothermal development in Indonesia 2009. (<http://cdm.unfccc.int/filestorage/N/X/E/NXEWSM4DTZVUQ6I91OC3058JP2KBLF/Enclosure%203.pdf?t=bEZ8bHg4YWU2fDBEAx4pApO6FmeANLHG44qX> (accessed 3/1/12).
- [5] de Wilde, A. Accelerating geothermal development in Indonesia 2009. (<http://cdm.unfccc.int/filestorage/N/X/E/NXEWSM4DTZVUQ6I91OC3058JP2KBLF/Enclosure%203.pdf?t=bEZ8bHg4YWU2fDBEAx4pApO6FmeANLHG44qX> (accessed 3/1/12).
- [6] Ministry of Energy and Mineral Resource, Regulation of the No. 22 of 2012 (Reg. 22/2012), Jakarta, Ministry of Energy and Mineral Resource, 2112.
- [7] International Atomic Energy Association (IAEA), Country report: Indonesia. Vienna, IAEA, 2011.
- [8] International Atomic Energy Association (IAEA), Country report: Indonesia. Vienna, IAEA, 2011.
- [9] Permana, S. Research and development of nuclear science and technology in preparing the nuclear industry in Indonesia. *Journal of Sustainable Energy and Environment*, vol. 3, 2012, pp. 67-72.
- [10] Energy Fair, The financial risks of investing in new nuclear power plants, Anglesey, UK, Energy Fair, 2012.
- [11] International Energy Agency, Nuclear Energy Agency and Organisation for Economic Co-operation and Development, projected costs of generating electricity. Paris, OECD, 2010.
- [12] World Nuclear Association, The new economics of nuclear power, London, World Nuclear Association, 2005.
- [13] Energy Fair, The financial risks of investing in new nuclear power plants, Anglesey, UK, Energy Fair, 2012.
- [14] Engineering and Consulting Firms Association, Pre-feasibility study for geothermal power development projects in scattered islands of east Indonesia. Tokyo, Engineering and Consulting Firms Association, 2008.
- [15] GeothermEx, Inc. An assessment of geothermal resource risks in Indonesia. Richmond, CA, GeothermEx, Inc., 2010.
- [16] PT Castlerock Consulting, Ministry of Energy and Mineral Resources Phase 1 report: review and analysis of prevailing geothermal policies, regulations and costs. Jakarta, PT Castlerock Consulting, 2010.
- [17] PT Castlerock Consulting, Ministry of Energy and Mineral Resources Phase 2 Report: The new geothermal policy framework (draft). Jakarta, PT Castlerock Consulting, 2011.
- [18] Sanyal, S. Cost of geothermal power and factors that affect it. Stanford University, Proceedings of the Twenty-Ninth Workshop on Geothermal Reservoir Engineering, 2004.
- [19] Sanyal, S., Morrow, J., Butler, J. and Robertson-Tait, A. Cost of electricity from enhanced geothermal systems, Stanford University, Proceedings of the Thirty-Second Workshop on Geothermal Reservoir, 2007.
- [20] SKM, Assessment of the current costs of geothermal power generation in New Zealand (2007 basis). Auckland, Sinclair Knight Merz, 2009.

- [21] Smith, P. The Potential for investment in Indonesia's geothermal resource, *International Journal of Engineering and Technology*. April 3, 2012.
- [22] Smith, P. Renewable energy options for Vietnam: an economic and social appraisal, *Proceedings of the Forth International Conference on Vietnamese Studies*, 26-28, November. Hanoi, Vietnam Academy of Social Science, 2012.
- [23] Engineering and Consulting Firms Association, *Pre-feasibility study for geothermal power development projects in scattered islands of east Indonesia*. Tokyo, Engineering and Consulting Firms Association, 2008.
- [24] Permana, S. Research and development of nuclear science and technology in preparing the nuclear industry in Indonesia. *Journal of Sustainable Energy and Environment*, vol. 3, 2012, pp. 67-72.
- [25] <http://www.bbc.co.uk/news/world-17546420> (accessed 29/3/12).
- [26] Energy Fair, *The financial risks of investing in new nuclear power plants*, Anglesey, UK, Energy Fair, 2012.
- [27] Nuttall, W. and Roques, F. *Certain aspects of the sustainability of nuclear power*. CESSA Working Paper. University of Cambridge, 2008.
- [28] Marshall, A. The case against nuclear power development in Indonesia. *Journal of Geography and Regional Planning*, vol. 5, issue. 1, 2012, pp. 1-5.
- [29] Asia Pacific Energy Research Centre, *Nuclear power generation in the APEC region*. Tokyo, Asia Pacific Energy Research Centre, 2004.
- [30] Marshall, A. The case against nuclear power development in Indonesia, *Journal of Geography and Regional Planning*, vol. 5, issue. 1, 2012, pp. 1-5.
- [31] International Energy Agency, *Energy policy of IEA countries: France*. Paris, International Energy Agency, 2009.
- [32] Federal Ministry of Economics and Technology, *Germany's new energy policy: heading towards 2050 with secure, affordable and environmentally sound energy*, Berlin, Federal Ministry of Economics and Technology, 2012.
- [33] Smith, P. Sustainable development options for Papua? *International Journal of Technology*, vol. 2, issue. 2, 2011, pp. 171-178.

# New Approach on Renewable Energy Solar Power Prediction in Indonesia based on Artificial Neural Network Technique: Southern Region of Sulawesi Island Study Case

Andhika Prastawa

Center for Energy Conversion and Conservation Technology  
 Agency for the Assessment and Application of Technology  
 Jakarta, DKI Jakarta, Indonesia  
[andhika.prastawa@bppt.go.id](mailto:andhika.prastawa@bppt.go.id)

Rinaldy Dalimi

Department of Electrical Engineering, Faculty of Engineering  
 University of Indonesia  
 Depok, West Java, Indonesia

**Abstract**— Indonesia located at  $94^{\circ}$  -  $141^{\circ}$ E and  $6^{\circ}$ N -  $11^{\circ}$ S is the largest archipelago in the equator on earth. As a tropical country, Indonesia is endowed with abundant solar energy potential. This study is focused on modeling the Global Solar Radiation using Artificial Neural Network to predict GSR in a location which is available with meteorological data but lack with radiation measurement data. A case study on 5 locations in South Western region of Sulawesi was used to develop the model. The ANN model used 4 location with 5 years monthly meteorological and radiation data for training, and one location for testing. The simulation shows that an ANN with 4 layers and 5 neurons is the most appropriate model with an MSE of 0.003 and  $r$  of 0.99937. The model provides an excellent performance of prediction of with an MPE of 0.1427% and  $r^2$  of 0.999967. The predicted radiation data is in reasonable agreement with the actual data at the testing location; this shows the ability of ANN technique in generalization of data unavailability and produces an accurate prediction

**Keywords**— Global Solar Radiation, Artificial Neural Network, Feed Forward, Back Propagation, Mean Square Error, Renewable Energy

## I. Introduction

Sufficient sustainable energy supply is one of key ingredient for national economic growth. Indonesia is currently facing some major challenges in fulfilling its energy needs, including the limited number of conventional fossil fuel energy resources, and the international demand for lowering the energy related greenhouse gasses emission. In this concern, renewable energy utilization is becoming a strategic alternative for energy source, particularly solar energy as this is available almost everywhere in any part of the nation, and free from greenhouse gasses emission.

During the planning process of solar energy conversion system, accurate information regarding the energy availability is critical for a fine design of the system. Good and reliable global radiation data is essential for an appropriate design of various solar power system designs including for, PV module and energy storage sizing for stand-alone solar power, as well as estimating energy yield and PV system performance for solar PV on-grid type. Ideally, the global radiation data should be obtained by direct local measurement; however, in

Indonesia it is rare if not difficult to have extensive data of global solar radiation measurement. Estimating the global solar radiation using prediction techniques could help as an alternative to provide global solar radiation data.

Indonesia is located at the equator, and the largest archipelagic nation in the world. It has various energy resources, but as a tropical country Indonesia is blessed with abundant amount of solar energy potential. Provided with 4.5 kWh/m<sup>2</sup>/day of average solar energy potential, this energy resource is a strategic option for supplying energy not only for its abundance, and environmental friendly type of energy, but also for its flexibility for supplying electricity particularly for remote, and isolated area. This would significantly help the National Program of Electrification.

The solar energy potential in Indonesia is not distributed evenly around the country. This is shown in the following Fig.1. [1] which graphs a processed measurement data from 18 location in Sumatra, Java, Nusa Tenggara Timur, Nusa Tenggara Barat. Eastern part of Indonesia, represented by measurement in Sumatra and Java is shown with lower value compare to eastern part measurement represented by Nusa Tenggara area measurement. Eastern part of Indonesia has an average of 5.1 kWh/m<sup>2</sup>/day as to compare with 4.6 kWh/m<sup>2</sup>/day of western part solar energy potential.

There are various methods in estimating the global solar radiation, in which some empirical methods have been developed by some researchers. Prescott [2] estimates the global solar radiation based on the ration between earth surface and extraterrestrial solar radiation, while Glover and McCulloch [3] introduce the use of geographical position to refine the estimation. Gophinatan [4] developed estimation formula that also includes the elevation of a location. Hargreeves et.al [5] formulated a simple estimation of global solar radiation which includes the local temperature factor. A formulation that takes into account the cloud covering was developed by Supit and Van Kappel [6].

Despite its wide use, the empirical model has not met the desirable accuracy required from a reliable prediction model. It does not wholly capture nonlinear characteristics exhibited by weather parameter.

Based on this concern, several authors have attempted to develop solar radiation prediction model based on the Artificial Neural Network (ANN) technique. S.M. Al-Alawi et.al [7], and Mohandes et.al [8] used the ANN to predict monthly solar radiation based on geographic parameter and solar hour data. Other ANN based prediction model developed by Reddy et.al [9], and Krishnaiah et.al. [10] used more weather parameter in their model. The difference between the two models is in the number of data, and the ANN structure. From both model it is shown that the use of larger number of data, and more number of layer in the ANN structure, as exhibited in Krishnaiah work, would provide better result in prediction.

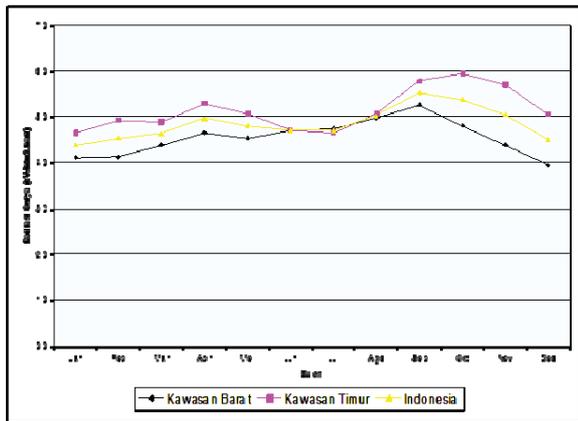


Fig. 1. Indonesia Global Solar Radiation

In this paper a study on the applicability of ANN technique in modeling a prediction tool of solar radiation is explored. Commonly available geographical and meteorological data is used as the model input basis: solar hours, latitude, longitude, elevation, maximum and minimum air temperature, humidity, and rainfall. To improve the model in capturing the seasonal period, the month of the respected data is also incorporated. Five locations are selected in Southern Region of Sulawesi Island as the study case. Data from four locations are used for developing the ANN model, while data set from one other location is used for validating the model.

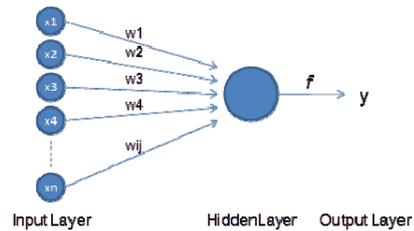
## II. Artificial Neural Network Model

An ANN model is an artificial intelligence technique, working by intensive data processing, learn and memorize them, and simulate the data structure. The advantage of ANN is that this able to capture and simulate data patterns within a multidimensional information domain [12]. It comprises of an integrated network with

A neural network typically is as shown in Fig. 2. comprises of input, hidden, and output layer. Each layer is connected through a transfer function or activation function in a connecting point called as node.

In mathematical form, the process in each neuron is represented by (1), where for a input vector X, and weight

factor W, then the product of input  $x_i$  and weight factor  $w_{ij}$ ,  $x_i w_{ij}$  is as the argument of the activation function  $f$ , where  $i$  is the number of input, and  $j$  is the number of nodes.



$$y = f\left(\sum_{i=1}^p x_i w_i\right) \quad (1)$$

The activation function  $f$  define the output of a neuron, may consist of simple linear transfer function, or more complex non-linear function. Sigmoid function is the most common transfer function used in the ANN due to its ability to provide smooth transition output from low to high value [12], represented as:

Fig. 2. Typical ANN Topology

$$f(y) = \frac{1}{1 + e^{-y}} \quad (2)$$

The most prominent characteristic of ANN is its ability to learn about the data pattern, so that enables the model to provide prediction of next data [Error! Reference source not found., Error! Reference source not found.]. The learning process of ANN is done through a training procedure. The most common training algorithm is the back propagation method. In this method, the network is fed with a group of input data, entering the activation function and produces the output. During the process, adjustment of the weigh is done through utilizing the error occurred between the produced and expected output. The back propagation method minimizes the error function which is defined as:

$$e_j^p = d_j^p - o_j^p \quad (3)$$

Where  $e$  is error,  $d$  is expected output,  $o$  is the ANN output,  $j$  is the number of output node, while  $p$  is the number of input-output pair data. Hence, the Mean Squared Error (MSE) is defined as:

$$E = \frac{1}{PJ} \sum_{p=1}^P \sum_{j=1}^J \frac{1}{2} (d_j^p - o_j^p)^2 \quad (4)$$

The learning rule is to minimize the MSE function, known also as *delta rule* atau *Widrow-Hoff rule* [Error! Reference source not found.]. According to this *delta rule*, in the training process the weigh factor  $w_{ij}$  is adjusted as the error exist, with an adjustment factor  $\Delta w_{ij}$ :

$$\Delta w_{ij}^p = \eta e_i^p x_i^p \quad (5)$$

Where  $\eta$  is a positive constant number as the *learning rate*. The adjustment factor is then used for computing a new weigh factor for the next iteration step of  $n+1$  from the previous weigh factor at iteration step  $n$ :

$$w_{ij}^p(n+1) = w_{ij}^p(n) + \Delta w_{ij}^p(n) \quad (6)$$

The iteration process continues until reaches a determined error level, or when the adjustment is not significantly affects the output anymore. When this condition is obtained then the ANN is ready for testing process. A linear regression of expected output and the ANN output is used to evaluate the correlation coefficient  $r$ , which should close to 1 for the best result

### III. Modeling Result

In this study, an ANN model is developed to predict Solar Energy Potential of Global Solar Radiation in a location in Indonesia with no solar radiation measurement data. A case study was conducted in southern part of Sulawesi Island, covering area about 200 by 700 km<sup>2</sup>, as shown in Figure 3. Data used in this study provided by a survey conducted during the Renewable Energy Project (REI) by BPPT in 1989 – 1995.



Fig. 3. Location of case study

There are five measurement sites in this area, which geographical data is presented in Table 1. below.

Data used in the ANN model development are longitude, latitude, elevation, month, and average monthly data of solar hours, maximum, and minimum air temperature, humidity, rainfall, and solar radiation.

Table 1. Site geographical data

No.	Site	Coordinate		Elevation, m
		latitude	longitude	
1	Majene	3.18 <sup>o</sup>	119.00 <sup>o</sup>	29
2	Masamba	2.37 <sup>o</sup>	120.17 <sup>o</sup>	50
3	Madai	5.04 <sup>o</sup>	119.33 <sup>o</sup>	14
4	Paotere	5.08 <sup>o</sup>	119.24 <sup>o</sup>	2
5	Panakukang	5.10 <sup>o</sup>	119.28 <sup>o</sup>	15

The model used the Multi-Layer Feed Forward (MLFF) ANN, with Back-Propagation training. Several configuration of number of nodes and layer are tested to get the best configuration, as this cannot be done deterministically. Five ANN with 1 to 5 hidden layers is each evaluated using 5, 10, 15, 20, 25, and 30 nodes.

Data from 5 sites, 4 sites are randomly selected for developing the ANN: Majene, Masamba, Maedi, dan Paotere. There are 288 data point in these 4 sites, where 50% as the training data, 25% for testing, dan 25% for validation. The 5th site, Panakukkang, is not included in the development process, and will be used as the prediction site target for testing the ANN.

Using the best network then a prediction is conducted for the target area, Panakukkang, and plotted the result as shown in Figure 5.

The running result of configuration evaluation shows in Table 2., which indicates the performance of each configuration. From the result, the 4 hidden layers with 5 Nodes is the best network, with MSE 0,003, r-value of 0,99958. The MSE (SIM) is the MSE value during ANN development, and the Case is when it was applied for the target site

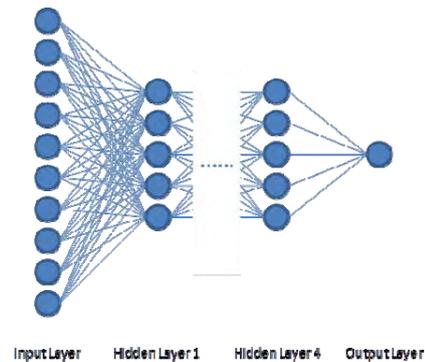


Fig. 4. ANN Structure for the Case Study

Table 2. Simulation Result in Developing the ANN

HIDDEN LAYER	NODES	MSE (SIM)	R (SIM)	MSE (Case)	R (Case)
1	5	0.003	0.99958		
2	5				
3	5				
4	5				
5	5				

1	10	0.0048	0.99934	0.0060	0.99941
2	5	0.0039	0.99945	0.1182	0.98790
3	5	0.0124	0.99830	0.0161	0.99841
4	5	<b>0.0030</b>	<b>0.99958</b>	<b>0.0098</b>	<b>0.99937</b>
5	5	0.0109	0.99863	0.0375	0.99652

The prediction result using this model is tested using the commonly used prediction performance measure as also used in previous works [8, 9, 10, 11]. Mean Percentage Error (MPE),  $r^2$  (coefficient of determination) defined by:

$$MPE = \frac{\sum_{k=1}^K \frac{d_k - o_k}{d_k}}{K} \times 100 \quad (7)$$

$$r^2 = 1 - \frac{\sum_{k=1}^K (d_k - o_k)^2}{\sum_{k=1}^K (d_k)^2} \quad (8)$$

The developed model was successfully used as prediction tools as its performance shows a satisfactory result. The MPE and  $r^2$  of the model is respectively 0,1472% and 0,999967, while similar research in other study such as Mohandes for Saudi Arabia area resulted with MPE 19,1% [8], Reddy for India area with MPE 12,5% [9], Sozen in Turkey dengan MPE 6,78% [10]. Best prediction showed in Krishnaiah work in 2007, yang improving Reddy's work, with MPE 4,61% and  $r^2$  0.999954 [11].

Mohandes and Sozen models both include the sun-hours and exclude the precipitation variable, but Sozen used more variable than Mohandes which includes only geographical data. Sozen model provide better performance than Mohandes. Reddy and Krishnaiah used more variable than Sozen. Their models include time of day, relative humidity, wind speed, rainfall, and ambient air quality in Krishnaiah, but exclude the sun-hour, in addition to the variable that was used by Sozen. Reddy Sozen's has better accuracy than Reddy although it employed fewer variables, this showed that the sun-hours, which was not used by Reddy, improved significantly Sozen's model. In contrary, although did not use sun-hour but ambient air quality instead, the Krishnaiah model provide better performance than Sozen. This shows that ambient air quality also may have strong correlation with solar irradiation.

In our study we utilized sun-hours, and all variable that is used in Krishnaiah except time, wind speed, and ambient air quality. It was revealed that sun-hour variable improved the model as our model has better accuracy.

#### iv. Summary

ANN technique has demonstrated its noble feature in providing prediction model for solar radiation. It shows that

the model has successfully captured the irregularity and stochastic nature of weather data for predicting the solar radiation value. This study exhibited that prediction modeling with ANN technique is possible to obtain solar radiation value using commonly available weather data with a satisfactory result.

The study also shows that the developed model has better performance compared to previous works in the similar field for sites at the other part of the world. Selection of variable has significant effect to the model quality, in this work, it is revealed that sun-hours is the most important variable.

#### References

- [1] Studi Pembangkit Energi Terbarukan (Renewable Energy Based Electricity Generation Study), PT. PLN Persero (State Utility Company), 2005.
- [2] Prescott, J., Evaporation from a water surface in relation to solar radiation. *Trans R. Soc. South Australia*, 64: 114-118, 1940.
- [3] Glover, J. and J.S.G. McCulloch., The empirical relation between solar radiation and hours of bright sunshine. *Q.J.Roy.Meteorol.Soc.*, 84: 172-175, 1958
- [4] Gopinathan. K.K., A general formula for computing the coefficients of the correlation connecting global solar radiation to sunshine duration. *Solar Energi*, 41(6): 499-502, 1988.
- [5] Hargreaves, G.L., G.H. Hargreaves and P. Riley, Irrigation water requirement for Senegal River Basin. *Journal of Irrigation and Drainage Engineering ASCE*, 111: 265-27, 1985.
- [6] Supit, I. and R.R. Van Kappel, A simple method to estimate global radiation. *Solar Energi*, 63: 147-159, 1988.
- [7] S. M. Al-Alawi and H. A. Al-Hinai, An ANN-Based Approach for Predicting Global Radiation in Locations with No Direct Measurement Instrumentation, *Renewable Energy*, Vol. 14, Nos. 1-4, pp. 199-204, 1998.
- [8] Mohandes, M., Rehman, S., and Halawani, T. O. Estimation Of Global Solar Radiation Using Artificial Neural Networks, *Renewable Energi*, Vol. 14, Nos. 1-4, pp. 179-184, © Elsevier Science Ltd, 1998
- [9] Reddy, K.S., Ranjan, M., Solar resource estimation using artificial neural networks and comparison with other correlation models, *Energi Conversion and Management* 44 (2003) 2519–2530, Elsevier Science Ltd, 2003.
- [10] Sozen, A., Arcakliogulu, E. and Ozalp, M., Estimation Of Solar Potential In Turkey By Artificial Neural Networks Using Meteorological And Geographical Data, *Energi Conversion and Management*, 45: 3033-3052, 2004.
- [11] Krishnaiah, T., Srinivasa Rao, S., Madhumurthy, K, Reddy, K.S., Neural Network Approach for Modelling Global Solar Radiation, *Journal of Applied Sciences Research*, 3(10): 1105-1111, INSInet Publication, 2007
- [12] Kalogirou S.A., Artificial neural networks in renewable energy systems applications: a review. *Renew Sustain Energy Rev*;5:373–401, 2001
- [13] Haykin, S., *Neural Network : A Comprehensive Foundation*, 2nd Edition, Pearson Prentice Hall, Singapore, 2005.
- [14] Jain, A.K., Mao, J., Mohiuddin, K.M, *Artificial Neural Networks: A Tutorial*, IEEE Computing Society, "Computer", vol. 29, no. 3, pp. 31-44, Mar. 1996
- [15] Tang, H., Tan, K.C., Zhang, Y., *Neural Network: Computational Model and Applications*, Springer-Verlag, Berlin, Heidelberg, 2007. Clerk Maxwell, *A Treatise on Electricity and Magnetism*, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68-73.

# Voltage and Current Distortion Correlation Characteristics of Compact Fluorescent Lamp in Frequency Range of 2-150 kHz

Budi Sudiarto, Aji Nur Widyanto, Holger Hirsch  
Institute of Power Transmission and Storage  
Universität Duisburg-Essen  
Duisburg, Germany  
[sudiarto@ets.uni-due.de](mailto:sudiarto@ets.uni-due.de)

**Abstract**— Voltage and current distortions in the frequency range of 2-150 kHz are currently subject in research and standardization work. The reasons are that the appliances potentially generating such distortions are increasingly used and that the regulation and standardization are not completely covering and defining the limits and methods for that distortion. As consequence some interference problems have already been reported and it can be foreseen that more EMC problems will occur. Since many appliances potentially generating distortions and devices potentially susceptible to these distortions have been developed without any EMC requirements in that frequency band the discussions on suitable compatibility levels in the standardization will become critical.

This study investigates the characteristics of correlation between voltage and current distortion in the frequency range of 2-150 kHz for compact fluorescent lamp. The characteristics of correlation are important to analyze the current distortion generated by the load when specific voltage distortion is occurred. The level and frequency distortions of voltage input were set from 0-5 Volt and 2-65 kHz respectively. The Measurements of voltage and current were conducted in time domain and converted to frequency domain using Discrete Fourier Transform. The results show correlation characteristics and impedance properties for each specific frequency distortion. There are differences in the behavior depending on frequency.

**Keywords**— Frequency 2-150 kHz; Distortion; Compact Fluorescent Lamp; Impedance; Correlation.

## I. INTRODUCTION

International standards have firmly regulated the level of disturbance for the frequency range below 2 kHz (harmonics) and above 150 kHz (disturbance voltage, disturbance field strength), but the frequency range between 2 kHz and 150 kHz is not sufficiently covered. Some measurements were conducted and informed us that many equipment due to its operation characteristics produce distortion in frequency range of 2-150 kHz[1]. Since the lack of regulation for many devices and the adverse effects of the distortion in this frequency range are not significant yet even the risk of interference are possible[2], the efforts in managing the distortion for that frequency range are less. However, the increasing use of

appliances generated current distortion in frequency range of 2-150 kHz force us to observe the characteristics of the disturbance.

Compact fluorescent lamp is one of the devices producing current distortion for frequency range of 2-150 kHz. Since the widely use of appliances particularly in household installation, it is important to observe the characteristics of distortion in order to ensure their compatibility. Until recently, most of researcher focused on measuring the characteristics of distortion generated by appliances for the normal voltage input condition which is obtained from main network. There are several measurements have been conducted to observe the distortion characteristics of lighting in frequency range of 2-150 kHz including the current distortion emission characteristics[3][4] and the distortion characteristics of individual-simultaneous operation[5]. Refer to the measurement result, it can be noticed that the fluorescent lamp generated current distortion in frequency range of 2-150 kHz. The current distortion generated by the load obviously can influence the voltage quality by generating the distortion in the voltage. The study will focused on observing the characteristics of current distortion generated by compact fluorescent lamp when the voltage input contains distortion. The voltage distortions were adjusted both in frequency and level in order to get comprehensive results.

## II. MEASUREMENT SCHEME

This research activity is intended to find the characteristics of current distortion generated by the low watt compact fluorescent lamps when the voltage input contains distortion in frequency range of 5-70 kHz. In order to generate adjustable voltage input distortion, the testing circuit contained PC-Based function generator and power amplifier was designed and built as shown is figure 1.

Due to the limitation of PC sound card and Power Amplifier frequency range operation, the voltage input distortion was only generated from frequency range of 5-70 kHz. The measurement of Voltage-Current correlation was conducted in several testing group based on the frequency

distortion range of the voltage input. The grouping scheme can be seen in figure 2.

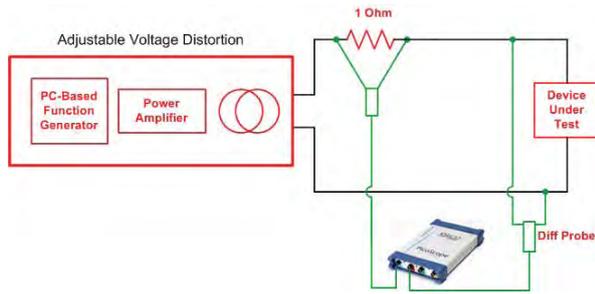


Fig. 1. Measurement Diagram

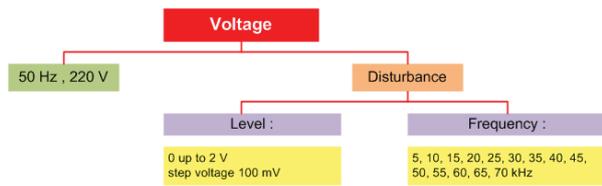


Fig. 2. Voltage Input Distortion Scheme

The measurement was conducted by Picoscope 3425 differential USB oscilloscope device. The frequency and time sampling of the current measurements were 2.5 MSa/sec and 20 ms respectively. Each measurement data contains 50.000 points of one full period current wave 50 Hz. Data was processed by Matlab software using DFT principle. From the current wave data, it can be obtained the current frequency spectrum for the range of 50 Hz up to 1.2 MHz (at 50 Hz interval), however in this paper only concern to the current distortions in the frequency range of 2-150 kHz.

### III. RESULT AND DISCUSSION

The devices under test used in this measurement were 2 brands of low watt power (7 Watt) CFL, that devices were chosen regarding to the limitation of voltage distortion source capacity. Based on the measurement result, we obtained the correlation characteristics between voltage and current distortion for compact fluorescent lamp which are shown in Table 1. and Fig. 3. According to the Table 1, it can be noticed that the correlation between voltage and current distortion is very strong since the correlation values are above 0.99 for both lamps. The high correlation value indicates that the current distortion generated by appliances is proportional with the input voltage distortion. It is mean that the current distortion generated by appliances will be higher when the voltage input distortion applied to the appliances is higher.

TABLE I. VI CORRELATION VALUE

freq (kHz)	V-I Correlation	
	Brand A	Brand B
5	0.995	0.991
10	0.996	0.992
15	0.995	0.992
20	0.993	0.993
25	0.992	0.994
30	0.993	0.995
35	0.995	0.995
40	0.994	0.993
45	0.994	0.989
50	0.993	1.000
55	0.994	0.993
60	0.991	0.992
65	0.997	0.992
70	0.995	0.989

The current produced by lamp for voltage distortion level 1-5 Volts in frequency range 5-65 kHz are shown in figure 3(a) and (b). Some properties of current distortion that can be noticed from the graph are current-voltage distortion values for each frequency is relatively linear and the gradient of linearity values between current and voltage is depending on the frequency. The gradient value between current and voltage is relatively high at frequency 5 kHz, then it will decrease when the frequency distortion increase up to 30 kHz. At frequency above 30 kHz up to 65 kHz the gradient is relatively constant. The graph in figure 3 shows the plot of current distortion produced for each voltage distortion level applied.

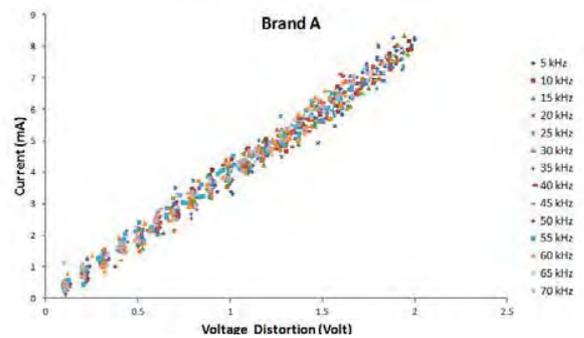


Fig. 3(a). Current and Voltage distortion value for Brand A

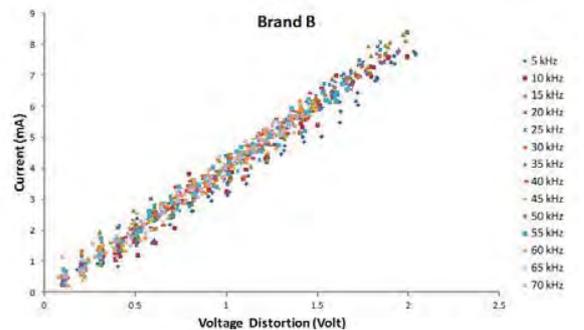


Fig. 3(b). Current and Voltage distortion value for Brand A

To simplify the current-voltage correlation for each frequency distortion, we calculate the average current distortion for specific voltage input distortion 0.5, 1, 1.5 and 2 V. The graph of current to frequency relation for specific voltage distortion can be seen in Fig 4(a) and 4(b). The graph show us clearly the current distortion produced by the lamps in specific range of voltage distortion for each frequency range from 5 to 65 kHz. The current distortion level decline at frequency 5-30 kHz then it is relatively constant at frequency range 30 to 65 kHz. We can also notice that there is a slight increase of current distortion at frequency 45 to 55 kHz. This similar trend occurred for all voltage distortion level.

The gradient between current and voltage is depended on the impedance characteristics of the device under test which is influenced by the frequency of distortion. The impedance values of both lamps for specific voltage distortion for all frequency range between 5-65 kHz are shown in figure 5(a) and (b).

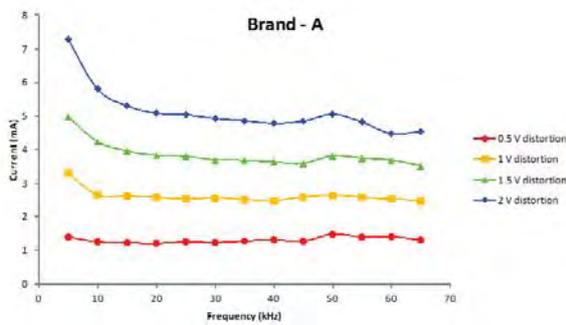


Fig. 4(a) Current value at each frequency distortion in specific voltage input level for Brand A

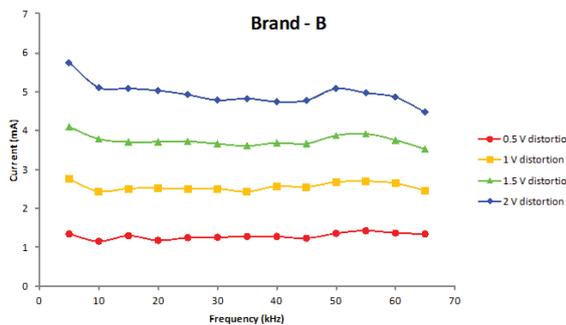


Fig. 4(b) Current value at each frequency distortion in specific voltage input level for Brand B

Fig.5. shows the impedance characteristics of the device under test. According to the graph, we can determine that the impedance of lamp is higher when the frequency distortion applied is higher. This condition occurred at frequency range 5 to 30 kHz, after that the impedance is relatively constant. We can also notice that the impedance is also depending on the voltage magnitude of disturbance, the higher voltage magnitude of disturbance the lower impedance of the lamp for

all frequency distortion range. Both of the lamps have relatively similar trend of impedance characteristics, the differences only in the magnitude value.

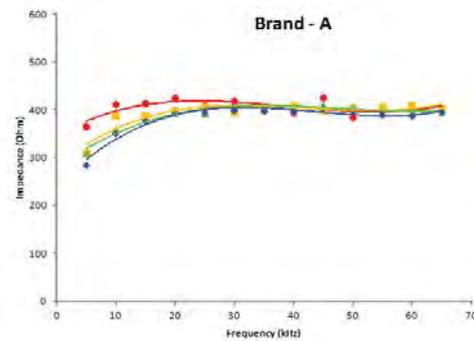


Fig. 5(a) Current value at each frequency distortion in specific voltage input level for Brand A

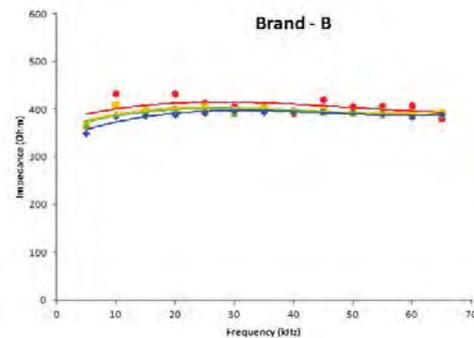


Fig. 5(a) Current value at each frequency distortion in specific voltage input level for Brand B

Refer to the all characteristics of current distortion and impedance of CFL lamps under test for frequency range of 5-65 kHz, we should pay attention more for the voltage distortion in frequency below 30 kHz since the current distortion produced by the lamp are relatively higher than the current in frequency above 30kHz. We can take one comparison for lamp Brand A as an example, when the voltage distortion applied was 2 volt at frequency 5 kHz the current distortion produced was 7.28 mA while for frequency 60 kHz the current produced was 4.47 mA for similar voltage applied. It is mean that the current distortion produced at frequency 5 kHz is around 60% higher than the current distortion at frequency 60 kHz.

#### IV. CONCLUSION

The measurement gives us two characteristics of current distortion for frequency range of 2-150 kHz. The first is that the correlation between voltage and current distortion is very strong since the correlation values are above 0.99. The high correlation value indicates that the current distortion generated by appliances is proportional with the input voltage distortion. The second characteristic is that the current-voltage distortion values for each frequency are relative linear and the gradient of

linearity value between current and voltage is different and depending on the frequency. Refer to this characteristics the attention of current distortion should be more given for specific range of frequency than the other range since the current produced by the lamp for the same voltage distortion value are not same and depending on the frequency. Particularly for the CFL under test, the higher current distortion produced for frequency range below 30 kHz. However, the characteristics of current distortion explained in this paper only were occurred for the compact fluorescent lamp under test, it is means that the characteristics of other device (different CFLs, computer, TV and etc) may has different characteristics and should be observed in further work.

#### REFERENCES

- [1] A. Larrson, M. Bohlen "Emission and Immunity of Equipment in The Frequency Range of 2-150 kHz" IEEE Bucharest Power Tech Conference, Bucharest, June 2009.
- [2] C.M. Lundmark, E.O.A. Larsson, M.H.J. Bollen "Unintended consequences of limiting high-frequency emission by small end-user equipment" [Power Engineering Society General Meeting, IEEE, 2006](#)
- [3] S. Rönnerberg, M. Wahlberg, M. Bohlen "Total conducted emission from a costumer in the frequency range 2 to 150 kHz with different type of lighting" in The 21th international Conference on Electricity Distribution (CIRED), Paper no 0173, Frankfurt, June 2011.
- [4] A. Larrson, M. Bohlen "Emmision (2-150 kHz) From a Light Installation" The 21th international Conference on Electricity Distribution (CIRED), Paper no 0250, Frankfurt, June 2011.
- [5] B. Sudiarto, H. Hirsch "current distortion characteristics of a single and simultaneous operated load in the frequency range of 2-150 khz" in The 5th Indonesia Japan Joint Scientific Symposium 2012, Japan, October 2012.

# Wind Powered Turbine for Urban Environment as an Adaptation to Climate Change

Dany Perwita Sari

Research and Development Unit for Biomaterials  
Indonesian Institute of Sciences (LIPI)  
Cibinong, Indonesia 16911  
E-mail: dany.perwitasari@gmail.com

**Abstract**—Climate change and energy crises nowadays become global issues in recent years which make alternative energy becomes more necessary than fossil fuels which limited availability. The use of wind generation in urban environments has increased in scale in recent years and provides significant potential. There has been an increasing interest in urban wind energy which using wind turbine in high rise building. The paper highlights to function wind turbine for high rise building, it is important to balance between BIWT (Building Integrated Wind Turbines) aerodynamic building shape design and geographic area and climate. In this paper study case in Tropical Climate, Java Island, Indonesia. Early research, designed some of numerous famous high rise building will be redesign and simulated using CFD (Computational Fluid Dynamics) analysis to find the most effective BIWT design in urban area and then validate using wind tunnel experiment. This BIWT design will adapt to chosen area in Indonesia. This paper, focus to the guidance that the results of wind power density around Java Island and combined with best design of BIWT. Main purpose of this research is helping Indonesian citizen, especially in Java Island to predict the wind energy for replace fossil fuel for their day life. The result shows that, West Java (Southern Hemisphere) has the best performance and potential for BIWT (turbine located in side of rounded shape building). Building energy can be optimized through aerodynamic building design, wind turbine position and best geographic area and climate to get maximum wind power for building energy consumption.

**Keywords**—climate change, building integrated wind turbines, wind power density, java island

## I. INTRODUCTION

Starting in the late 18<sup>th</sup> century with industrial Revolution, the global economy has increasingly relied on fossil fuels such as coal, petroleum, and natural gas [1]. Carbon dioxide and other gases are not dangerous. In fact, these gases naturally occur in the atmosphere and help moderate the global climate to support living organisms, including humans [2]. The problem is that the growing use of fossil fuels in increasingly the concentration of carbon dioxide and other gasses, which means increase the capacity of the atmosphere to absorb latent heat energy. Architects, as a designer, recognizing that the building sector is responsible for almost half of all greenhouse gas emissions annually [3]. Buildings are among the physical artifacts that society produces with the greatest longevity (50-

100 years). Consider the fact from US Department of Energy [4] that every year constructing and operating America's building generates 25% of the total municipal solid waste stream and 48% of all greenhouse gas emissions.

Recently the European Parliament [5], amending the 2002 Energy performance of Building Directive, has approved a recast of the Directive proposing that all new buildings built after 31 December 2018 will have to produce as much energy as they consume on-site. The UK Government has set some challenging targets, both the UK The Climate Change Act [6] and The Scotland Government Climate Change (Scotland) Act 2009 requires an 80% reduction by 2050.

Wind energy, one of alternative energy, therefore, is a catchall category of energy sources that can replace traditional fossil fuels in daily life, while causing less harm to the environment. The increasing population because of urbanization and fertility is difficult to control in urban area. Adaptation to the climate change is the best way to reduce the greenhouse effect. Now, it is the time to thinking how to build the high rise building in harmony with climate and using renewable energy resources. Building Integrated Wind Turbines (BIWT) nowadays becomes the new icon of Green Buildings. However to employ BIWT in urban area there are some limitation, wind energy operates effectively only in certain geographic area and climates. This paper is organized to place the best design BIWT in the best geographic area and climates in Tropical Climate (Java Island, Indonesia). It is interesting that Indonesian people, especially who lived in Java island exploit wind energy which cheap, environment friendly and renewable than fossil fuel.

## II. JAVA ISLAND WIND POWER DENSITY CALCULATION

Wind is a source of solar energy that does not rely on the condition of the sky. Wind energy creates very few greenhouse gases and will exist as long as the sun shines and wind blow. To maximize the performance of BIWT should combine with certain geographic area and climates. In this paper, Java Island is chose from all the available islands in Indonesia because the rapid growth population.

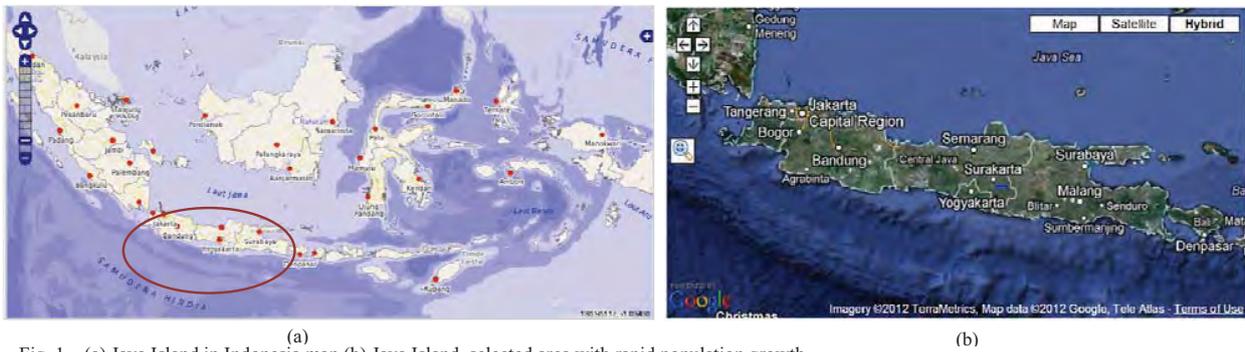


Fig. 1. (a) Java Island in Indonesia map (b) Java Island, selected area with rapid population growth  
 Source: <http://www.iccc-network.net/en/lib/map> [7], <https://maps.google.com/> [8]

The calculation of this wind power density of Java Island is adapted from Quanhua Liu, et al. research [1][9][10]. Firstly, calculation we find global power in Java Island, Indonesia which calculates around beach in Java Island (Figure 1) using Google map for looks for direction and geographic area. Wind turbine tower high calculated from 10, 25, 50, 100 and 200. We are putting wind turbine at higher altitude (minimum 10m) to capture more wind energy. Most wind energy is over the oceans, we calculated wind power around java island beach.

Wind power density as a tool to calculate annual electricity for BIWT. Firstly there are some assumptions for BIWT:

- BIWT is single building which use for office building
- BIWT consist of 16 floors, total area 4096m<sup>2</sup>
- Using 1 wind turbine in each BIWT
- Rotor diameter 20m

Wind power density result show in Figure 2. This graph also explain the higher the tower, the higher the wind power density. Southern hemisphere of Java island can produce wind energy higher than northern hemisphere because provide plenty of energy to atmospheric motions, and its roughness is generally smaller than northern which a lot of island.

### III. BIWT DESIGN WITH CFD AND WIND TUNNEL EXPERIMENT

The most important in BIWT is how much it can produce the power for energy consumption. Potential energy from the wind can be calculated using this equation [11]:

$$P_{\text{turbine}} = 0.5 \times \rho \times C_p \times A \times V^3 \quad (1)$$

Wind power (P) is depends on the wind velocity (V) raised to the third power (wind speed cubed). It can be seen that energy is dependent on the free wind velocity (1). If the wind velocity doubles, the power increases by a factor of eight (1). Wind velocity in addition to increases due to the height, can also be increased because of the shape of the building. The building architecture can be shaped to capture and tunnel wind through the turbines, which can in turn produce wind velocity through the turbines that are greater than the prevailing wind velocity. This study concentrates on looking for a BIWT that can increase the wind velocity in Java Island.

Wind created from differences in velocity on different earth surfaces [9]. Every country has wind load standards depending on their region. When wind hits the building structure, it will be deflected or stopped, thus converting the wind's kinetic energy into potential energy and pressure. This kinetic energy can make the blade from the wind turbine to start moving. Putting wind turbines on top of buildings, especially tall buildings, should allow them to take advantage of height without building an expensive, full size tower, especially in urban areas.

There are two kinds BIWT design are chose from earlier research [9] which simulated using CFD and validate using Wind Tunnel experiment. Computational Fluids Dynamics (CFD) is the science of predicting fluid flow, heat and mass transfer, chemical reactions, and related phenomena by solving numerically the set of governing mathematical equations.

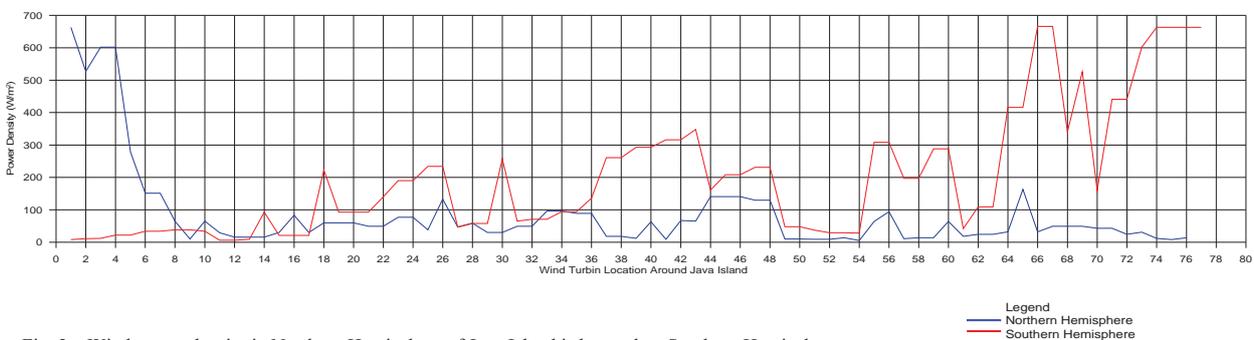


Fig. 2. Wind power density in Northern Hemisphere of Java Island is lower than Southern Hemisphere

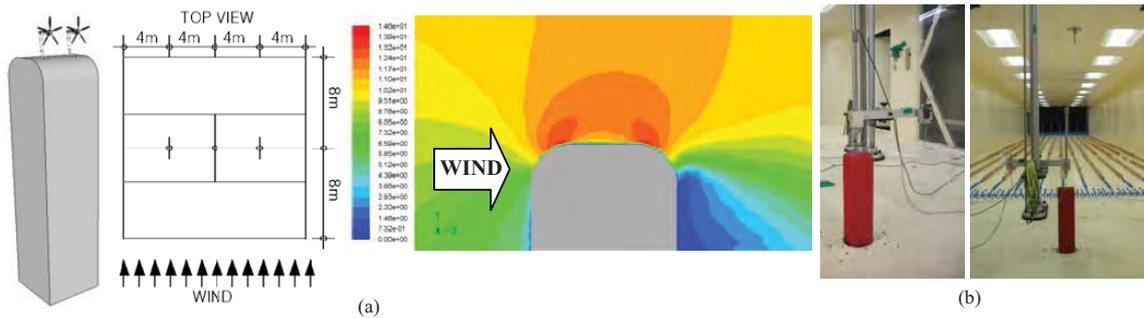


Fig. 3. Building A (a) CFD analysis (b) Wind Tunnel validate using Cobra Probes

CFD provides a cost-effective alternative to experimental fluid mechanics. A well developed and reliable computational code can be easily used to study flows in various geometries, boundary conditions, and flow parameters [12]. After analyze numerous design using CFD, BIWT best result make a prototype and validate the CFD result using wind tunnel experiment. Wind tunnel experiment is methods of analysis which can be used to predict the complicated flow of wind and its effect on the response of the building and its components have not been developed for routine office use. Wind tunnel experiment is generally accepted in the scientific and engineering community.

Some limitations imposed on the experiment are:

- BIWT is single building with The size of the building using high rise building scale depth:width:height = 1:1:4
- The basic form of model is rectangular in shape with the same ratio.
- Building design is redrawn using Sketchup 7 and Autocad 2009
- Building design with scale 1:150 to make similarities with wind tunnel model.
- BIWT is single building which use for office building
- These design buildings are only adaptations of the appearance of BIWT which currently exist and from literature.
- BIWT consist of 16 floors, total area 4096m<sup>2</sup>
- BIWT annually electricity consumption for office building in Indonesia 240 kWh/m<sup>2</sup>.year [13]

- For calculation electricity consumption, assume only using 1 wind turbine in each BIWT

A. Building A (Wind Turbine on The Top of Rounded Roof) CFD and Wind Tunnel Analysis Result

Building A is adapting from Near North Apartments, USA's building design. Contour (Figure 3;a) from Building A show that the wind velocity increases as it passes through a rounded shape. Highest wind velocity is near the rounded shape because the wind velocity increases because the rounded building restricts the passage of wind. Rounded shape restricts the passage of wind, causing the streamlines of the wind to coverage on the windward slope. The height of the building brings the gradient wind closer to surface, resulting in a reduction of the gradient of the rounded shape, which causes an increase in the wind velocity within the boundary layer. Wind velocity increase 39.29% from wind velocity approach. CFD and Wind Tunnel result (Cobra Probes and Pitot Tube) show that the result are almost similar (Figure 3;b). Building A is the best design for wind turbine which need high tower only in one side wind direction. For this kind building, HAWT (Horizontal Axis Wind Turbine) is the best solution.

B. Building B (Wind Turbine in The Side of Rounded Shape) CFD and Wind Tunnel Analysis Result

Some studies indicate that the position of the turbine on the side of buildings can increase wind speed. Several high rise buildings already use this method such as Kinetica Building, United Kingdom and Anti Smog Building, France Wind turbine of this building is located in the side of building and near with ground.

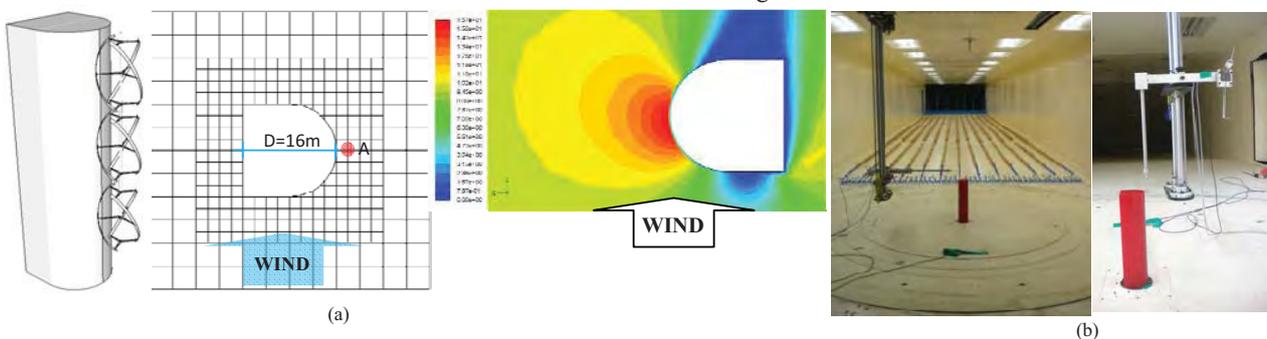


Fig. 4. Building B (a) CFD analysis (b) Wind Tunnel validate using Cobra Probes

Some high rise building will create wind flow around it which sometimes dangerous for low rise building and people which stays around it. Figure 4 shown wind turbine position to calculate wind velocity with height 1.5m up to 64m on the ground. In CFD analysis, writer also calculated wind velocity around the building. Wind velocity contour in Figure 4 show the high wind velocity is around the rounded shape. Highest velocity located  $1/8D$  or 2m (red dot A; Fig.4) in the side of rounded building and in the height 1.5 up to 8m from the ground. Rounded shape could increase wind velocity from 18.58% up to 182.02%. Wind velocity coefficient increase in the height of wind turbine 1.5m to 16m from the ground, stable in the height 16m to 56m, and decrease when almost in the rooftop.

### C. The Placement BIWT design (Building A and Building B) in Java Island

West Java (Southern Hemisphere) has the best performance and potential for BIWT because of its wind power density. In this area, we do not need high tower for wind turbine. The best design for BIWT is Building B which its wind turbine in the side of building (Figure 4). Those designs do not need high tower to harvesting maximum wind energy. From some assumption above, use one wind turbine, can supply almost 45% annual energy consumption every year. If there are 3 wind turbines, it means this BIWT office building does not need energy from fossil fuel anymore. Central Java and East Java in Southern Hemisphere does not have high wind energy performance like West Java. In this area another BIWT design is needed. Especially, BIWT design with higher wind turbine tower such as in Building A (Figure 3). Wind turbine in this kind building can support annual BIWT office building's electricity 15% every year.

## IV. CONCLUSION

Wind tunnel experiment and CFD analysis can be used as a tools to shown the increasing wind resources around the BIWT. Wind tunnel experiment and CFD analysis almost similar but have to be carefully when making the model for wind tunnel experiment especially in rounded shape Investing in urban renewable energy, pollution caused by the burning of fossil fuel will reduced allowing the quality of live in urban centers to increase. Building A and Building B could increase wind energy as the rounded shape.

Performed calculation and results show that single wind turbine for Building A is the best in Central Java and East Java and could reduce the electricity 15% every year. Building B could reduce 45% annual energy consumption every year in West Java (Southern Hemisphere), Java Island, Indonesia is easily accessible goals (Figure 11).

This research can be observed that Building Integrated Wind Turbines (BIWT) it is not harvesting wind energy only by Aerodynamics shape, at least in this case best geographic area and climate could increase the perform of wind turbines. We also hope that with the establishment of design is able to support the Government of Indonesia to reduce fossil fuel

consumption by 26% by the year 2020 [14]. The use of wind energy in Building Integrated Wind Turbines in urban area to generate electricity is especially advantages to developing countries, because of the new employment opportunities it will create, as well as the stimulation of local economies by attracting investment.

Generic conclusion cannot be drawn from one single case study, we do hope that this framework will inspire and enable other researchers and architect to perform similar studies in other rapid development area in Indonesia. Thus helping the adaptation in climate change and reduce the greenhouse gasses and global warming. We hope that our research could helping Indonesian citizen, especially in Java Island to predict the wind energy for reduce fossil fuel and solving land use problem because of rapid development area with BIWT.

## ACKNOWLEDGMENT

Our thanks to Indonesian Institute of Sciences (LIPI), Wonkwang University and CKP Wind Solutions for allowing this study to be undertaken and to the staff at each institute and university for taking the time to participate in the study.

## REFERENCES

- [1] Q. Liu, Q. Miao, J. J. Liu and W. Yang, "Solar and Wind Energy Resources and Prediction", Journal of Renewable and Sustainable Energy 1, 043105 (2009), American Institute of Physics
- [2] S. George Philander, "Encyclopedia of Global Warming and Climate Change", Sage Publications (2008) pp. 32-49
- [3] K. P. Cho, S. H. Jeong, D. P. Sari, "Harvesting Wind Energy from Aerodynamic Design for Building Integrated Wind Turbines", International Journal of Technology (2011) 3, ISSN 2086-9614, pp. 189-198
- [4] US Department of Energy, "Fifth Edition: Green Building Guidelines Meeting The Demand for Low-Energy-Efficient Homes, Sustainable Buildings Industry council: Beyond Green", Washington DC (2007) pp.7-8
- [5] A. Ferrante, MT Cascella, Zero Energy Balance and Zero on-Site CO<sub>2</sub> Emission Housing Development in The Mediterranean Climate, Energy and Buildings Journal, 43 (2011) pp. 2002-2010
- [6] [http://www.decc.gov.uk/en/content/cms/legislation/en/content/cms/legislation/cc\\_act\\_08/cc\\_act\\_08.aspx](http://www.decc.gov.uk/en/content/cms/legislation/en/content/cms/legislation/cc_act_08/cc_act_08.aspx)
- [7] <http://www.iccc-network.net/en/lib/map>
- [8] <https://maps.google.com/>
- [9] D. P. Sari, "Strategy for Improving Wind Resources from Building Aerodynamic Design for Building Integrated Wind Turbines", Thesis Master Degree, Wonkwang University, Iksan South Korea (2011)
- [10] <http://www.renewableenergyst.org>
- [11] A. Alexandrou, "Principles of Fluid Mechanics, Pretice-Hall.
- [12] Sinisa, S. Campbell, Harries, "Urban Wind Energy", Earthscan, UK and USA, 2009.
- [13] Indonesia National Standard (SNI) 03-6196-2000, "Prosedur Audit Energi pada Bangunan Gedung", National Standardization Agency of Indonesia (BSN).
- [14] Presidential Regulation (Peraturan Presiden) No.6/2011, "Rencana Aksi Nasional Penurunan Emisi Gas Rumah Kaca", National Standardization Agency of Indonesia (BSN).

# Cost Allocation of Transmission Usage Based on Current Magnitude

Hermagasantos Zein  
 Energy Conversion Departement  
 State Polytechnic of Bandung (Polban)  
 Bandung, Indonesia  
 e-mail: hermaga\_s@yahoo.co.id

**Abstract**—Transmission is one of the key utilities in the electricity market mechanism. Generally, it is managed by a provider that is monopoly but not in business. However, all costs that have been embedded in the transmission must be refunded by all transmission users, or generators. The paper proposes a method for determining the cost allocation of transmission usage with current magnitude as the basis for calculation. As a result, current flow contributions of each generator on the lines must be determined. Then it applies a method to decompose the actual current, of the load flow results, on every line. Mathematically, the proposed method has been illustrated clearly in this paper without approximations and assumptions. While the formulations have been tested with 5-bus system and the results have been compared to the published methods. The test results show that the proposed method gave slightly different results with the published methods. But it is in line with what were expected.

**Keywords**—Transmission; Cost Allocation; Generator; Current Magnitude; Contribution.

## I. INTRODUCTION

Cost allocation of transmission usage becomes an important issue when transmission is operated openly. It is always maintained under natural monopoly company. However, The transmission provider will be required to offer the basic transmission services in conjunction with a number of mandatory and/or voluntary ancillary services. This has been studied by A. Zobian and M.D. Ilic [1], about unbundling of transmission and L. Willis. et al [2], about unbundled service. Basic transmission service refers to the path provision function of the transmission grid while ancillary services, such as operating reserves, regulation, load following and voltage control, are the necessary for maintaining the reliability of the bulk system as well as undertaking commercial transactions across the grid.

A few references have published various methods to calculate cost allocation of transmission usage, such as generation shift distribution factors (GSDFs), line utilization factors (LUFs), Bialek and Kirschen algorithm. These methods have been reviewed by Jiuping P.. et al [3] through numerical examples that use 5 bus system and the results are enough different among one another, see Tables II and III, although they use the same active power flow as basic calculation.

This paper will propose a different basic calculation, current magnitude, through the decomposition method that has been studied by Hemagasantos Z. [4]. Decomposition

techniques here are done after results of load flow calculation are found, where these results are as a base case. Then the base case will be used to determine flowing current contribution from a generator to the lines. After the current contributions from generators are obtained, finally is continued to calculate the cost allocation of transmission usage for all of the generators.

To see the performance of the proposed method will be tested with the 5 bus system that was said above. the results will be compared with the results of the methods that have been published.

## II. PROBLEM FORMULATION

### A. Cost Allocation of Transmission Usage

Formulation for calculating cost allocation of transmission usage in this paper follow general equation from MW-Mile regulation, which is expressed by equation (1).

$$TC_i = \sum_{k \in K} C_k \frac{|F_{i,k}|}{\sum_{t \in T} |F_{t,k}|} \quad (1)$$

Where  $TC_i$  is total cost that is allocated to generator  $i$ ,  $C_k$  is the embedded cost of the facility  $k$  (included costs of wires, towers, connecting, arresters or others),  $|F_{t,k}|$  is power/current magnitude flowing on facilities  $k$  caused by generator  $t$ , and  $K$  &  $T$  are the number of transmission facilities and generators on the system. This equation (1) shows that direction of flow does not influence the responsibility of payment. This is analogous to the TOL (tax of line) usage for vehicles. The power magnitude used in the equation (1) can consist of active power (MW) or apparent power (MVA). So we have to choose one of the others (MW and MVA). Power usage in determining cost allocation of transmission usage will be influenced by losses, such as shown by Fig. 1 this below. This figure is a line of facility  $k$  with impedasi  $Z_{jk}$ . Furthermore it is assumed power from generator  $i$  to flow from left to right is equal to  $F_{i,k}^{LR}$  and the power was accepted on the right side bus is  $F_{i,k}^{RL}$ . There is line impedance will produce loss in the line, so that  $F_{i,k}^{RL}$  received on the right side of the bus will be reduced.

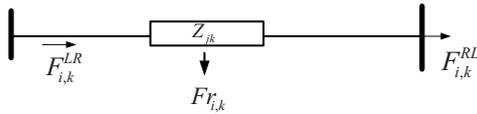


Fig. 1. Power flows in the line

Where  $Z_{jk}$  is line impedance. If generator i cause power losses,  $Fr_{i,k}$ , in the line (Fig. 1), power genertor i,  $F_{i,k}^{RL}$ , flows from right to left and received at right side is

$$F_{i,k}^{RL} = F_{i,k}^{LR} - Fr_{i,k} \quad (2)$$

While the power loss depends on the line impedance. For a fixed current flow, the power loss would be great if the line impedance is also getting bigger. In practice, the line impedance is not always zero. So  $F_{i,k}^{RL}$  is always less than  $F_{i,k}^{LR}$ .

Before equation (1) is applied, the direction of power flow on each line must be chosen first, from left to right or vice versa. Because of the power loss in the lines, the direction of power flows that have been chosen is definitely affect the calculation results. For example, the power flowing from generator i is from right to left. If direction of the power chosen is from left to right, the generator i will be getting profit.

In this paper will propose current flows as the basis for determining cost allocation of transmission usage. The idea is based on reality that current flows in transmission lines according to electrical laws, i.e. they did not changed (or no losses) after flowing across the transmission grid. So, using current as a basis calculation will more fortunate than using power in determining cost allocation of transmission usage. Then equation (1) in current variable is rewritten as this following equation.

$$TC_i = \sum_{k \in K} C_k \frac{|I_{i,k}|}{\sum_{t \in T} |I_{t,k}|} \quad (3)$$

Where  $I_{t,k}$  is the current from generator t that flows in the line k.

#### B. Current Contribution from a Generator to the Lines

General working equation of the electric network in the matrix can be expressed by following equation.

$$[I_{bus}] = [Y_{bus}] [V_{bus}] \quad (4)$$

Where  $[I_{bus}]$  is the bus injection current matix,  $[Y_{bus}]$  is the bus admittance matrix and  $[V_{bus}]$  is the bus voltage matrix.

Whereas the  $[I_{bus}]$  matrix consists of the bus injection current matrix of genertors,  $[I_{bus}^G]$ , and the bus injection current matrix of loads,  $[I_{bus}^L]$ . So equation (4) can be rewritten as this following equation.

$$[I_{bus}^G] - [I_{bus}^L] = [Y_{bus}] [V_{bus}] \quad (5)$$

Or.

$$[I_{bus}^G] = [Y_{bus}] [V_{bus}] + [I] [I_{bus}^L] \quad (6)$$

Where  $[I]$  is identity matrix. Based on study from Hermagasantos Z. [4], the current flow to the load at bus i can be expressed by

$$I_i^L = \left( \frac{S_i^L}{V_i} \right)^* = y_i^L V_i \quad (7)$$

Where,

$$\alpha + \beta = y_i^L = \frac{P_i^L (1) j Q_i^L (1)}{|V_i|^2} \quad (8)$$

Where  $V_i$ ,  $P_i^L$  and  $Q_i^L$  are the actual voltage, active power and rective power, repevively. In matrix form of equation (7) is substituted into equation (6) and yield

$$[I_{bus}^G] = [Y_{bus}] [V_{bus}] + [y_{bus}^L] [V_{bus}] \quad (9)$$

Where  $[y_{bus}^L]$  is diagonal matrix of load admittances expressed by equation (8). From the equation (9) is get bus voltage, that is

$$[V_{bus}^G] = [Z_{bus}^{\#}] [I_{bus}^G] \quad (10)$$

Where,

$$[Z_{bus}^{\#}] = ([Y_{bus}] + [y_{bus}^L])^{-1} \quad (11)$$

From the latest equation is applied superposition technique to calculate current contributions of each generator that flows in lines. For example, for generator at bus i, equation (11) can be rewritten to be the following expression.

$$\begin{bmatrix} V_1^{Gi} \\ V_2^{Gi} \\ \vdots \\ \alpha + \beta \\ \vdots \\ V_n^{Gi} \end{bmatrix} = \begin{bmatrix} Z_{11}^{\#} & Z_{12}^{\#} & \bullet & \bullet & \bullet & Z_{1n}^{\#} \\ Z_{21}^{\#} & Z_{22}^{\#} & \bullet & \bullet & \bullet & Z_{2n}^{\#} \\ \bullet & \bullet & \bullet & \bullet & \bullet & 0 \\ \bullet & \bullet & \bullet & \bullet & \bullet & 0 \\ \bullet & \bullet & \bullet & \bullet & \bullet & 0 \\ \bullet & \bullet & \bullet & \bullet & \bullet & 0 \\ Z_{n1}^{\#} & Z_{n2}^{\#} & \bullet & \bullet & \bullet & Z_{nm}^{\#} \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 0 \\ I_i^G \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad (12)$$

Where  $V_j^{Gi}$  is voltage at bus j caused by generator at bus i,

$Z_{ji}^{\#}$  is element of new bus impedance matrix on row j and column i and  $I_i^G$  is the injected current at bus i. From the equation (12) above is easily obtained voltage on each bus, that is

$$V_j^{Gi} = Z_{ji}^{\#} I_i^G \quad (13)$$

The following step, Fig. 2 will be used to calculate current flow contribution of a generator in the line. It is phi equivalent circuit of a line having admittance  $y_{jk}$  and half line charging susceptance  $y_{jk}^{sh}$ . The line connects bus j to bus k, where  $V_j^{Gi}$  and  $V_k^{Gi}$  are nodal voltage as consequence of the injected current at bus i.  $\alpha + \beta = \chi$ . (1) (1)

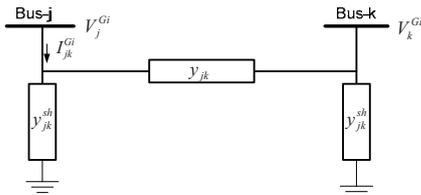


Fig. 2. Phi equivalent circuit of line j-k

From Fig. 1, the current flowing in the line j-k derived from generator at bus i is easily determined through a circuit theory, that is

$$I_{jk}^{Gi} = (V_j^{Gi} - V_k^{Gi})y_{jk} + V_j^{Gi}y_{jk}^{sh} \quad (14)$$

Or,

$$I_{jk}^{Gi} = F_{jk} I_i^G \quad (15)$$

Where,

$$F_{jk} = (Z_{ji}^{\#} - Z_{ki}^{\#})y_{jk} + Z_{ji}^{\#}y_{jk}^{sh} \quad (16)$$

### III. ALGORITHM

The proposed method explained in section II needs clearer procedure, so that it can be applied in computer calculations. These procedures are steps of algorithm to run a program from the proposed method. Then the procedure in this paper are realized by an algorithm as the following steps.

- Step-0: Start.
- Step-1: Input data of transmission, loads, generators, and embedded cost of each facilities.
- Step-2: Run program load flow with condition at step-1.
- Step-3: Form a new bus impedance matrix from the load flow results, by equation (11)
- Step-4: Determine a generator, for example  $G_i$ , that will be observed and calculate its current generated,.
- Step-5: Calculate voltage every bus that is caused by the  $G_i$ .
- Step-6: Calculate current that flows in each line base on bus voltages that are got from step-4.
- Step-7: Continue to step-5 for another generator until all generators have been observed.
- Step-8: Calculate cost allocation of transmission usage for all generators.
- Step-9: Write the results.
- Step-10: Stop.

Step-1 inputs all data, both data of line costs of every line and parameters of system. The data are used to obtain a base case by running load flow program in step-2. The base case is used to calculate bus admittance through equation (8) and then forming bus admittance matrix through equation (11) in step-3. Afterward, it is forming a bus impedance matrix from the bus admittance matrix in step-4. Choose a generator to be observed then uses equation (12) to determine bus voltages in step-5. After obtaining bus voltages, it is continued to calculate current flows in every line from the generator through equation (14) or (15) in step-6. In step-7 the process goes back to step-5 and choose again one of the other generators until all generators have been processed. Next step, it is continued to calculate cost allocation for every generator through equation (1) in the step-8. Finally, it is obtained cost allocations of transmission usage from each generator and

process is stopped.

### IV. NUMERICAL EXAMPLES

This section presents a illustrative example base on the 5-bus test system that was proposed by Jiuping P., et al [3]. It is aimed to see performance of the proposed method that was discussed above. The 5-bus test system is depicted in Fig. 3. This figure consist of two generators, three loads and seven facilities/lines. Total capacity of the loads of system is equal to 145 MW, which is distributed on bus 3, 4 and 5. The cost of each line in Tabel 1 is an annual cost which includes costs of wires, towers, connecting, arresters or others.

Table I gives the transmission data including the base case flows and the transmission revenue requirements. In the case, loads at bus 3, 4 and 5 are (45+j15 MVA), (40+j5 MVA) and (60+j10 MVA), respectively. The generator from bus 2 is fixed as 20 MW and bus 1 is the slack bus.

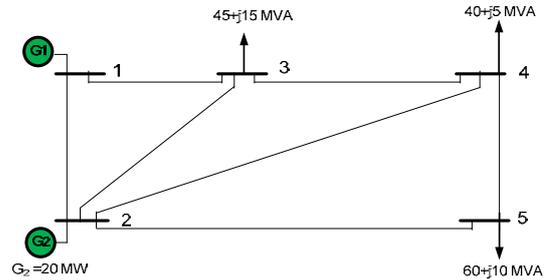


Fig. 3. The 5-bus test system

TABLE I.  
TRANSMISSION DATA AND BASE CASE FLOWS

Line	R (pu)	X (pu)	Cost (10 <sup>6</sup> \$)	Flows (MW)	Flows (MVA)
1-2	0.02	0.06	0.1863	89.51	118.27
1-3	0.08	0.24	0.8250	41.76	47.45
2-3	0.06	0.18	0.5499	24.51	24.71
2-4	0.06	0.18	0.5499	27.75	28.05
2-5	0.04	0.12	0.2809	54.76	55.96
3-4	0.01	0.03	0.0978	19.30	19.88
4-5	0.08	0.24	0.8250	6.54	6.94

TABLE II.  
TRANSMISSION USAGE AND CHARGES (G<sub>1</sub>)

Line #	Methods			
	GGDFs (MW)	LUFs (MW)	Bialek (MW)	Kirschen (MW)
1-2	92.3039	87.0940	89.5100	89.5100
1-3	38.9661	37.4753	41.7600	41.7600
2-3	20.0297	20.3981	20.0337	21.2698
2-4	23.0893	23.6008	22.6820	24.0815
2-5	47.0241	48.7091	44.7509	47.5121
3-4	18.2359	18.7771	17.9774	16.7485
4-5	6.1712	6.4908	5.6545	5.6754
Cost (\$/MW)	2.5880	2.5756	2.5604	2.6178

TABLE III.  
TRANSMISSION USAGE AND CHARGES (G<sub>2</sub>)

Line #	Methods			
	GGDFs (MW)	LUFs (MW)	Bialek (MW)	Kirschen (MW)
1-2	-2.7939	-2.7488	0	0
1-3	2.7939	2.8034	0	0
2-3	4.4803	4.6201	4.4763	3.2402
2-4	4.6607	4.8344	5.0680	3.6686
2-5	7.7359	8.1780	9.9991	7.2380
3-4	1.0641	1.2257	1.3226	2.5515

4-5	0.3688	0.4424	0.8855	0.8646
Cost (\$/MW)	1.9354	2.0147	2.1151	1.7381

Tables II and III consist of the test results of the published methods. These tables show generator-related active power flows for the base case determined by general generation distribution factors (GGDFs), line utilization factors (LUFs), Bialek and Kirschen tracing algorithm. They stated the generator-related MW flows and generator charges determined by GGDFs and LUFs are very close. From Table III for lines 1-2 and 1-3, Bialek and Kirschen algorithms resulted in zero charges for G2 and full responsibility of G1 to use them. However, the two algorithms have very different results for generator charges, i.e. 2.1151 \$/MW for Bialek and 1.7381 \$/MW for Kirschen.

While Table IV shows that the generator-related current flows for base case determined by the proposed method, where  $I_{G1}$  and  $I_{G2}$  are the generator-related current flows of  $G_1$  and  $G_2$ , respectively, in per-unit (pu). From the base case, G1 and G2 generate 131.27 MW and 20 MW, respectively. Power of G1 is so dominant so that  $I_{G1}$  is the very influential to every line. The next table consist of total cost, in unit \$/MW, of the five methods. The last row of the table contains the cost allocation for each generator. From the calculation results is obtained cost allocation for generator 1 is 2.5553 \$/MW and generator 2 is 2.1483 \$/MW. These results show that cost allocation from generator 1 is more than generator 2. The same is also indicated by the results of the published methods on Table II and III

TABLE IV.  
 TRANSMISSION USAGE AND CHARGES ( $G_1$  AND  $G_2$ )

Line #	$I_{G1}$ (pu)	$I_{G2}$ (pu)
1-2	0.9252	0.0304
1-3	0.3873	0.0304
2-3	0.2081	0.0506
2-4	0.2378	0.0525
2-5	0.4797	0.0871
3-4	0.1823	0.0128
4-5	0.0616	0.0043
Cost (\$/MW)	2.5553	2.1483

After the cost allocation of transmission usage was determined, then total revenues, or  $TR$ , of the methods can be calculated with the following equation.

$$TR = \sum_{i=1} C_{Gi} P_{Gi} \quad (16)$$

Where  $C_{Gi}$  is cost allocation of transmission usage for  $G_i$  and  $P_{Gi}$  is the injected power of  $G_i$ . Then equation (17) is used to calculate deviation:

$$\Delta = \frac{TR - EC}{EC} 100\% \quad (17)$$

Where  $\Delta$  is deviation and  $EC$  is total embedded cost of transmission. From Table I  $EC$  for the 5 bus system in the fig.3 is 3.3148 ( $10^6$  \$/year) or 378.4018 \$/hour.

Table V shows that there is slightly difference between  $TR$  and  $EC$  for the published methods. LUFs & Kirschen give negative deviation and GGDFs & Bialek give positive deviation. Which  $EC$  for ideal conditions is equal to  $TR$  (or zero deviation). This deviation occurs because it is influenced by losses when power is applied as a basis of calculation; It will become worse when losses increase. While the proposed method gives zero deviation. This is caused by the use of current magnitude as a basis of calculation. Current has advantages when compared to power, current magnitude flowing in both ends of each line is same. This has inspired writer to study current as basis of calculation in determining cost allocation of transmission usage. From the illustrative example, the proposed method gives very satisfying results.

TABLE V.  
 COST ALLOCATION OF TRANSMISSION USAGE FOR 5 METHODS

Method	Cost (\$/MW)		Total Revenue	$\Delta$
	$G_1 = 131.27\text{MW}$	$G_2 = 20\text{MW}$	$TR(\$)$	(%)
<b>Proposed</b>	<b>2.5553</b>	<b>2.1483</b>	<b>378.4018</b>	<b>0</b>
GSDFs	2.5880	1.9354	378.4348	0.0087
LUFs	2.5756	2.0147	378.3930	-0.0023
Bialek	2.5604	2.1151	378.4057	0.0010
Kirschen	2.6178	1.7381	378.4006	-0.0003

## V. CONCLUSION

A method for determining cost allocation of transmission usage has been proposed in this paper. Mathematically, the formulations have been illustrated clearly without assumptions and approximations. The method uses current magnitude as a basis of calculation so that the calculation results are not affected by the determination of the flow, either from left to right or from right to left. This is caused by current magnitude at two ends of line is same.

While the published methods use power magnitude as a basis of calculation so that the calculation results are influenced by losses. Determination of power flow will affect the calculation results due to the power flow from left to right be not equal to the power flow from right to left. The greater the losses in the line can make the calculation results that deviate further and further away.

Table IV shows that the proposed method can be applied with satisfactory results. From the table it can be shown that the current flow from each generator on each line can be determined properly. With the current flow can be separated perfectly well in each line are like well shown by the Tabel IV then this makes the key to the success of the proposed method. This is shown by Table V, the published methods gave a non-zero deviation whereas the proposed method gave a zero deviation. The smallest deviation is given by Kirschen algorithm, -0003%. It is very close to the proposed method.

From the test results, the published methods gave a small deviation. However, for large systems, they will give a large deviation. This is thier weakness when compared the proposed method, which the deviation is not influenced by the size of system.

## REFERENCES

- [1] A. Zobian and M.D. Ilic, "Unbundling of transmission and ancillary services-part I: Technical issues and part II: cost based pricing

- framework”, IEEE Trans. on Power system, Vol. 12, No. 2, pp. 539-558, 1997.
- [2] L. Willis, J. Finney and G. Ramon, “Computing the cost of unbundled services”, IEEE Computer Application in Power, (1997), pp. 245-256, 1997.
- [3] Jiuping P., Yonael T., Saifur R, and Koda J., “Review of Usage-Based Transmission Cost Allocation Methods under Open Access”, IEEE Transaction on Power Systems, Vol.15, No.4, 2000.
- [4] Hemagasantos Z., “A Proposed method for Determining Power Decomposition”, The 12<sup>th</sup> Internasional Conference on QiR (Quality in Research), Program Book, Faculty of Engineering Universitas Indonesia, pp. 513-520, 2011.
- [5] Hemagasantos Z., “Penentuan Biaya Pokok Penyediaan Tenaga Listrik pada Suatu Sistem Regional”, Seminar & Pameran Teknologi dan Bisnis Ketenagalistrikan Nasional 2011, Sasana Budaya Ganesha-Bandung, Institute Technology of Bandung, Proceeding Daftar isi no. 25, 2011.
- [6] Hemagasantos Z. and Erwin D., “Cost Allocation of Transmission Losses in Electric Market Mechanism”, Journal of Telkomnika, Vol.10, No.2, pp. 199-208, 2011.
- [7] Exposito AG, Santos JMR, Garcia TG, Velasco EAR, “Fair Allocation of Transmission power losses”, IEEE Trans. on Power System, Vol. 15, No. 1, pp. 184-188, 2000.
- [8] JM Vignolo and Paul MS, “Allocation of Loss Costs in Distribution Networks: The Nodal Factor Pricing Method”, International Journal of Power Systems, Vol. 10, No. 10, 2004.
- [9] Pan J, et al, “Review of Usage-Based transmission Cost Allocation Methods under open Access”, IEEE Transaction on Power System, Vol. 15, No. 4, (2000).
- [10] PM De Oliveira-De Jesus and MT Ponce de Leão, “Cost Loss Allocation in Distribution Networks with Embedded Generation: A Fuzzy Approach”, Proceedings of IEE MedPower Limassol, 2004.
- [11] MW Mustafa, SN Khalid, H Shareef and A Khairuddin, “Transmission Usage Allocation in Pool and Bilateral Trades Using Artificial Neural Network”. WSEAS Trans. on Power Systems, Vol. 2, No.9, pp. 215-224, 2007.
- [12] Hemagasantos Z., Yusra S and Ali M., “Implementation of Electricity Competition Framework with Economic Dispatch Direct Method”, Journal of Telkomnika, Vol.10, No.4, pp. 667-674, 2012.

**Hemagasantos Zein** is a lecturer in Energy Conversion Department, Politeknik Negeri Bandung (Polban), Indonesia. He was born in Pasaman Barat, West Sumatra, Indonesia in July 11, 1959. He received S1's degree in Electrical Engineering with the subject Distribution Network, from Institut Teknologi Bandung, Indonesia in 1985 and S2's (Master's) degree in Electrical Engineering with the subject Bad Data Identification in Electrical System from Institut Teknologi Bandung, Indonesia in 1991. He obtained the Doctoral degree in Electrical System with the research subject Reduction Step in Interior Point for Optimal Power Flow from Institut Teknologi Bandung, Indonesia in 2005

# Magneto-Static Flux Manipulator Prepared for Future Geomagnetic Power Plant

Teti Zubaidah, Bulkis Kanata, Paniran  
 Jurusan Elektro, Fakultas Teknik  
 Universitas Mataram  
 Jl. Majapahit 62, Mataram 83125, INDONESIA  
 tetizubaidah@te.ftunram.ac.id  
 uqikanata@te.ftunram.ac.id  
 paniran@te.ftunram.ac.id

**Abstract**—Magnetic flux resulting from geomagnetic anomaly is a natural energy source that never runs out, driven by tectonic settings or specific rock structures. Unfortunately, this natural resource has not been exploited at all; therefore frontier technological innovations in electromagnetic fields are required. Geomagnetic flux concentrator is a system designed to actively collect the Earth's magnetic fluxes and direct them in a catchment area, in order to increase the geomagnetic output flux densities to meet the required densities of common electrical generators. Earth's magnetic fields are of very low frequency or nearly static field that must be firstly manipulated to achieve a cut-off frequency, needed to be able to steer them through the waveguides. The designed magneto-static flux manipulator worked by periodically placing a round shielding sheet, which is continuously fast rotated across the constant magnetic fluxes flow. Hence the fluxes on the opposite side of the shielding sheet will turn into high frequency geomagnetic pulses (of some MHz), so that they will be just like a series of electromagnetic waves which are spatially separated, then they will be able to be further guided and concentrated. This paper report the initial results of performance tests of the magneto-static flux manipulator, tested with a Helmholtz coil in a calibrated semi-anechoic chamber. The manipulator was tested in the Lombok Island, which is located at the highest intensity of the geomagnetic anomaly of Indonesian region. Results show that the manipulator performed good frequency manipulations up to about 60 Hz for rotated shielding of 900 rpm, which will be possible to reach the higher frequencies.

**Keywords**—Geomagnetic anomalies; flux density; concentrator; waveguides

## I. INTRODUCTION

Geomagnetic studies over the Lombok Island regions have been conducted continuously since 2004 by a team of researchers from the Mataram University [1, 2, 3], where the results of a recent survey carried out in collaboration with the *Deutsches Geo-Forschungszentrum* (GFZ) Potsdam - Germany showed a difference in the intensity of the magnetic in the strongest dipolar structure up to 1000 nT [4, 5, 6]. The high Earth's magnetic fluxes density in the Lombok Island regions can become natural sources of inexhaustible energy, while their source comes from the tectonic settings of this region which is between two active subductions [6]. Unfortunately, these

natural resources have not been utilized at all, hence necessitating a frontier technological innovation in electromagnetic in order to practically utilize the geomagnetic field for electrical generators.

A multilevel concentrator system will be designed to collect and increase the geomagnetic flux density with a gain of 10, to finally get static magnetic intensity of 10,000 gauss from five levels concentrator. While Earth's magnetic fields are of very low frequency or nearly static field, so that they must be firstly manipulated to achieve a cut-off frequency, needed to be able to steer them through the waveguides. Therefore, what we need first to make the flux concentrator work is a magneto-static manipulator. This paper report the initial results of performance tests of the magneto-static flux manipulator, tested with a Helmholtz coil in a calibrated semi-anechoic chamber.

## II. DESIGN AND TESTING OF MANIPULATOR

The designed magneto-static flux manipulator worked by periodically placing a round shielding sheet, which is continuously fast rotated across the constant magnetic fluxes flow. Hence the fluxes on the opposite side of the shielding sheet will turn into high frequency geomagnetic pulses (of some MHz), so that they will be just like a series of electromagnetic waves which are spatially separated, then they will be able to be further guided and concentrated. The manipulator was tested in a semi-anechoic chamber 3 m x 3 m x 3 m equipped with a pair of 100 turns Helmholtz coils with a diameter of 2 m. We have previously demonstrated that our self arranged chamber can reduce external static magnetic fields from outside with shielding effectiveness of 87.5% [11], and refinement of the Helmholtz coils have been done in order to induce larger and more uniform static magnetic fields [12].

The manipulator basically consists of two round shape shielding sheets, each with diameter of 1 m. The sheets are of 3 mm thick of Mu-metal material, with nearly 70 % Nickel and the rest 30 % of mixed metals (i.e. Iron, Cadmium and Cobalt). The two sheets are sliced so as to make four identical holes as well as four shielded areas on each sheet, which their dimensions suitable with the planned waveguides (cut-off frequency around 1 MHz).

When the manipulator is in operation, the shielding sheets which placed in the rear will be kept static (no motion), while another sheet in the front will be turned around. The moving sheet is coupled to a 1500 rpm three phase induction motor via a fix rubber belt. While it runs with the moving shielding sheet as load, its maximum speed is reduced from 1500 rpm down to about 900 rpm. The motor speeds are controlled by a voltage regulator, which its output currents have been previously calibrated by using a photo tachometer to get the desired speed. During tests, all electrical parts including the magnetic fields measuring equipment (SPECTRAN NF-5035®) are controlled

from outside the chamber, and live monitored by two sets of CCTV cameras. Results of field measurements can be logged or live monitored using MCS computer program.

Fig. 1(a) shows the manipulator when it is placed between a pair of Helmholtz coils in a semi-anechoic chamber, while Fig. 1(b) shows the placement and setting of measuring equipment in front of the manipulator (behind the shielding sheet). Fig. 2 illustrates the electrical circuit used for the tests, while the sequences of tests as well as inputs and outputs parameters are given in Table 1.

TABLE I. TEST SEQUENCES AND PARAMETERS

Sequence	Parameters		Conditions
	Inputs	Outputs	
Shielding effectiveness	Fixed inducing current in the Helmholtz coil (2 A)	Magnetic fields intensities behind the shielding in x-, y- and z- directions	The shielding sheet is in no motion mode and the holes are in fully open condition
Frequency response	<ul style="list-style-type: none"> <li>Fixed inducing current in the Helmholtz coil (1 A)</li> <li>Velocity of rotated shielding (by regulating the voltage input of induction motor)</li> </ul>	<ul style="list-style-type: none"> <li>Magnetic fields intensities behind the shielding</li> <li>Frequency of magnetic fields behind the shielding</li> </ul>	The shielding sheet is in motions mode, with variations of speed (900 – 400 rpm).
Background frequency	Current in the Helmholtz coil	Magnetic fields intensities behind the shielding	The Helmholtz coil without and with fixed inducing current (1 A); while the shielding sheet is in three different states: <ol style="list-style-type: none"> <li>No motion mode and the holes are in fully open condition,</li> <li>No motion mode and the holes are in fully closed condition,</li> <li>Full speed of 900 rpm.</li> </ol>

### III. MANIPULATOR PERFORMANCE

#### A. Shielding Effectiveness Test

Shielding effectiveness test is performed in no motion mode and the four holes are in fully open condition. Fig. 3 shows the results of shielding effectiveness test, when a constant of 2 A inducing currents are given to the Helmholtz coils. Here we show that the shielding material is quite effective to stop the flux directed through the x-axis, evident by generated discrete pulses of very low frequency of some 2 Hz. In contrast, the fluxes on the other two axes will remain unchanged, because the shielding is placed orthogonally in front of x-axis.

#### B. Frequency Response Test

Frequency response test is performed in motion mode with various speeds, i.e. 900 – 400 rpm, in 100 rpm step. Twenty to twenty five data are collected and then averaged for each speed variations. Fig. 4 shows the results of frequency response test, when a constant of 1A inducing currents are given to the Helmholtz coils. Here again we show that the shielding is quite effective to stop the flux directed through the x-axis, evident by changes in magnetic intensity due to difference speed of shielding motions. In this case, the fluxes on other two axes will also be changed, because now the fields are no more static but have frequencies of some hertz. Magnetic intensities are linear to the velocity of shielding; due to how frequent the fluxes can pass the shielding through the holes. The frequency



(a)



(b)

Fig. 1. (a). The Magneto-Static Flux Manipulator, placed between a pair of Helmholtz coils in the semi-anechoic chamber. (b). Placement and setting of measuring equipment (SPECTRAN NF-5035®)

responses are quite good, nearly similar to the theoretical values.

### C. Background Frequency Test

Background frequency test is performed for two conditions, i.e. when the Helmholtz coils with and without induced current. For each condition, the manipulator is tested while the shielding is in three different states: a). no motion mode and the holes are in fully open condition, b). no motion mode and the holes are in fully closed condition, and c). in full speed of 900 rpm. Ten to fifteen data are collected and then averaged for each condition and state. Results for initial conditions, when no induced currents are applied on the coils, are listed in Table 1. They will be compared to the results when 1A inducing currents are applied as in Table 2. Fig. 5 shows the comparison of results under both conditions, while the shielding sheet is in three different states (fully open, fully closed, and 900 rpm). Frequency ranges are set from 15 Hz to 75 Hz in 15 Hz steps.

Here we show that for all cases of all frequency ranges, there are no changes in the magnetic intensities in the direction of y and z-axis as long as the shielding is in no motion mode. These are also valid in the case of no or with inducing currents applied on the coils, and whether the shielding holes are fully open or fully closed. It means that the inducing currents, when no motion of shielding, only induced static magnetic fields and affect only magnetic intensities in the direction of x-axis. In this direction, magnetic intensities will decrease for the higher frequency ranges. Besides, when inducing currents are applied, the intensities of fully open conditions are slightly higher than the fully closed ones. It means that by applying inducing currents, there should be low frequency magnetic pulses generated in the direction of x-axis.

Further, we should analyze the effects of shielding motions in the induced magnetic intensities. It is clear that by inducing currents in full speed motion state, the intensity in x-axis dramatically increase. On the other hand, the intensities slightly decrease in other two axes directions.

### IV. DISCUSSION

Testing of magneto-static flux manipulator shows that the manipulator performs good manipulations for various shielding velocities up to of 900 rpm, equal to the induced magnetic field frequency of about 60 Hz. However, comparing to the previous results when the manipulator has not been placed on the chamber, the static magnetic inductions (after correction factors applied) are 31,143.88 nT on the direction of x-axis [12]. It means that not all of the static magnetic flux (only about 0.16% of them) can be manipulated to frequency 60 Hz by placing the 900 rpm rotating manipulator in the chamber. Therefore, more detail calculation should be made before we decide how many levels of concentrators are needed to get the required flux densities and to be applicable for common electrical generators. Other alternative solutions, such as using parallel flux manipulators, probably more applicable to increase the intensity of output fluxes. However, economical costs investments should also be considered, since using valuable Mu-metals as shielding materials are clearly very expensive.

The manipulator was tested in the Lombok Island, which is located at the highest intensity of the geomagnetic anomaly of Indonesian region [5, 6]. The main objective of this research is therefore using natural anomalous phenomena of the Earth's magnetic field over the Lombok Island to supply electrical energy from renewable and environmentally friendly resources. Results of this research are expected to be applicable in other areas with high geomagnetic anomaly over the World. Some potential areas are in Indonesian region as mapped by the CHAMP satellite, which are along the northern island of Java, the island of Bali, the island of Sumbawa, and the north island of Sulawesi [7, 8, 9]. Moreover, [10] have marked several high potential geomagnetic anomalies in the first World Digital Magnetic Anomaly Map (WDMAM), which are in the Chicxulub crater in the North America, the Bangui anomaly in the Middle Africa, the Thromsberg anomaly in the South Africa, the Richat structure in the West Africa, the Bay of Biscay, along the Java Trench in Indonesia and the Paris Basin. These specific places are quite potential for locations of the geomagnetic flux concentrator applications.

### V. CONCLUSION

We have demonstrated the performance of magneto-static flux manipulator, and conclude that:

1. The shielding material with its holes is quite effective to stop the flux in the direction orthogonal to it, evident by generated discrete pulses of very low frequency of some 2 Hz.
2. The frequency responses of manipulator are quite good, nearly similar to the theoretical values. Magnetic intensities are linear to the velocity of shielding; due to how frequent the fluxes can pass the shielding through the holes.
3. When no motion of shielding, the coils induce static magnetic fields only. In the direction orthogonal to the shielding, magnetic intensities will decrease for the higher frequency ranges.
4. Not all of the static magnetic flux (only about 0.16% of them) can be manipulated to frequency 60 Hz by placing the 900 rpm rotating manipulator in the chamber.
5. More detail calculation should be made to decide how many levels of concentrators are needed to get the required flux densities for common electrical generators.

### ACKNOWLEDGMENT

This research is funded by the Indonesian Ministry of Research and Technology under SINas 2012 program entitled "Konsentrator Fluks Geomagnetik untuk Pembangkit Listrik Tenaga Magnet Bumi (RD-2012-481)". We gratefully thanks to the researchers of EMC Laboratory LIPI at the Puspiptek Serpong for their valuable assistances during preparation phases of our research. TZ is alumni of Electrical Engineering Dept. of University of Indonesia (0493037152).

TABLE II. INITIAL MAGNETIC INTENSITY, WITH NO INDUCING CURRENT ON THE HELMHOLTZ COILS

Freq. range	Magnetic Intensity (nT)								
	$B_x-O$	$B_y-O$	$B_z-O$	$B_x-C$	$B_y-C$	$B_z-C$	$B_x-900$	$B_y-900$	$B_z-900$
15-30 Hz	150.81	225.78	114.90	149.79	234.69	114.90			
30-45 Hz	79.51	118.30	58.92	79.51	118.30	59.11			
45-60 Hz	53.79	79.32	39.87	53.79	79.32	39.87			
60-75 Hz	41.03	59.31	30.20	41.03	59.31	30.20	17.85	39.30	47.33

TABLE III. MAGNETIC INTENSITY, WITH 1A INDUCING CURRENTS ON THE HELMHOLTZ COILS

Freq. range	Magnetic Intensity (nT)								
	$B_x-O$	$B_y-O$	$B_z-O$	$B_x-C$	$B_y-C$	$B_z-C$	$B_x-900$	$B_y-900$	$B_z-900$
15-30 Hz	251.70	226.67	114.90	243.84	224.32	114.86			
30-45 Hz	127.08	118.69	57.88	123.06	118.3	58.73			
45-60 Hz	87.85	79.32	39.62	94.33	79.32	39.18			
60-75 Hz	80.37	59.31	30.18	70.05	59.31	30.20	52.94	38.66	42.99

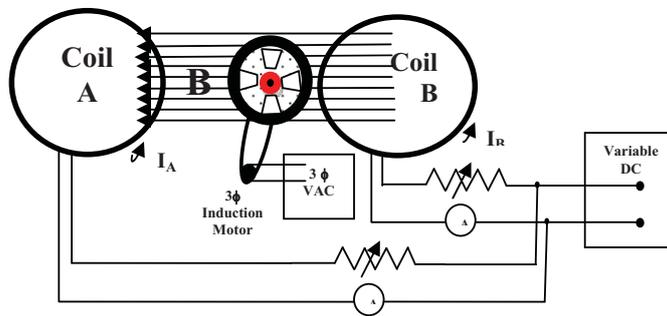


Fig. 2. Electrical circuit diagram used for testing of manipulator.

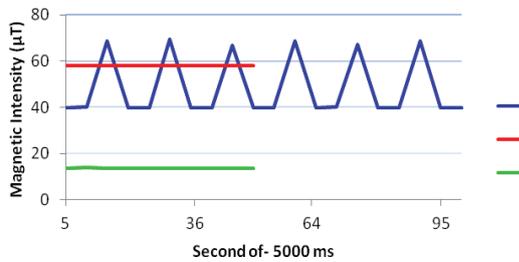


Fig. 3. Results of shielding effectiveness test, shows that the shielding is quite effective by performing flux manipulations on the x-axis (the axis of Helmholtz coil); while fields on the other two axes are remain static.

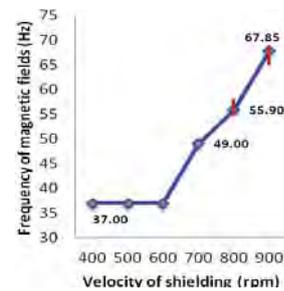
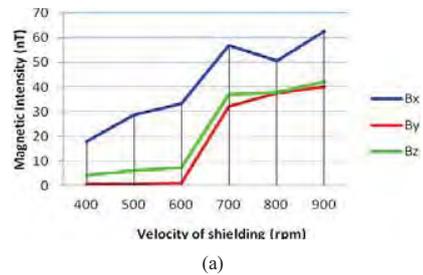


Fig. 4. (a). Magnetic intensity when the shielding is in motion with various speeds. (b). Frequency response of induced magnetic fields due to shielding motions.

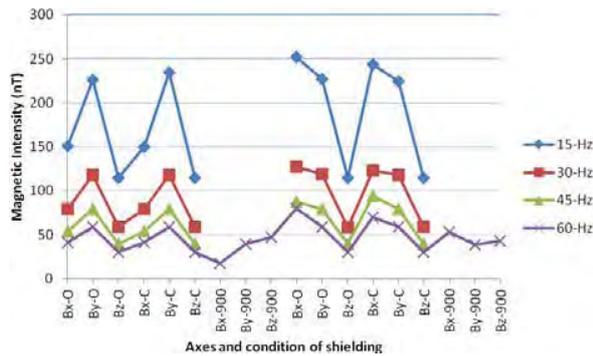


Fig. 5. Results of background frequency test for two conditions: without and with inducing current on the Helmholtz coils, as respectively depicted on the left and right side of the graphic. The magnetic intensity for three different states of shielding sheet are symbolically depicted as -O, -C, and -900.

#### REFERENCES

- [1] Zubaidah T, Kanata B, Islamiyah N, Arumdati N (2004) Investigasi potensi anomaly medan magnet bumi di kota Mataram pulau Lombok propinsi Nusa Tenggara Barat. Laporan akhir penelitian – Proyek Semi QUE V, Jurusan Elektro FT-UNRAM.
- [2] Zubaidah T, Kanata B, Utama W, Arumdati N (2005) Pengembangan metodologi elektromagnetik dan aplikasinya untuk evaluasi sumber anomaly magnet bumi: Kajian tentang potensi Sumber Daya Alam di kota Mataram pulau Lombok propinsi Nusa Tenggara Barat. Laporan akhir penelitian – PRSD MIPA tahun 2005, Jurusan Elektro FT-UNRAM.
- [3] Zubaidah T, Kanata B, Nurhandoko BEB, Bijaksana S (2006) Pemantauan keberadaan anomaly geomagnet ekstrem di pulau Lombok NTB: Penentuan pola variasi anomaly geomagnet untuk prediksi terjadinya gempa tektonik di daerah patahan. Laporan akhir penelitian – Hibah Pekerti tahun 2006, Jurusan Elektro FT-UNRAM.
- [4] Zubaidah T, Kanata B, Utama W, Arumdati N (2007) Hasil-hasil awal pemantauan keberadaan anomaly geomagnet ekstrem di pulau Lombok: Penentuan pola variasi anomaly geomagnet untuk prediksi terjadinya gempa tektonik di daerah patahan, Jurnal Rekayasa, Fakultas Teknik Universitas Mataram, Mataram.
- [5] Zubaidah T, Korte M, Manda M, Quesnel Y, Kanata B (2010) Geomagnetic field anomalies over the Lombok Island region: an attempt to understand the local tectonic changes. *Int. J. Earth Sci. (Geol. Rundsch.)*, 99 (5): 1123–1132, doi: 10.1007/s00531-009-0450-4.
- [6] Zubaidah T (2010) Spatio-temporal characteristics of the geomagnetic field over the Lombok Island, the Lesser Sunda Islands region: New geological, tectonic, and seismo-electromagnetic insights along the Sunda-Banda Arcs transition. *Scientific Technical Report of GFZ, STR10/07*, ISSN 1610-0956, doi: 10.2312/GFZ.b103-10079.
- [7] Maus S, Rother M, Hemant K, Stolle C, Lühr H, Kuvshinov A, Olsen N (2006) Earth's lithospheric magnetic field determined to spherical harmonic degree 90 from CHAMP satellite measurements. *Geophys. J. Int.* 164: 319–330, doi: 10.1111/j.1365-246X.2005.02833.x.
- [8] Maus S, Lühr H, Rother M, Hemant K, Balasis G, Ritter P, Stolle C (2007) Fifth-generation lithospheric magnetic field model from CHAMP satellite measurements. *Geochem. Geophys. Geosyst.* 8, Q05013, doi: 10.1029/2006GC001521.
- [9] Maus S, Yin F, Lühr H, Manoj C, Rother M, Rauberg J, Michaelis I, Stolle C, Müller RD (2008) Resolution of direction of oceanic magnetic lineations by the sixth-generation lithospheric magnetic field model from CHAMP satellite magnetic measurements. *Geochem. Geophys. Geosyst.*, Technical Brief 9 (7), Q07021, doi: 10.1029/2008GC001949, ISSN: 1525-2027.
- [10] Manda M, Thébault E (2007) The changing faces of the Earth's magnetic field. *CGMW, Paris*. ISBN: 978-2-9517181-9-7.
- [11] Zubaidah T, Kanata B, Paniran, Irmawati B (2012) Self arrangement of anechoic chamber and Helmholtz coil for EMC test. *Proceeding, Seminar Nasional Teknik Elektro I, Fakultas Teknik Universitas Mataram*.
- [12] Zubaidah T, Kanata B, Paniran (2012) Rekalibrasi Kumparan Helmholtz untuk Pengujian Sistem Konsentrator Fluks Geomagnetik. *Proceeding (in press), Seminar Nasional INSINas 2012, Kementerian Riset dan Teknologi, Bandung*.

# Design of Slotted Core Axial Flux Wound Rotor Synchronous Generator

Abdul Multi

Electrical department  
 National Institute of Science and Technology  
 Jakarta Selatan, DKI Jakarta  
 multiab@yahoo.com

Iwa Garniwa

Electrical department  
 University of Indonesia  
 Depok, Jawa Barat  
 iwa@eng.ui.ac.id

**Abstract**— The generator designed in this research is Axial Flux Wound Rotor (AFWR) and as two air gaps machine. It has a planar and somewhat adjustable air gap with slotted stator and rotor. This generator is small-scale capacity which has 380 V, 1 kW and 750 rpm. The windings are laid into slots made from laminated core. The generator has a single double-sided slotted wound stator sandwiched between twin rotor. The generator relates only to wound rotor machine with disc type rotor and stator. The axial flux machine generally uses permanent magnets mounted on the rotor. Replacing the permanent magnet with a winding in the rotor, makes it possible to control the flux by varying the current flowing into the field winding. The results of design computation reveal electric quantities suited with respect to performance of the generator. Varying the airgaps and excitation voltages of the axial flux generator, its performance might be controlled to meet the need of a load attached to its terminal. It has been found out that for the airgap of 1.0 mm and the excitation voltage of 11 V, the field current and the efficiency are 3.82 A and 85.30% respectively.

**Keywords**— Synchronous generator, axial flux, efficiency, air gap.

## I. Introduction

The axial flux permanent magnet (PM) machines have a number of distinct advantages over radial flux machines (RFM). They can be designed to have a higher power-to-weight ratio resulting in less core material. Moreover, they have planar and easily adjustable airgaps. The noise and vibration levels are less than the conventional machines. Also, the direction of the main air gap flux can be varied and many discrete topologies can be derived. These benefits present the AFMs with certain advantages over conventional RFMs in various applications [1].

Besides these benefits, the flux density is reduced due to the large airgap. However, one important advantage of this machine is that the structure transfers the heat from the stator frame very easily. Therefore, machine electrical loading can be relatively high. This is an important feature of axial flux machines because suitable shape and size to match the space limitation is crucial for some applications such as electric vehicle. From a construction point of view, brushless AFPM machines can be designed as single-sided or double-sided, with or without armature slots, with or without armature core,

with internal or external PM rotors, with surface mounted or interior PMs and as single stage or multi-stage machines. Stator and rotor positions can be interchanged, the number of stator and rotor can be multiplied and the air gap distance can easily be varied. Some configurations of axial flux permanent magnet machines as shown Fig. 1 [2].

This research will analyze the performance of three phase axial flux wound rotor synchronous generator. With the limited generator output power, it will be sought at what width of air gap, number of stator turns, diameter of stator conductor and excitation voltage will be obtained the highest efficiency. When the rotation of rotor is not constant caused by the prime mover rotation that is not constant, the output voltage generated by the generator will vary. To make a constant voltage, the flux should be controlled by varying the field current flowing through the rotor winding. Therefore the expected advantage of the result of this study is to obtain a precise distance measurement of the air gap, the number of stator turns, the diameter of stator conductor and the excitation voltage on the axial flux wound rotor (AFWR) synchronous machine having the capacity 1 kW with high efficiency. Since a large number of poles can be accommodated, these machines are ideal for low speed applications.

Electrical machine which has high power and high efficiency and also small dimensions while lower price is the

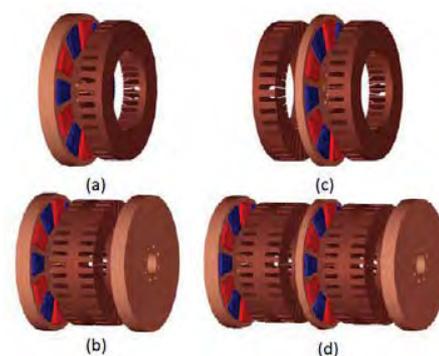


Fig. 1. Axial flux machine configurations.  
 (a) Single rotor - single stator structure, (b) Two rotor - single stator structure, (c) Single rotor -two stator structure, (d) Three rotor - two stator structure.

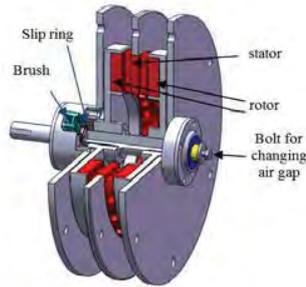


Fig. 2: AFWR synchronous generator

axial flux permanent magnet machine. However, the study has not been performed yet in three phase axial flux wound rotor synchronous generator which its air gap and voltage excitation can be varied. The air gap changes can affect machine parameters and the voltage excitation changes can affect the output voltage.

In the case of engine/generator sets most interest has focused on axial flux generator topologies that have two rotor discs and one stator disc. Such an axial flux generator can be usefully integrated with an engine as it is axially very short and so can be mounted directly on the engine output shaft, eliminating the need for separate bearings or couplings. The generator has, or can be designed to have, a moment of inertia that makes the flywheel redundant [3].

An axial flux machine with wound rotor is referred to as an axial flux wound rotor (AFWR). A cross sectional schematic of the AFWR machine is shown in Fig. 2. The AFWR generator consists of two wound rotor that two windings are connected in parallel. The stator of AFWR generator is located between two opposing wound rotors. The double-sided rotor simply called twin rotor with slots are located at sides of stator and rotor lamination core.

## II. DESIGN OF THE MACHINE

The design of axial flux synchronous generator is done by calculations based on the equations of the axial flux and the radial flux machines. Equations applied are related to electric circuits, magnetic circuits and mechanics on the stator and the rotor. The Matlab program is used for accuracy and precision calculations, while Solidworks software is used for drawing the machine and its parts.

The design of synchronous generator is started with determining the specifications of the machine, then selecting materials and assigning design parameters. Before processing the design of the electrical circuit, the magnetic circuit and the mechanics, it is first assumed the parameter optimizations associated with the specification of the machine. It is expected at the end of the design process, the performance of the machine is met the need. If the performance has not met yet, then the design process should be repeated by changing

optimization parameters. If the performance has been met, the design data sheet can be printed. Stages of the design are

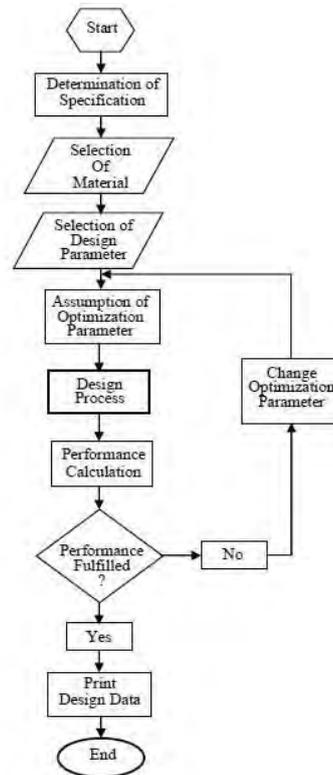


Fig. 3. The flowchart of design process

shown in the flowchart in Fig. 3. The process of optimization in the design of the machine aims to obtain higher efficiency with power output fixed previously.



Figure 4: The slotted stators and rotor, before and after winding

The machine designed is three phase axial flux wound rotor (AFWR) synchronous generator where magnetic flux lines cross the air gap in axial direction with the machine axis. The stator and rotors are disc shaped and located in parallel next to each other. The stator having two side slots are located between twin slotted rotors. Windings are then laid into slots carved in the rotor and stator face shown in Fig. 4.

In principle, the electromagnetic design of AFPM machines is similar to its radial flux PM (RFPM) counterparts with cylindrical rotors. However, the mechanical design, thermal analysis and assembly process are more complex [4]. Specifications of three phase AFWR synchronous generator designed is the nominal quantity (rated). Quantities include output power, terminal voltage (phase to phase), frequency, rotor rotation and power factor. The input power and the load torque are on the shaft of prime mover which rotates the generator rotor windings. The rotor winding is connected to a source of direct current so that the field current flows through the field winding. The field current produces a steady-state magnetic field in the rotor.

A synchronous generator can be operated as motor. The synchronous motor have several advantages in comparison with the induction motor such as controllable power factor and larger air gap. The drawbacks of induction motor are their small air gap, which are needed to create higher efficiency. However, the air gap of those of two machines can not be adjusted. In this case the nonmagnetic air gap is large and high energy magnet are required. The air gap magnetic flux density decreases as the air gap increases [5].

### III. MANUFACTURING OF THE MACHINE

This section contains the manufacturing of the generator based on the results of design calculations. The manufacturing is started from stator and then rotor parts. The stator and the rotor parts consist of core, slot, brush and slipring while mechanical parts consist of shaft and bearing. After calculations using Matlab software, the drawings either two-dimensional or three-dimensional can be done by using Solidworks software. Manufacturing of the generator is based on two-dimensional plot of Solidworks.

#### A. Manufacturing Of Stator

This AFWR generator is designed to produce frequency of 50 Hz, rotation of 750 rpm and has the number of 8 poles. Terminal voltage is 380 V and phase voltage is 220 V. Output power is 1.000 W. With  $\epsilon = 0.9607$ ,  $k_d = 0.5714$ ,  $n_s = 12,5$  rps,  $B_{mg} = 0,6305$  Wb/m<sup>2</sup>,  $A_m = 5.712$  A/m<sup>2</sup>,  $\cos\phi = 0,83$  and  $k_D = 0,1323$  obtained from the given equation, the disk outer and inner of stator and rotor are 0,28 m and 0.16 m respectively.

The stator and rotor core of the machine are made from CRGO (Cold-Rolled Grain Oriented) silicon electrical steel

with M-5 specification and thick of 0,3 mm. Rolled Silicon steel plate is shown in Figure 5. This generator has two rotors with single side slot and one stator with two slot sides. Each side either stator or rotor has the same number of slots. The



Fig. 5. Rolled silicon steel plate lamination

TABLE I. DIMENSION OF STATOR AND ROTOR

Parameter	Symbol	Stator	Rotor
Number		1	2
Side		2	1
Slot	S	24	16
Outer diameter	$D_{out}$	0,28 m	0,28 m
Inner diameter	$D_{in}$	0,16 m	0,16 m
Thickness	$d_s / d_r$	0,0405 m	0,0203 m
<b>Slot</b>			
- slot diameter	$d_{sc}$	0.0135 m	0.0135 m
- stator opening	$b_{14}$	0.003 m	0.003 m
- Cross section area	$A_s$	0.0143 m <sup>2</sup>	0.0143 m <sup>2</sup>

stator and rotor discs have 24 slots respectively. The dimensions of stator and rotor are listed at Table I. Rolled silicon steel plate lamination before slotting is shown in Fig. 5. The rated output current in a single side stator  $I_a = 1.0203$  A, so that the total output current from the generator will be 2.0406 A, where the three stator winding are Y-connected and the number of phase  $m_1 = 3$ , the number of armature turns of a single stator per phase  $N_1 = 440$  turns per phase.

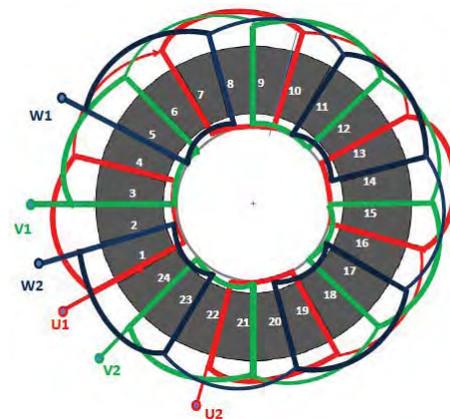


Fig. 6. A circle stator winding diagram which producing eight-magnetic poles

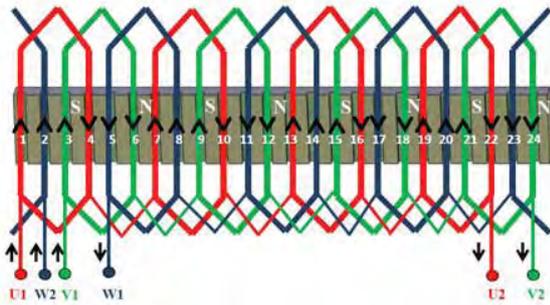


Fig. 7. A winding diagram of stator, showing how the stator currents produce north and south magnetic poles.

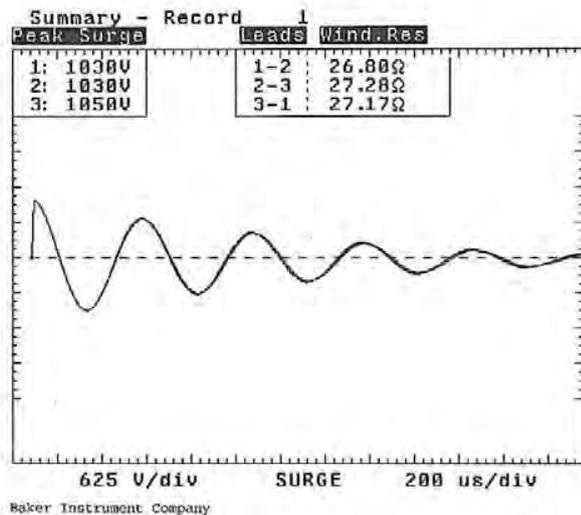


Figure 8: Voltage wave to know the balanced impedance of the three stator winding.

The stator is wound with coil pitch of 3 slots, so the coils must span 3 stator slots. It means for a conductor in slot 1 goes into slot 4 and for a conductor in slot 4 goes into slot 7 and so on. In order to get 8 poles in the stator, it might be wound as shown in Fig. 6 and 7. Copper wire conductors that are wound in the stator have cross section area  $s_a = 1.96 \times 10^{-7} \text{ m}^2$ , then its conductor diameter is 0.5 mm.

Using the class F (115 °C) enamel insulation of the armature conductors having thick ( $t_e$ ) of 0.024 mm, the diameter of the wire with insulation  $d_e$  is 0.548 mm. Hence, the total cross sectional area of all conductors in the stator slot  $A_{sc} = 5.3776 \times 10^{-5} \text{ m}^2$ , diameter and the cross section area of a single slot is approximately  $d_{sc} = 13.5 \text{ mm}$  and  $A_{scir} = 1.43 \times 10^{-4} \text{ m}^2$  respectively. The resulting slot fill factor  $k_{fs} = 0.3757$  showing the stator can be easily wound, since the

average slot fill factor for low voltage machines with round stator conductor is about 0.4. A circle and horizontal stator wiring diagram are shown in Fig. 6 and 7.

In order to know the balance of resistance among the three stator winding, test is done by giving an impuls voltage. From the test, it is obtained that the three voltage waves of phase winding are lines up with each other. It shows the balanced resistance of the three stator windings. The three balanced resistances are 26.80 Ω, 27.28 Ω dan 27.17 Ω respectively. The results of test records of balanced stator winding resistances are shown in Fig. 8. Each of phase winding in a stator side is connected in parallel with a phase winding in other stator side, the resistance of the three stator windings are divided by two then each resistance becomes 13.4 Ω, 13.64 Ω and 13.585 Ω.

#### B. MANUFACTURING OF ROTOR

This machine has 2 rotors (twin), each rotor consists of 24 slots. The slots will be filled with conductors of field coil flowed direct current fed by source voltage of 10 V. The rotor is wound with coil pitch of 2 slots, it means for a conductor in slot 1 will go to slot 3 and the conductor in slot 4 will go to slot 6 and so on. In order for the rotor to have 8 poles, it is wound as shown in Fig. 9. Conductor wound in the rotor has a diameter of 1,7 mm.

The rotor mmf  $AT_n = 314,06 \text{ AT}$ , resistivity of copper in the temperature of 20°C  $\rho = 2,1277 \times 10^{-8} \text{ } \Omega \text{ m}$ , the average of field coil turn  $I_{fav} = 0.4276 \text{ m}$  and the voltage of each field coil  $E_{fc} = 1,2 \text{ V}$ , the cross section area of field coil  $s_f = 2,18 \text{ mm}^2$

For the class F enamel insulation of the field conductors with thick of 0,024 mm, the diameter of wire  $d_{fc} = 1,748 \text{ mm}$ . The number of conductors in a rotor slot  $N_{fs} = 63$  conductors. To supply the dc power from an external dc source to the rotor winding, slip rings and brushes are used. The brush is made from graphite carbon material which has application limit for current density 8 to 12 A/cm<sup>2</sup> in continuous operation and maximum operation of 30 A/cm<sup>2</sup> with peripheral speed permitted until 25 m/s [6].

With dc current flowing through the field winding of 3.82 A, brushes are needed which have dimensions 10 mm x 16 mm EG367J (10x16x25 mm<sup>3</sup>). If the positive end of a dc voltage source is connected to one brush and the negative end is connected to the other, its total contact surface is 10 mm x 16 mm = 1,60 cm<sup>2</sup>. The current density is  $4,1260 \text{ A}/1,6 \text{ cm}^2 = 2,57875 \text{ A}/\text{cm}^2$ .

Because the rotor rotates and the brush is stationary, the machine needs slip ring as a media connecting rotor winding and brush. To connect external dc source with rotor winding which the ends of the two rotor wires are tied to slip rings on the rotor's shaft, it is required two brushes and two slip rings. The stationary brushes ride on each rotating slip ring. Slip rings are copper rings completely encircling the shaft of a machine but insulated from it. Each slip ring has a dimension of 12 mm x 2,5 mm = 30 mm<sup>2</sup>. This slip ring is capable carried the current more than 50 A [11]. Whereas the field

current flowing in this slip ring only 3.82 A with field voltage  $E_{fe} = 1,2$  V and field resistance  $R_f = 0,28 \Omega$ .

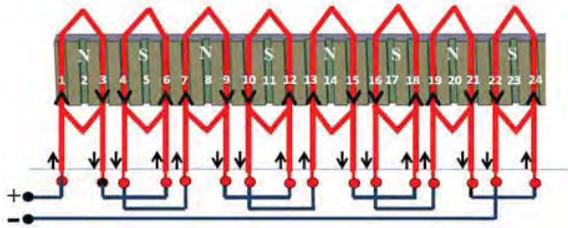


Fig. 9. A rotor winding diagram which producing eight-magnetic poles, showing how the rotor currents produce north and south magnetic poles.

#### IV. MACHINE PARAMETERS AND PERFORMANCE

The parameter values of this machine are obtained from calculations using MATLAB and it is used to analysis performance of the machine based on output power. The core losses are assumed 5% and the friction and windage losses are 7% of the output power [4, 7]. The principal problems are based on output power and efficiency of the machine. The magnitude output power has been fixed, while the efficiency is sought to the highest value. The output power and the efficiency will be changed by varying parameters.

An optimal efficiency value is sought in the fixed output power. The optimal efficiency is obtained by varying optimization parameters consist of airgap, excitation voltage, conductor diameter and number of stator turns. The specification of machine operation is shown in Table II.

The calculation results showing the output power of 1 kW and efficiency of 85.30% are shown in Table III. Varying optimization parameters, other machine parameters will also change. In the efficiency calculation, optimization parameter is spanned, while efficiency is spanned and output power is examined and selected. From the calculation, it is also obtained dimensions of stator and rotor slots.

From the calculation, it is obtained in the airgap of 1.0 mm, excitation voltage of 11 V, stator conductor diameter of 0,5 mm and number of stator turns per phase of 440 turns give the best solution. The effect of airgap, excitation voltage, number of turns and stator conductor diameter changes on efficiency of the machine are shown in Fig. 10, 11, 12 and 13.

Stator and rotor dimensions are kept constant in the calculation of optimization, so that the changes of number of turns and stator conductor diameter should be examined

TABLE II. MACHINE OPERATION SPECIFICATION

Quantity (unit)	Value
-----------------	-------

Output power (W)	1,000
Terminal voltage (V)	380
Number of poles	8
Frequency (Hz)	50
Power factor	0.83

TABLE III. OPTIMIZATION PARAMETERS IN THE EFFICIENCY OF 85.30 % AND OUTPUT POWER OF 1KW.

Quantity (unit)	Value
Airgap (mm)	1.0
Excitation voltage (V)	11
Number of stator turns per phase	440
Diameter of conductor (mm)	0,5

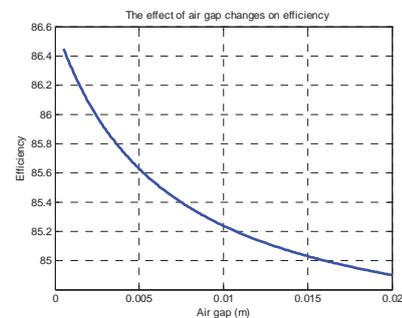


Fig. 10. The effect of air gap changes on efficiency

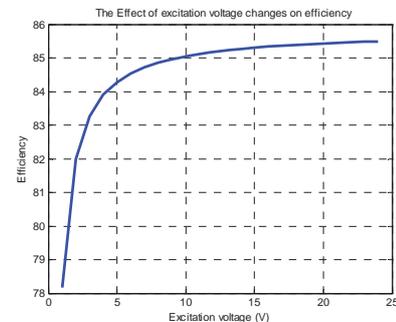


Fig. 11. The effect of excitation voltage changes on efficiency

wether they meet the requirements or not for the slot dimensions. The requirement examination is based on *slot fill factor*. For number of stator turns  $N_1 = 440$  turns, number of conductors per slot is 220 and conductor diameter  $d_a = 0,5$  mm, then according to the given equations, slot fill factor  $k_{fs}$  is 0,3629.

The slot fill factor for rectangular conductors and low voltage machines can be assumed to be 0.6. While the slot fill factor for circular conductors and low voltage machines can be assumed to be 0.4 [5]. In standard motors, copper occupies only half of the slot winding space, because the slot fill factor is about 0.5 [5].

From the calculation, the efficiency of three phase AFWR synchronous generator is higher than induction motor (copper rotor) [8], asynchronous motor (*single layer*), asynchronous motor (3 phase sinusoidal) [9] and TORUS

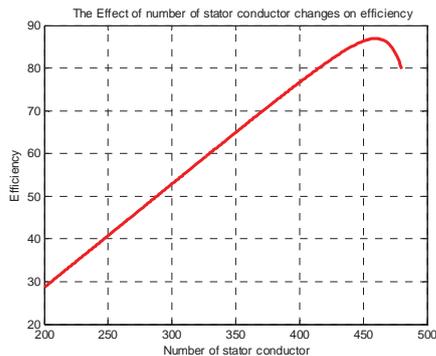


Fig. 12. The effect of number of turn changes on efficiency

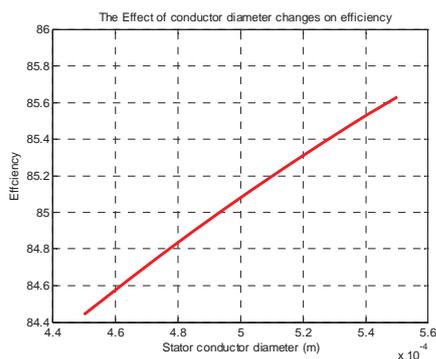


Fig. 13. The effect of conductor diameter changes on efficiency

generator [10] with nearly the same power output. The higher efficiency is obtained by utilizing the optimization parameters that have been previously calculated. The comparison of efficiencies in several machines is shown in Table IV.

TABLE IV. COMPARISON OF EFFICIENCIES IN SEVERAL ALTERNATING CURRENT MACHINES

Type of Machine	Rated Power (W)	Losses (W)	Efficiency (%)
Induction Motor (copper rotor)	1,100	229.2	82.8
Asynchronous Motor (single layer)	1,008	402	71.5
Asynchronous Motor (sinusoidal 3 phase)	1,103	337	76.6

winding)			
Torus Generator	1,000	231.9	81.18
AFWR Synchronous Machine	1,000	184.6	85

## V. RESULT AND DISCUSSION

From the result of AFWR generator design calculated by Matlab software, it is possible to make the complete drawings by SolidWorks. If the calculation of stator, rotor, slot and tooth dimensions are not right, then it will be seen incorrectness at their drawings or occurred fault when they are drawn by SolidWorks.

The efficiency of 85.30% obtained in air gap of 1.0 mm, excitation voltage of 11 V, diameter of stator conductor of 0.5 mm and number of stator turns per phase of 440 turns are constrained by output power of 1 kW. If in the calculations, the efficiency is increased to more than 85.30%, parameters of the machine will occur changes include output and input power. The Conductor size obtained from the calculation results have not been adjusted to the size of the conductors in the market.

The efficiency of AFWR synchronous generator is higher than the efficiencies of alternating current machines because of total losses are lower especially copper losses. The total losses in the AFWR machine is 175.79 W, while in the TORUS AF machine is 231.9 W. Similarly, the total losses in the induction machine (copper rotor), the asynchronous machine (3 phase winding) are higher than AFWR machine 229.2 W and 402 W respectively.

For the number of stator turns per phase  $N_1 = 440$  turns, number of conductors per slot is 220 and the diameter of stator winding conductor  $d_a = 0.5$  mm, Slot fill factor is found to be  $k_{fs} = 0.3629$ . This value of fill factor still meets the requirement because of the value is less than 0.4 for circular conductors and low voltage machines.

Using the number of stator turns per phase  $N_1 = 440$  lilitan, this 3 phase generator will have total turns of 1320 turns. By using the number of conductors per slot and the number of turns per phase, it is possible to obtain the same total turns.

In the first experiment, the measurement of the output voltage result indicates 380 V at 750 rpm. The load connected to the terminal is tube lamp with voltage of 220 V (line to neutral voltage). For the other experiments such as no load test, short circuit test, on load test and the test of effect of air gap changes on the machine can be discussed for further work.

## VI. CONCLUSION

Calculations by using the given equations yield the air gap length is 1.0 mm, the excitation voltage is 11 V, the number of stator turns is 440 and diameter of stator winding conductor is 0,5 mm reveal the best solution at efficiency of 85.30%. With

the number of conductor per slot of 220 and diameter of stator conductor of 0,548 mm, the resulting slot fill factor is 0.3757 that still meets the requirement for rectangular conductors and low voltage machine. From the test of winding resistance, the three waves plot of phase winding voltages coincide with each other. Therefore, they reveal the balance resistance in the three phase stator winding and the resistances are 26.80  $\Omega$ , 27.28  $\Omega$  and 27.17  $\Omega$  respectively.

#### REFERENCES

- [1] M. Aydin, S. Huang and T. A. Lipo, "Axial Flux Permanent Magnet Disc Machines: A Review", Wisconsin Electric Machines & Power Electronics Consortium, University of Wisconsin-Madison, Madison, WI 53706-1691, 2004, p. 1.
- [2] Asko Parviainen, "Comparison Between Permanent-Magnet Low-Speed Machines And Performance Comparison Between Radial-Flux And Machines Axial-Flux", Thesis for the degree of Doctor of Science (Technology), Lappeenranta University of Technology, Digipaino, 2005, p. 17.
- [3] J. R. Bumby And R. Martin, "Axial Flux, Permanent Magnet, Generators For Engine Integration", Published At The 12th International Stirling Engine Conference, Durham, Sept 2005, p. 1.
- [4] Jacek F. Gieras, Rong-Jie Wang, Maarten J. Kamper, "Axial Flux Permanent Magnet Brushless Machines", Kluwer Academic Publishers, London, 2004, p. 1.
- [5] Jacek F. Gieras, "Advancements in Electric Machines", Springer, Bydgoszcz, 2008, p. 122.
- [6] Brushes For Electrical Machines Technical Guide, Iso 9001: 2000, Iso 14001, Carbone Lorraine, Applications Électriques, 10 Rue Roger Dumoulin, F-80084 Amiens Cedex, 2 – France.
- [7] Hamid A.Toliat Gerald B.Kliman, "Handbook Of Electric Motors, Taylor & Francis Group, Boca Raton", 2004.
- [8] S. Asghar Gholamian, M.T. Abbasi Ablouie, A. Mohseni and S. Esmaili Jafarabadi, "Effect of Air Gap on Torque Density for Double-Sided Axial Flux Slotted Permanent Magnet Motors using Analytic and FEM Evaluation", Journal of Applied Sciences Research, 5(9): 1230-1238, Tehran, 2009.
- [9] Juha Pyrhönen, Tapani Jokinen, Val'eria Hrabovcov'A, "Design Of Rotating Electrical Machines", John Wiley & Sons, New Delhi, 2008, p.460.
- [10] Yicheng Chen, "Axial-flux PM Wind Generator with A Soft Magnetic Composite Core", In proceeding of: Industry Applications Conference, 2005. Fourtieth IAS Annual Meeting. Conference Record of the 2005, Volume: 1.
- [11] Current-Carrying Capacities And Other Technical Tables, www.micomcables.com, 13-03-2012.

# The Effect of Number of Blades on the Performance of H-Darrieus type Wind Turbine

Agus Sunyoto, Frederikus Wenehenubun, Hadi Sutanto

Department of Mechanical Engineering

Atma Jaya Catholic University, Jakarta 12930, Indonesia

Tel: (021) 5708826. Fax: (021) 57900573

e-mail: [whenahand@yahoo.com](mailto:whenahand@yahoo.com), ; [hadi.sutanto@atmajaya.ac.id](mailto:hadi.sutanto@atmajaya.ac.id)

**Abstract** - Wind turbines are widely regarded as an alternative source for electrical power generation. Modern wind turbines are classified into horizontal axis wind turbine (HAWT) and vertical axis wind turbine (VAWT) categories. Vertical axis wind turbines (VAWTs) are attractive for applications in the built environment due to their ability to capture wind from different directions. One type of VAWTs is Darrieus turbine or H-type turbine. Experiments conducted in this paper aims to investigate the effect of number of blades in the performance of H-Darrieus type wind turbine. The experiments used 2,3 and 4 blades to show rotation, torque and TSR (tip speed ratio) of wind turbine. A simulation using ANSYS 13.0 software will show the coefficient of power of wind turbine. The results of experiments showed that the number of blades rotation and torque influence the performance of wind turbine.

**Keywords**—wind turbine, vertical axis, H-Darrieus type, blades, tip speed ratio, coefficient of power

## I. INTRODUCTION

Energy resources from earth's fossil energy are limited and the global production of oil, gas and coal will come beyond their peak in the next decades. In other side the need of the energy will rise and also the price of the fossil energy. At the same time there is strong political opposition against global climate change as a result of carbon-dioxide and sulphur-dioxide emission from the burning of fossil fuels. Effective mitigation of climate change will require deep reductions in that green house gas emission. The use of renewable energy as a cost-effective and reliable low-carbon energy sources is becoming an important objective of energy policy in the world. Renewable energy is a climate-friendly energy due to the absence of emissions detrimental to the environment. Some forms of renewable energy are solar thermal and photovoltaic, tidal wave, wind, hydro, geothermal, OTEC and bio-fuel.

Hydropower has been used in electrical power stations and pumped storage systems since many decades, but the use of wind power conversion in larger ratings has begun only in the 1980s. After that, wind energy has shown the fastest rate of growth of any form of electricity generation with its development stimulated by concerns of national policy makers over climate change, energy diversity and security of supply. Figure 1 shows the global cumulative wind power capacity worldwide based on the projection in the 2004 World Energy

Outlook report from the International Energy Agency (IEA) [1].

The wind as a fuel for producing electricity is inexhaustible, free and always available somewhere – and there is enough of it. Hence, wind energy offers a promising renewable energy source and wind turbines are the only way to extract energy from the wind. Wind turbines produce electricity by using the power of the wind to drive an electric generator. Classification according to their constructional design has two kinds of wind turbines, HAWT (horizontal axis wind turbines) and VAWT (vertical axis wind turbines). HAWT has a horizontal axis of rotation, but VAWT has a vertical axis of rotation. VAWT can catch the wind from all direction and at lower wind speed than horizontal axis one. There have been two distinct types of vertical axis wind turbines, the Darrieus and the Savonius types (figure 2). The first aerodynamic VAWT which look like a giant egg whisk was invented by Georges Darrieus and first patented in 1927 [2]. In the 80s, several wind farms with commercial Darrieus turbine was built with a rated power of 4 MW [3]. Peter Musgrove et.al. investigated the original Darrieus turbine with straight blades in the 80s and other researchers developed the straight-bladed Darrieus turbine called H-Darrieus [4]. Some of the most notable researches about H-Darrieus prototypes include a 500 kW version at Camarthen Bay [5].

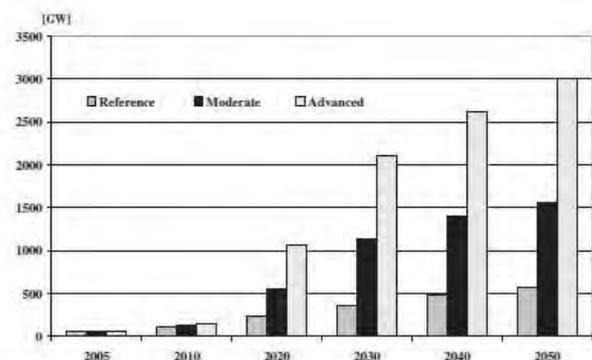


Figure 1. Global cumulative wind power capacity worldwide [1]

H-Darrieus turbine also called giromill and cyclo-turbine as shown in Figure 2c, have been built in recent years with different specifications. The performance of H-Darrieus turbine is related with some parameters such as turbine solidity, number of blades, airfoil selection, blade pitch angle and turbine aspect ratio (H/D).

Studies of small scale vertical-axis wind turbine have attracted a great deal of attention because of the possibility to use a wind tunnel. The advantage of using wind tunnels for research and development is that one can validate the design specification in a relatively short turn-around time. A case of providing the detailed comparison between wind tunnel tests and the full-scale field measurement was reported by Sheldahl [7]. This paper aims at studying the effect of number of blades on the performance of the H-Darrieus vertical axis wind turbine through wind tunnel test.

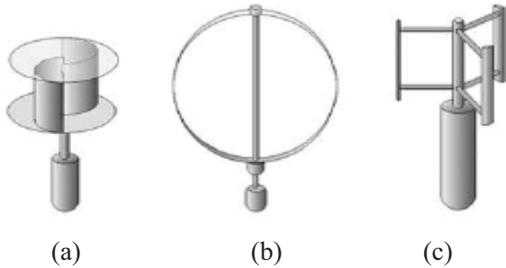


Figure 2. VAWT turbines: (a) Savonius rotor ; (b) Darrieus rotor ; (c) H-Darrieus rotor [6]

## II. WIND TURBINE THEORY

One of the important components of wind turbine is the blades which capture the kinetic energy of wind to generate thrust force as drag or lift force. The thrust force will be converted into mechanical energy or rotation of the shaft of turbine rotor and then converted into electrical energy by the generator. Wind turbine has rotational speed related with electric power as shown in figure 3. Cut in speed is the increasing of rotational speed and starting to generate the electrical energy. Cut out speed is the speed when the wind speed is over and wind turbine will reduce its strength. Rated wind speed is the speed when the wind turbine reaches the average of peak power from generator or rotor.

Coefficient of power or  $C_p$  is the ratio between  $P_k$  and  $P_a$  or

$$C_p = \frac{P_k}{P_a} \quad (1)$$

where  $P_k$  (W) is the power produced by the turbine and  $P_a$  (W) is the power supplied by the wind. The value of  $C_p$  will determine the performance of blades of a wind turbine.

The power of wind turbine is

$$P_k = T \frac{2\pi n}{60} \quad (2)$$

Where  $T$ (Nm) is the torque and  $n$  is the rotation of turbine shaft.

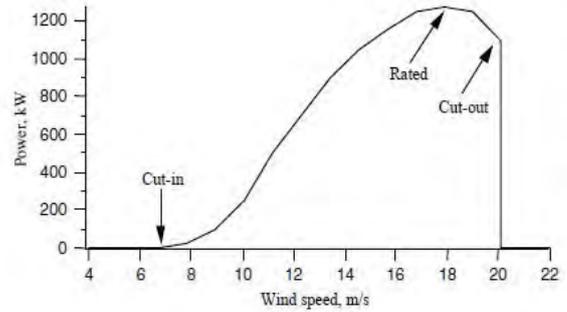


Figure 3. The curve of wind turbine power related with wind speed [8]

A parameter related with rated wind speed, rotation and rotor diameter defined as tip speed ratio (TSR). TSR as a ratio between the speed of tip blade and wind speed through it, can be determined as [9]

$$TSR = \frac{2\pi n}{60v} \quad (3)$$

where  $v$  is the wind speed (m/s).

TSR maximum or  $TSR_{max}$  can be determine related with number of blades as,

$$N_b = \frac{4\pi}{TSR_{max}} \quad (4)$$

where  $N_b$  is number of blades ( $N_b = 2, 3, \text{ or } 4$ ).

In recent research project one common number of blades is three, for various reason. The variation of 2, 3, and 4 number of blades was introduced to explore the effects of blade position againts upwind and downwind.

When the value of  $TSR > 1$  means more lift force in part of the blades, but if  $TSR < 1$  more drag in part of the baldes.

Number of blades will influence to the performance of the wind turbine, conforming with the solidity of the turbine. Solidity of wind turbines is the ratio between the area of blades and rotor sweeping, determined by [11],

$$\sigma = \frac{N_b C}{r} \quad (5)$$

where  $C$  is the length of blade chord (m) and  $r$  is radius of rotor (m).

Figure 4 shows the curve of power coefficient  $C_p$  and tip speed ratio TSR as an effect of solidity of turbine performance [8]. The curve shows that one blade has smaller solidity and the curve of  $C_p$  relatively flat which caused by higher drag force. Three blades gave optimal solidity with  $C_p$  maximum and they produced more energy.

## III. EXPERIMENTAL SET UP

Experiment used a model of H-Darrieus wind turbine were performed in a low speed open circuit wind tunnel, as in figure 4 (a). The model of H-Darrieus wind turbine consist of

one shaft, plank, connecting plate, and blades. Model has dimensions as in figure 4 (b) with rotor diameter is 40 cm, rotor height is 32 cm, table height is 103,2 cm, table width is 30 cm and table length is 40 cm. The blade of wind turbine model used airfoils as in figure 4 (c) with the length of chord (c) is 9 cm, the height of blade (h) is 32 cm and the maximum thickness of blade (t) is 1,6 cm.

Wind tunnel was started to produce wind and an anemometer measured the velocity of wind. When the wind from wind tunnel pushed the blades of wind turbine model, the rotor will rotate. The rotation of rotor was measured by tachometer and noted for three times of experiments. Each experiment with two, three and four blades respectively used the speed of wind from 1 to 15 m/s. The torque of wind turbine was also measured by a torque meter related with the speed of wind.

The specified speed of wind from 10 to 15 m/s were determined based on the assumption that small wind turbine in high speed wind will tend to split in angular motion. High speed of wind exerts high pressure on blade causes the rotation of rotor may exceed its design limit and become difficult to measure.

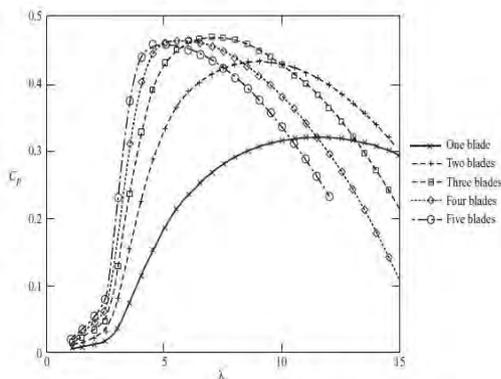


Figure 4. Curve of power coefficient  $C_p$  and tip speed ratio TSR of wind turbine [8]

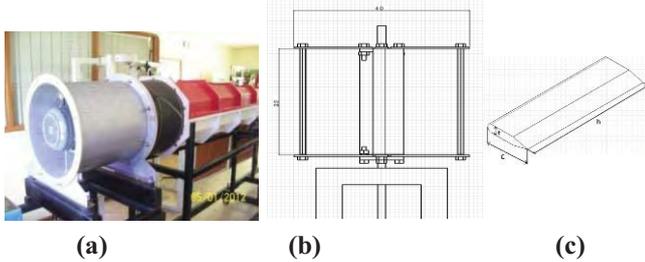


Figure 5. Wind tunnel (a) and model of H-Darrieus wind turbine (b) with airfoil (c)

#### IV. RESULTS AND DISCUSSION

Results of the experiment shows that wind turbine model with three blades has higher rotor rotation than that of two and four blades (figure 6). Wind turbine with three blades has attack angle more efficient than wind turbine with two and

four blades. As consequence is the wind turbine has rotation higher when the wind is also higher as shown in figure 6. Wind turbines with two and four blades have pressure coefficient in balance as a result of each blade has opposite pressure. Three blades wind turbine has three angles as  $0^\circ$ ,  $120^\circ$  and  $240^\circ$  that cause the wind turbine will rotate without obstacle from blade pressure.

Pressure distribution on wind turbine model with three blades (figure 12) is quite smoother than that of wind turbines with two and four blades (figure 11 and 13). It is caused by pressure coefficient on two and four blades adjust to balance with the result that more drags is produced and the rotor of wind turbine become difficult to rotate. Figures 11, 12 and 13 show pressure distribution for the model of H-Darrieus type wind turbine using simulation of contour of velocity from ANSYS 13.0 program. The simulation of contour velocity using constant wind speed at 15 m/s as in figure 11, 12 and 13. The results of simulation of contour velocity for many wind speeds is shown in table 1.

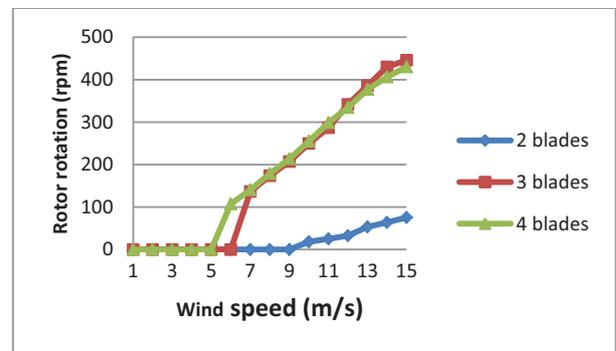


Figure 10. Rotation of wind turbine rotor (rpm) with wind speed (m/s) in wind tunnel

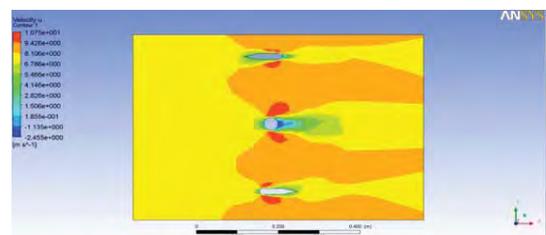


Figure 11. Contour of velocity for wind turbine model with two blades

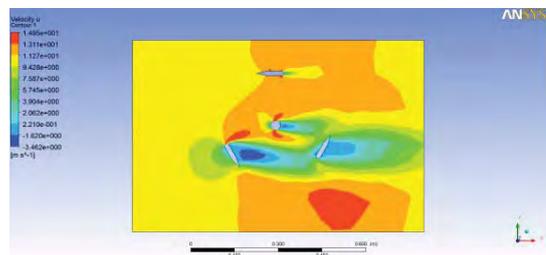


Figure 12. Contour of velocity for wind turbine model with three blades

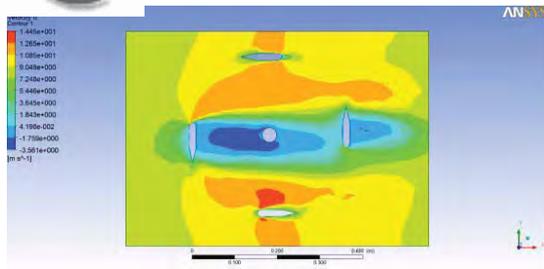


Figure 13. Contour of velocity for wind turbine model with four blades

Table 1. Pressure on two, three and four blades for wind speed (m/s)

Wind speed (m/s)	Pressure on the blades of airfoil (Pa)		
	2	3	4
1	0,407	1,348	1,765
5	14,08	33,62	43,86
10	55,56	134,6	174,4
15	128,8	303,6	392,6

The measurement of torque for two, three and four blades wind turbine model related with wind speed is shown in figure 14. The graphs in figure 14 shows that the torques of two blades wind turbine is smaller than torques of three or four blades wind turbine. Maximum torques at wind speed 15 m/s are 1,15 Nm for two blades ; 5,32 Nm for three blades and 5,53 Nm for four blades. Number of blades of H-Darrieus type wind turbine influence torque of rotor of wind turbine. If number of blades become increasing, then the wind turbine need more force and wind speed that torque produced is become higher.

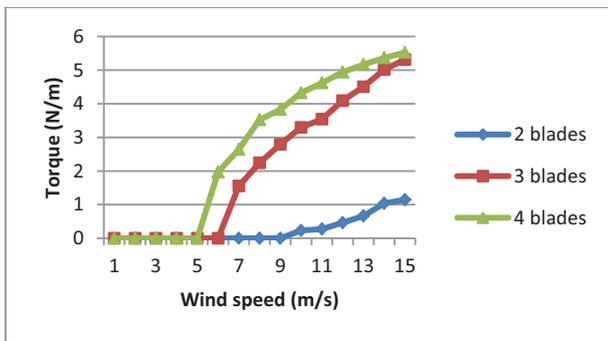


Figure 14. Torque of wind turbine rotor for different wind speeds

The relationship between tip speed ratio and coefficient of power for H-Darrieus type wind turbine model is shown in figure 15. Tip speed ratio for two blades wind turbine, 0 – 0,1 has low coefficient of power ( $C_p$ ), but the coefficient  $C_p$  for three and four blades wind turbines are higher. Three blades type wind turbine has cut in speed at 7 m/s related with TSR (tip speed ratio) = 0.409 and  $C_p$  = 0.828. Rated wind speed at 10 m/s has TSR = 0.522 and  $C_p$  = 1.098, and cut in speed at 15 m/s has TSR = 0.622 and  $C_p$  = 0.937. Four blades type wind turbine has cut in speed at 6 m/s related with TSR = 0,375 and  $C_p$  = 1.309. Rated wind speed at 8 m/s has TSR =

0.468 and the wind turbine produce  $C_p$  = 1.641. Cut out speed at wind speed = 15 m/s has TSR = 0.600 and  $C_p$  = 0.940.

Figure 15 shows that wind turbine model with two blades has slow performance and reduce more wind energy. Four blades wind turbine at wind speed of 6 to 11 m/s has higher rotation compared with three blades wind turbine. However, after the wind speed of 11 m/s the four blades wind turbine has low rotation and decreasing power when the wind speed between 9 m/s to 15 m/s. Three blades wind turbine has better performance than that four blades wind turbine. At wind speed 6 m/s to 15 m/s three blades wind turbine model has increasing power and the rotation produced can exceed the rotation of four blades wind turbine.

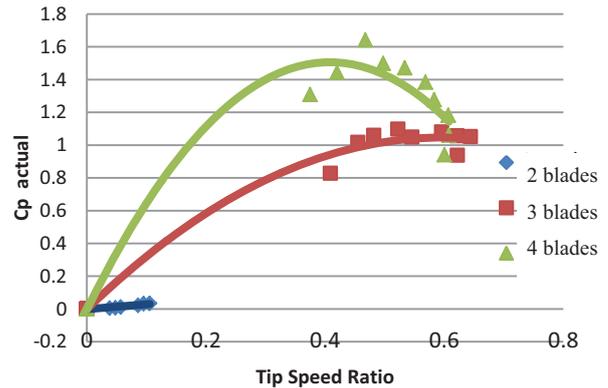


Figure 15. Power coefficient ( $C_p$ ) related with tip speed ratio

## 5. CONCLUSIONS

Some conclusions on the experimental study of H-Darrieus type wind turbine model in wind tunnel are,

- Number of blades will influence the rotor rotation of wind turbine. More number of blades used in wind turbine make easier the wind turbine to rotate with low wind speed.
- Data of torque, coefficient of power and tip speed ratio showed that more number of blades result in short performance and higher torque.
- Three blades rotor of wind turbine has performance more stabil than that two or four blades.

## REFERENCES

- [1] GWEC, Global Wind Energy Council 2006, *Global Wind Energy Outlook 2006*.
- [2] National Renewable Energy Laboratory, Technical Report: NREL/TP-28607, 2001, The history and state of the art of variable-speed wind turbine technology, 2001.
- [3] P. Musgrove, Wind energy conversion: recent progress and future prospects, *Solar and Wind technology*, 4 (1), 1987, pp. 37-49.
- [4] H.Dodd, Performance predictions for an intermediate-sized VAWT based on performance of the 34-m VAWT test bed, In : Berg DE, editor, *Proceeding of the ninth ASME wind energy symposium*, Sandia National Laboratories, January 1990.

- [5] I. Price, UK. large-scale wind power programme from 1970 to 1990: the Camarthen Bay experiments and the Mushgrove vertical-axis turbines, *Wind Engineering*, 30(3), May 2006, pp. 25-42.
- [6] E. Hau, *Wind Turbines: Fundamentals, Technologies, Application, Economics*, 2nd. ed., Springer, 2005
- [7] RE. Sheldahl, Comparison of field and wind tunnel Darrieus wind turbine data, SAND80-5469, 1981.
- [8] T. Burton et.al., *Wind Energy Handbook*, John Wiley & Sons, England, 2001.
- [9] J. Andreas and Nick Jelly, *Energy Science: Principles, Technologies and Impacts*, Oxford University Press, UK, 2007.

# Development of Data Acquisition System for Hybrid Power Plant

Aryuanto Soetedjo

Department of Electrical Engineering  
National Institute of Technology (ITN)  
Malang, Indonesia  
aryuanto@gmail.com

Yusuf Ismail Nakhoda

Department of Electrical Engineering  
National Institute of Technology (ITN)  
Malang, Indonesia  
yusuf\_nakhoda@yahoo.com

Dana Suryadi

Department of Electrical Engineering  
National Institute of Technology (ITN)  
Malang, Indonesia

**Abstract**— In this paper, the data acquisition system is developed to monitor the wind speed, solar irradiation, and PV temperature based on a low-cost AVR microcontroller. Instead of using an expensive pyranometer, a low-cost PV module is used as the solar irradiation sensor. The integrated-circuit temperature sensor LM35 and a cup-type anemometer are used to measure the temperature and the wind speed respectively. To provide the flexibility of the data acquisition system, the Modbus protocol is adopted for communicating with other monitoring software or HMI. This feature enables the system to communicate with SCADA system. It provides useful information about the environment conditions for operating the hybrid power system effectively. The developed data acquisition system is tested in real environment and comparisons to the standard measurement instruments are conducted. The measurement errors of 4.46%, 3.45%, and 3.47% are obtained for the wind speed, solar irradiation, and PV temperature measurement respectively.

**Keywords**— *hybrid power system; data acquisition system; wind speed; solar irradiation; PV temperature; Modbus protocol.*

## I. INTRODUCTION

Recently, hybrid power system plays a significant role for providing electrical energy to the customer, especially in rural area. The hybrid power system combines several energy resources, usually the renewable energy such as wind power and solar power. The objective of hybrid system is to maximize the energy obtained from the resources, while maintaining the supply continuously. Naturally, the power generated by wind and solar power are affected by the weather or environment conditions, namely the wind speed for wind power, the solar irradiation and the temperature of solar panel for solar power. Therefore it needs to monitor those parameters in real-time for operating the hybrid power system effectively.

Many researchers have developed the data acquisition systems for monitoring the renewable energy plants [1] – [4]. The data acquisition system was developed to monitor the meteorological data such as wind speed, solar irradiation, humidity, temperature, and the operational parameters of the

renewable energy sources such as the voltage and current of photovoltaic and wind turbine generator [1]. The system was implemented using DAQ card installed on a PC. The LabVIEW software was employed to control the system. The LabVIEW was also employed in [2] to monitor hybrid wind-PV power systems. The data acquisition system based-on client/server architecture was developed to monitor and control the wind-PV power systems [3]. In the system, a data acquisition unit is connected to the data collection computer using a wireless system, while the internet was employed to communicate between the client measurement station and the server measurement station. In [4], they proposed a low cost data acquisition system for renewable energy plants using an USB interface. The system was developed for developing countries, thus the firmware and hardware is free and open source.

Instead of using PC for data collection, a microcontroller-based data acquisition system was developed in [5], [6]. A 8-bit microcontroller system with analog input was developed for solar irradiation monitoring [5]. A serial EEPROM was used to store the measurement data. In [6], a 10-bit microcontroller system was used in the wireless data acquisition system to collect solar irradiation, temperature, photovoltaic voltage and current of the PV water pumping station. The system was equipped with GSM module for data transmission over GSM network.

To monitor and control hybrid wind-PV-battery power system, a SCADA (Supervisory Control and Data Acquisition) was proposed in [7]. It performed the real-time measurement of the electrical parameters of hybrid power system.

In this paper, the data acquisition system is developed to monitor the wind speed, solar irradiation, and PV temperature based on a low-cost 8-bit AVR microcontroller. The main contribution of the work is on the Modbus protocol which is employed for communicating between the data acquisition module and the other devices or PC. By introducing the Modbus protocol, the data acquisition system offers an easy way for reading the measurement data.

The rest of paper is organized as follows. Section 2 presents the hybrid power system which is considered in this work. The proposed data acquisition system is presented in section 3. Experimental results are covered in section 4. Section 5 presents the conclusions of the paper.

## II. HYBRID POWER SYSTEM

Fig. 1 shows the architecture of hybrid power system [8]. It consists of solar power, wind power, battery, and load. The maximum power generated by solar power system is 300 watt (6 x 50 Watt PV modules). The wind power system is able to generate the maximum power of 200 Watt. Thus the hybrid power system is suitable for supplying 500 Watt electrical power to a small home. The supervisory controller is employed to supervise the hybrid power system in providing continuous supply regardless of the environmental conditions. The environmental parameters that affect the output power of hybrid power system are solar irradiation, ambient temperature of PV panel, and wind speed as discussed below.

The I-V characteristics of PV are shown in Fig. 2 and Fig. 3. Fig. 2 shows the I-V curves under varying solar irradiation. From the figure, it is clear that when solar irradiation changes, the I-V curve changes accordingly. For a fixed voltage, the current of PV increases when solar irradiation increases. It means that by increasing solar irradiation, the output power of PV will increase. Fig. 3 shows the I-V curves under varying PV temperature. The figure shows that for a fixed current, the PV voltage increases when temperature decreases. Thus increasing PV temperature affects in reducing the power output of PV.

Fig. 4 shows the wind turbine power curves under varying wind speed. In the figure,  $V_{Wx}$  is the wind speed, where  $V_{W3} > V_{W2} > V_{W1}$ . From the figure, it is shown that when wind speed increases, the output power of wind turbine increases.

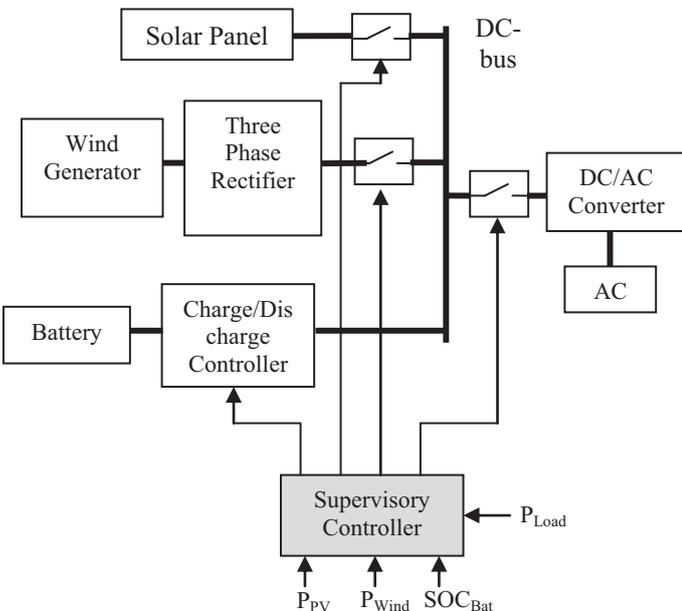


Fig. 1. Architecture of hybrid power system [8].

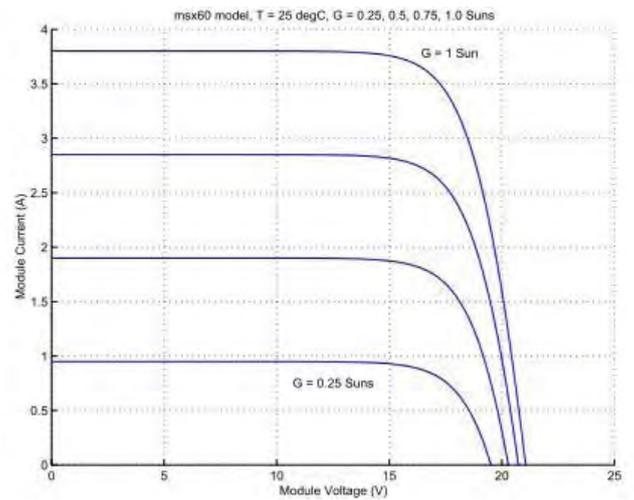


Fig. 2. I-V curves of PV under varying solar irradiation [9].

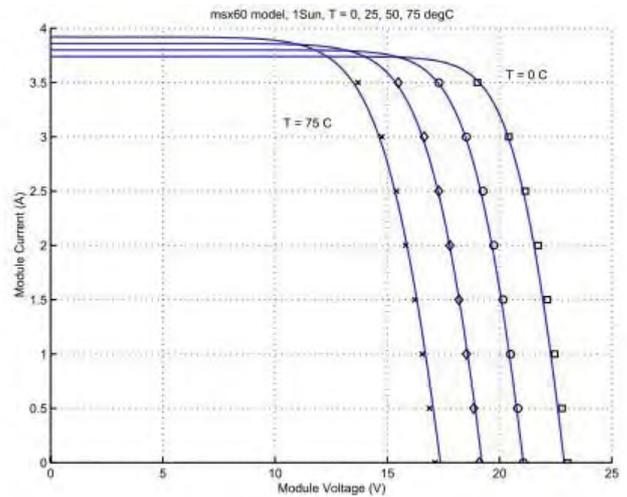


Fig. 3. I-V curves of PV under varying PV temperature [9].

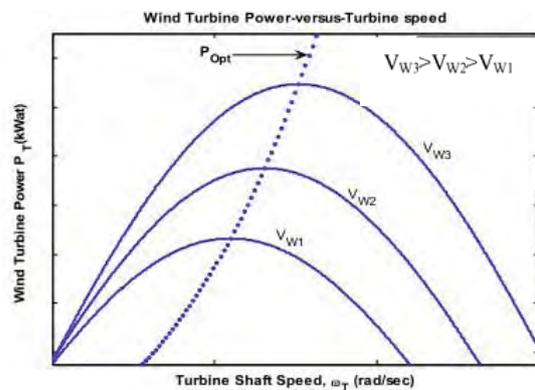


Fig. 4. Wind turbine curves under varying wind speed [9].

### III. PROPOSED DATA ACQUISITION SYSTEM

#### A. Hardware

The block diagram of proposed data acquisition system is shown in Fig. 5. It consists of a 8-bit AVR microcontroller system, a PV cell, an anemometer, LM35 temperature sensor, a Realtime clock (RTC), a LCD module, and a serial communication interface (RS232). A PV cell is used to measure the solar irradiation level. An anemometer is a sensor to measure the wind speed. LM35 is an integrated circuit (IC) used to measure temperature. A RTC (DS1307) is a serial I<sup>2</sup>C real-time clock module which is used as the clock/calendar. Using RTC, the measurement data could be recorded on time/calendar base. A LCD module is used to display the data measurement for local information or debugging the system. A serial RS232 is an interface for communicating between the microcontroller and a PC.

A small size PV cell (7 cm x 5.5 cm) is employed as the solar irradiation sensor. The output voltage and current of cell are 10 V and 30 mA respectively. In this work, the solar irradiation measurement is based-on the output voltage of PV cell. Since the maximum output voltage of the cell is 10 V, while the maximum input voltage of internal ADC of the microcontroller is 5 V, a simple voltage divider (divide by two) is employed.

A cup-type anemometer (from weather sensor assembly kit-Argent Data Systems) is employed to measure the wind speed. Fig. 6 shows the anemometer sensor. The anemometer has a contact switch which is closed when the cup rotates. The switch is close once per second if the measurement wind speed is 2.4 km/h. To interface with the microcontroller system, a pull-up resistor is put on the contact switch and connected to the external interrupt port of the AVR microcontroller.

LM35 is a precision integrated circuit temperature sensor. The output voltage is linearly proportional to the measured temperature (10 mV/°C). To interface this sensor to the microcontroller, a signal conditioner unit is added to gain the output of sensor by 5. Thus when measured temperature is 100 °C, the output of signal conditioner unit (input to ADC port of microcontroller) is 5 V.

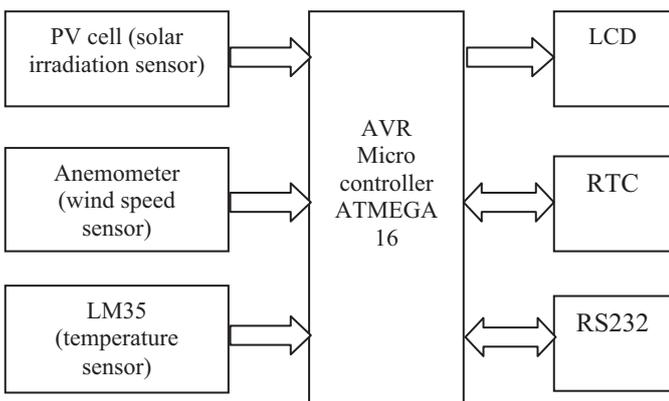


Fig. 5. Hardware architecture.



Fig. 6. Anemometer (Argent Data Systems).

#### B. Software

The program written for microcontroller system consists of the following parts : a) acquire data from sensor; b) display data to LCD module; c) transfer data to/from PC using Modbus protocol. To read data from solar irradiation and temperature sensors, the built-in 10 bit-ADC is used. The program reads the data from ADC buffer when the conversion is completed. While to measure the wind speed, it uses timer to generate five seconds interval for reading the number of pulses on the external interrupt port connected to the anemometer. Since the anemometer switch closes (i.e. triggers/interrupts the microcontroller) once per second if the wind speed is 2.4 km/h, then by counting the number of pulses in five seconds, the wind speed could be calculated.

The communication between data acquisition unit and PC is performed via serial communication using Modbus protocol. In this configuration, the client is PC and the server is the data acquisition unit. Therefore Modbus slave is implemented in the microcontroller. Modbus frame is shown in Fig. 7, where it consists of a protocol data unit (PDU) which is independent of underlying communications layer, and the application data unit (ADU) for mapping the protocol on network [11].

Additional address is the slave address (one byte). Function code denotes the action should be performed by the slave. In this work, only function code of 03 (read holding register) is used. The register address of the measurement data is described in Table 1. When packet data is sent by master device (received by slave device), data field contains of the starting register address and the number of data to be read. If there is no error, slave device will send data contains of the number of bytes and the register's value to be sent. Error check is CRC (cyclic redundancy check) value.

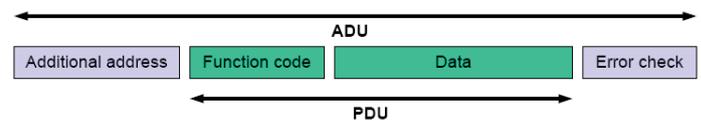


Fig. 7. Modbus frame [11].

TABLE I. REGISTER ADDRESS

Address	Content
16	Solar irradiation data
17	Solar temperature data
19	Wind speed data

#### IV. EXPERIMENTAL RESULTS

To test the functionality and performance of the developed data acquisition system, several experiments are conducted. In the experiments, the measurement data obtained by data acquisition unit are compared to the standard measurement instruments, i.e. solar power meter (TM-750, accuracy of +/- 5%), portable wind speed meter (Luxtron AM-4202, accuracy of +/- 2%), and room thermometer (accuracy of 1<sup>0</sup>C).

Table 2 shows the experimental results of the solar irradiation measurements. This measurement is conducted during sunny day from 10:00 AM to 04:00 PM. The measured data of the data acquisition unit are the data displayed on the LCD module. From the table, it is obtained that the average error is 3.45%. It is noted here that there are inconsistency in the measurements. In the measurements No. 11 and No. 26, the solar irradiation measured by solar power meter is the same, i.e. 960 Watt/m<sup>2</sup>, however the developed data acquisition system measures in the different values, i.e. 945 Watt/m<sup>2</sup> and 934 Watt/m<sup>2</sup> respectively. This phenomenon is caused by the non-linear I-V characteristic of PV under varying temperature as shown in Fig. 3. For a particular solar irradiation level, when PV temperature changes, the output voltage of PV will change. It results the different measurements of solar irradiation. Since the solar power meter does not use the PV cell for measuring the solar irradiation, the inconsistent measurement does not occur.

The experimental result of temperature measurement is shown in Table 3, where the average error is 3.47%. The experimental result of wind speed measurement is shown in Table 4. The wind speed measurement is conducted outdoor at the normal wind speed during two hours from 09:00 AM to 11:00 AM. From the experiments, the average error is 4.46%. The inconsistent measurements occur in the wind speed measurement are caused by the fact that the wind speed is not the steady value. The other factor affects the error is the non deterministic starting time of the timer used for counting pulse employed in the anemometer.

By considering the accuracy of the standard measurement instruments and average errors obtained from the experiments, it could be said that the developed data acquisition system is reliable for measuring solar radiation, temperature, and wind speed.

To test the Modbus communication, the microcontroller is connected to a PC using serial cable (RS232). Two SCADA software (Winlog SCADA and IntegraXor) are used for testing the Modbus protocol. In the SCADA software, the scanning interval for reading data from microcontroller is set to one second. From the experiment, it is shown that the measurement data could be read by SCADA software in real-time.

TABLE II. SOLAR IRRADIATION MEASUREMENT

No.	Solar irradiation (Watt/m <sup>2</sup> )		% error
	Measured by developed data acquisition system	Measured by solar power meter	
1	659	678	2.80
2	659	677	2.65
3	659	678	2.80
4	659	677	2.65
5	659	678	2.80
6	755	767	1.56
7	756	767	1.43
8	755	766	1.43
9	755	765	1.30
10	755	765	1.30
11	945	960	1.56
12	946	961	1.56
13	945	962	1.76
14	945	961	1.66
15	946	961	1.56
16	944	1004	5.97
17	945	1002	5.68
18	945	998	5.31
19	945	1002	5.68
20	944	1004	5.97
21	938	975	3.79
22	938	975	3.79
23	938	976	3.89
24	938	976	3.89
25	938	976	3.89
26	934	960	2.70
27	934	959	2.60
28	934	960	2.70
29	934	959	2.60
30	934	960	2.70
31	750	800	6.25
32	748	798	6.26
33	748	798	6.26
34	750	799	6.23
35	750	800	6.25
Average error			3.45

TABLE III. TEMPERATURE MEASUREMENT

No.	Temperature ( $^{\circ}$ C)		% error
	Measured by developed data acquisition system	Measured by thermometer	
1	28	29	3.44
2	28	29	3.44
3	28	29	3.44
4	27	28	3.57
5	29	30	3.33
6	27	28	3.57
7	27	28	3.57
8	28	29	3.44
9	28	29	3.44
10	28	29	3.44
Average error			3.47

## V. CONCLUSIONS

A data acquisition system for measuring the environmental conditions in the hybrid wind-PV energy system is proposed. The proposed system employs the low cost sensors and microcontroller systems to measure the solar irradiation, PV temperature, and wind speed. Comparing to the standard measurement instruments, it is obtained that the proposed data acquisition system is reliable to monitor the environment conditions in the hybrid power plant. The simple and low cost PV cell shows a good accuracy in measuring solar irradiation. The Modbus protocol implemented on the microcontroller system allows the data acquisition unit to be interfaced to the wide range of data acquisition system software and the SCADA software.

In future, the measurement accuracy will be improved and additional environmental parameters as well as the electrical parameters of hybrid power system will be added. Further, the developed data acquisition system will be extended for operating with SCADA system.

TABLE IV. WIND SPEED MEASUREMENT

No.	Wind speed (Km/h)		% error
	Measured by developed data acquisition system	Measured by Wind speed meter	
1	4.8	4.8	0
2	4.8	4.5	6.25
3	5.9	5.6	5.08
4	7.2	7.0	2.77
5	7.2	7.0	2.77
6	7.2	7.0	2.77
7	6.0	5.6	6.66
8	5.8	5.6	3.44
9	5.8	5.6	3.44
10	9.2	8.6	6.52
11	4.8	4.6	4.16
12	5.9	5.6	5.08
13	6.0	5.8	5.00
14	9.6	8.6	10.41
15	8.4	8.1	3.57
16	6.4	5.6	12.5
17	2.4	2.4	0
18	4.8	4.6	4.16
19	2.4	2.4	0
20	8.4	8.0	4.76
Average error			4.46

## REFERENCES

- [1] E. Koutroulis and K. Kalaitzakis, "Development of an integrated data-acquisition system for renewable energy sources systems monitoring," *Renewable Energy*, Vol. 28, 2003, pp. 139-152.
- [2] N. Watjanatepin and C. Boonmee, "Development of LabVIEW Monitoring System for the Hybrid PV-Wind Energy System," *Tech Connect World Conference and Expo*, 2010, California, USA.
- [3] S.C.S. Juca, P.C.M. Carvalho, and F.T. Brito, "A Low Cost Concept for Data Acquisition Systems Applied to Decentralized Renewable Energy Plants," *Sensors*, Vol. 11, 2011, pp. 743-756.
- [4] K. Kalaitzakis, E. Koutroulis, and V. Vlachos, "Development of a data acquisition system for remote monitoring of renewable energy systems," *Measurement*, Vol. 34, 2003, pp. 75-83.
- [5] R. Mukaro and X.F. Carelse, "A Microcontroller-Based Data Acquisition System for Solar Radiation and Environmental Monitoring," *IEEE Transactions on Instrumentation and Measurement*, Vol. 8, No. 6, 1999, pp. 1232-1238.
- [6] A. Mahjoubi, R.F. Mechlouch, and A.B. Brahim, "A Low Cost Wireless Data Acquisition System for a Remote Photovoltaic (PV) Water Pumping System," *Energies*, Vol. 4, 2011, pp. 68-89.
- [7] L. Wang and K.H. Liu, "Implementation of a Web-Based Real-Time Monitoring and Control System for a Hybrid Wind-PV-Battery Renewable Energy System," *International Conference on Intelligent Systems Applications to Power Systems*, 2007.
- [8] A. Soetedjo, Y.I. Nakhoda, A. Lomi, and M. Huda, "Supervisory Control for Hybrid Power System Using Smart Relay," *Seminar Nasional TEKNOIN*, Yogyakarta, Indonesia, 2012.
- [9] G.R. Walker, "Evaluating MPPT Converter Topologies Using a MATLAB PV Model," *Journal of Electrical and Electronics Engineering*, Vol. 21, No. 1, 2001, pp. 49-56.
- [10] S.M. Barakati, "Modeling and Controller Design of a Wind Energy Conversion System Including a Matrix Converter," PhD thesis in *Electrical Engineering*, University of Waterloo, Canada, 2008.
- [11] MODBUS Application Protocol Specification V1.1b(<http://www.Modbus-IDA.org>).

# Simulation Analysis on High Impedance Temporary Short Circuit in Induction Motor Winding

D. A. Asfani, Pressa Pradana Surya Saputra  
Electrical Engineering Department  
Institut Teknologi Sepuluh Nopember (ITS)  
Surabaya, Indonesia  
anton@ee.its.ac.id

I. M. Yulistya Negara, I.G.N. Satriyadi Hernanda,  
R. Wahyudi  
Electrical Engineering Department  
Institut Teknologi Sepuluh Nopember (ITS)  
Surabaya, Indonesia

**Abstract**— Stator fault of induction motor is one of the most common faults in industries. Fault detection in early stage of fault is importance to avoid catastrophic failure. This paper is concerned to analysis the behavior incipient stator fault that defined as high impedance and short time turn to turn short circuit. Mathematical model of induction motor with turn fault is developed to understanding the machine performance under fault operation. Moreover, detection system based on transient current during fault occurring is designed. Discrete wavelet transform is used to obtain the high frequency signal that used as detection parameter. The result shows that the proposed method can detect the temporary short circuit fault, even though the fault has high impedance and low current short circuit.

**Keywords**— High impedance fault, induction motor model, stator fault, wavelet transform.

## I. INTRODUCTION

Induction motors are one of the most important machines in industry. About 70% of utility in industry are uses this machine and it consume energy up to 60% of generated electricity energy in the industrialized nations [1-3]. In some application, motors are installed in harsh environment such as corrosive, high temperature and high humidity, which can lead motor deteriorated and failure. Based on industrial survey of induction motor fault, especially for medium voltage motor there are three component of motor that contribute high failure; bearing, stator and rotor. Stator related fault is give 26-66% of failure [4].

In order to avoid operating failure and sudden stop, monitoring system is needed to detect the fault in early stage of deterioration. This detection system is enable to fix the fault with well organized shutdown and will minimize the subsequence damage, outage time and repairing cost [5-7]. Several diagnostic techniques have been developed to detect incipient of fault such as an effective negative-sequence impedance detector [8, 9], line - neutral voltages monitoring [5], current frequency spectrum analysis [6], power decomposition technique [7], multiple reference frames theory for the diagnosis [10], adaptive observer [11], stator current envelopes [12], state observer [13], impedance identification approach [14], motor current signature analysis[15], also artificial intelligent techniques [16].

Moreover, mathematical and simulation model has been developed to understand fault characteristic. The fault signature and the effect on the motor performance can be analyzed using the simulation model [17]. Also, the model based analysis is give flexibility of modifying machine parameters, so that comprehensive and systematic analysis is easily to done. Some of proposed model are Finite element analysis based [18], winding function approach [6, 19], coupled circuit approach [20, 21], multiple coupled circuit [11, 22-24], a state-space model [10, 17, 25, 26], multi loop mathematical models [27], two orthogonal axis models [28, 29], bond graph model [30].

This paper is proposed mathematical model and simulation of induction motor under temporary and high impedance short circuit fault. Temporary short circuit is proposed to illustrate the early stage of short circuit fault that has the short time period and not permanently occurred. Moreover, high impedance fault is also considered as early stage of fault that produce low current short circuit fault. Stationary reference frame transformation is used in this model to investigate transient behavior of machine under fault [17, 28, 31]. The sensitive fault detection based on high frequency signal is proposed to detect low current fault. The proposed method is also not affected to unbalance operation.

## II. INDUCTION MOTOR MODEL UNDER HIGH IMPEDANCE TEMPORARY SHORT CIRCUIT

### A. Induction motor Model in Ideal operation

Electric and magnetic relation for induction motor model with ideal and balance winding is expressed as follows [28, 31].

$$\mathbf{v}_{abc}^s = \mathbf{r}_{abc}^s \mathbf{i}_{abc}^s + \frac{d\lambda_{abc}^s}{dt} \quad (1)$$

$$\mathbf{v}_{abc}^r = \mathbf{r}_{abc}^r \mathbf{i}_{abc}^r + \frac{d\lambda_{abc}^r}{dt} \quad (2)$$

$$\lambda_{abc}^s = \mathbf{L}_{abc}^{ss} \mathbf{i}_{abc}^s + \mathbf{L}_{abc}^{sr} \mathbf{i}_{abc}^r \quad (3)$$

$$\lambda_{abc}^r = \mathbf{L}_{abc}^{rs} \mathbf{i}_{abc}^s + \mathbf{L}_{abc}^{rr} \mathbf{i}_{abc}^r \quad (4)$$

The superscript  $s$  and  $r$  are represent the stator and rotor variable. Matrix for voltage, current resistance, flux linkage and inductance are expressed by  $\mathbf{v}$ ,  $\mathbf{i}$ ,  $\mathbf{r}$ ,  $\lambda$ , and  $\mathbf{L}$  respectively. Stator self mutual inductance  $\mathbf{L}_{abc}^{ss}$ , rotor self mutual

inductance  $\mathbf{L}_{abc}^{ss}$ , stator to rotor mutual inductance  $\mathbf{L}_{abc}^{sr}$ , and rotor to stator mutual inductance  $\mathbf{L}_{abc}^{rs}$ , are expressed as follow.

$$\mathbf{L}_{abc}^{ss} = \begin{bmatrix} L_{asas} & L_{asbs} & L_{ascs} \\ L_{bsas} & L_{bsbs} & L_{bscs} \\ L_{csas} & L_{csbs} & L_{cscs} \end{bmatrix}$$

$$\mathbf{L}_{abc}^{rr} = \begin{bmatrix} L_{arar} & L_{arbr} & L_{arcr} \\ L_{brar} & L_{brbr} & L_{brcr} \\ L_{crar} & L_{crbr} & L_{cr cr} \end{bmatrix}$$

$$\mathbf{L}_{abc}^{sr} = [\mathbf{L}_{abc}^{rs}]^T = \begin{bmatrix} L_{asar} \cos(\theta_r) & L_{asbr} \cos(\theta_r + \frac{2\pi}{3}) & L_{ascr} \cos(\theta_r - \frac{2\pi}{3}) \\ L_{bsar} \cos(\theta_r - \frac{2\pi}{3}) & L_{bsbr} \cos(\theta_r) & L_{bscr} \cos(\theta_r + \frac{2\pi}{3}) \\ L_{csar} \cos(\theta_r + \frac{2\pi}{3}) & L_{csbr} \cos(\theta_r - \frac{2\pi}{3}) & L_{cscr} \cos(\theta_r) \end{bmatrix} \quad (5)$$

Components of inductance matrix are calculated based on number of stator and rotor winding. The references of stator and rotor turn number are expressed by  $N_s$  and  $N_r$  respectively. Mutual and leakage inductance are expressed by  $L_m$  and  $L_{ls}$  respectively. Subscript *asbs* is used to express the relation between *phase-a* and *phase-b* stator windings.

$$L_{asbs} = L_{bsas} = \left(\frac{1}{2} N_a^s N_b^s\right) \left(\frac{2}{3} \frac{L_m}{N_s^2}\right)$$

$$L_{ascs} = L_{csas} = \left(\frac{1}{2} N_a^s N_c^s\right) \left(\frac{2}{3} \frac{L_m}{N_s^2}\right)$$

$$L_{bscs} = L_{csbs} = \left(\frac{1}{2} N_b^s N_c^s\right) \left(\frac{2}{3} \frac{L_m}{N_s^2}\right)$$

$$L_{asas} = \left(\frac{N_a^{s2}}{N_s^2}\right) \left(L_{ls} + \frac{2}{3} L_m\right)$$

$$L_{bsbs} = \left(\frac{N_b^{s2}}{N_s^2}\right) \left(L_{ls} + \frac{2}{3} L_m\right)$$

$$L_{cscs} = \left(\frac{N_c^{s2}}{N_s^2}\right) \left(L_{ls} + \frac{2}{3} L_m\right)$$

$$L_{arbr} = \left(-\frac{1}{2} N_a^r N_b^r\right) \left(\frac{2}{3} \frac{L_m}{N_s^2}\right) = \left(-\frac{1}{3} \frac{N_r^2 L_m}{N_s^2}\right)$$

$$L_{arcr} = L_{brar} = L_{brcr} = L_{crar} = L_{crbr} = L_{arbr}$$

$$L_{arar} = L_{lr} \left(\frac{2}{3} \frac{N_r^2 L_m}{N_s^2}\right)$$

$$L_{brbr} = L_{cr cr} = L_{arar}$$

$$L_{asar} = \frac{2}{3} \frac{N_a^s N_a^r}{N_s^2} L_m$$

$$L_{asbr} = L_{ascr} = L_{asar} = \frac{2}{3} \frac{N_a^s N_r}{N_s^2} L_m$$

$$L_{bsar} = L_{bsbr} = L_{bscr} = \frac{2}{3} \frac{N_b^s N_r}{N_s^2} L_m$$

$$L_{csar} = L_{csbr} = L_{cscr} = \frac{2}{3} \frac{N_c^s N_r}{N_s^2} L_m \quad (6)$$

The electromagnetic torque can be obtained using the following equation.

$$T_{em} = \frac{P}{2} [i_{abc}^s]^T \frac{d(\mathbf{L}_{abc}^{sr})}{d\theta_r} i_{abc}^r \quad (7)$$

In order to simplify equation model and simulation, the mathematical model of induction machine is transformed from *abc* to *dq0* stationary reference frame by matrix transformation.

$$\begin{bmatrix} f_q \\ f_d \\ f_0 \end{bmatrix} = [T_{qd0}^s] \begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix}$$

$$[T_{qd0}(\theta)] = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & -\frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \quad (8)$$

The conversion of the equation in to *dq0* axis with stationary reference frame yields:

$$\mathbf{v}_{qd0}^s = \mathbf{r}_{qd0}^s \mathbf{i}_{qd0}^s + \frac{d\lambda_{qd0}^s}{dt} \quad (9)$$

$$\mathbf{v}_{qd0}^r = \mathbf{r}_{qd0}^r \mathbf{i}_{qd0}^r - \omega_r \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix} \lambda_{qd0}^r + \frac{d\lambda_{qd0}^r}{dt} \quad (10)$$

Where  $V_{qd0}^s$  is represent to stator voltage,  $V_{qd0}^r$  is represent to rotor voltage and will be zero for squirrel cage motor,  $i_{qd0}^s$  is stator current,  $r_{qd0}^s$  is stator resistance,  $\lambda_{qd0}^s$  is stator magnetic flux. Similar to stator side, rotor quantities is marked by superscript *r*, while  $\omega_r$  is representing rotor speed. Stator resistance matrix is calculated as follow.

$$\mathbf{r}_{qd0}^s = \begin{bmatrix} r_{11}^s & r_{12}^s & r_{13}^s \\ r_{21}^s & r_{22}^s & r_{23}^s \\ r_{31}^s & r_{32}^s & r_{33}^s \end{bmatrix} \quad (11)$$

Each component inside the matrix is calculated as follows

$$r_{11}^s = \frac{2}{3} \left( r_a^s + \frac{1}{4} r_b^s + \frac{1}{4} r_c^s \right)$$

$$r_{12}^s = \frac{\sqrt{3}}{6} (r_b^s - r_c^s)$$

$$r_{13}^s = \frac{1}{3} (2r_a^s - r_b^s - r_c^s)$$

$$r_{21}^s = r_{12}^s$$

$$r_{22}^s = \frac{1}{2} (r_b^s + r_c^s)$$

$$r_{23}^s = -\frac{1}{2} r_{12}^s$$

$$r_{31}^s = \frac{1}{2} r_{13}^s$$

$$r_{32}^s = -r_{12}^s$$

$$r_{33}^s = \frac{1}{3} (r_a^s + r_b^s + r_c^s)$$

$$r_a^s = \frac{N_a^s}{N_s} r_s; \quad r_b^s = \frac{N_b^s}{N_s} r_s; \quad r_c^s = \frac{N_c^s}{N_s} r_s$$

Flux linkage between stator and rotor can be written as follows:

$$\lambda_{qd0}^s = \mathbf{L}_{qd0}^{ss} \mathbf{i}_{qd0}^s + \mathbf{L}_{qd0}^{sr} \mathbf{i}_{qd0}^r \quad (12)$$

$$\lambda_{qd0}^r = \mathbf{L}_{qd0}^{rs} \mathbf{i}_{qd0}^s + \mathbf{L}_{qd0}^{rr} \mathbf{i}_{qd0}^r \quad (13)$$

$$\mathbf{L}_{qd0}^{ss} = \begin{bmatrix} L_{11}^{ss} & L_{12}^{ss} & L_{13}^{ss} \\ L_{21}^{ss} & L_{22}^{ss} & L_{23}^{ss} \\ L_{31}^{ss} & L_{32}^{ss} & L_{33}^{ss} \end{bmatrix} \quad (14)$$

Each matrix component in equation (14) is calculated as follows.

$$\begin{aligned}
 L_{11}^{ss} &= \frac{2}{3} (L_{asas} + 0.25L_{bsbs} + 0.25L_{cscs}) \\
 L_{12}^{ss} &= \frac{1}{2\sqrt{3}} (L_{bsbs} - L_{cscs} - L_{asbs} + L_{ascsc}) \\
 L_{13}^{ss} &= \frac{2}{3} (L_{asas} - 0.5L_{bsbs} - 0.5L_{cscs} + \\
 &\quad 0.5L_{asbs} + 0.5L_{ascsc} - L_{bscs}) \\
 L_{21}^{ss} &= \frac{1}{\sqrt{3}} (0.5L_{bsbs} - 0.5L_{cscs} - L_{asbs} + L_{ascsc}) \\
 L_{22}^{ss} &= \frac{1}{2} (L_{bsbs} + L_{cscs} - 2L_{bscs}) \\
 L_{23}^{ss} &= \frac{1}{\sqrt{3}} (-L_{bsbs} + L_{cscs} - L_{asbs} + L_{ascsc}) \\
 L_{31}^{ss} &= L_{13}^{ss} \\
 L_{32}^{ss} &= L_{23}^{ss} \\
 L_{33}^{ss} &= \frac{1}{3} (L_{asas} + L_{bsbs} + L_{cscs} + 2L_{asbs} + 2L_{ascsc} + 2L_{bscs})
 \end{aligned}$$

Stator and rotor mutual inductance is expressed as follow.

$$\mathbf{L}_{qd0}^{sr} = \begin{bmatrix} L_{11}^{sr} & L_{12}^{sr} & 0 \\ L_{21}^{sr} & L_{22}^{sr} & 0 \\ L_{31}^{sr} & L_{32}^{sr} & 0 \end{bmatrix} \quad (15)$$

If rotor is symmetric, stator-rotor mutual inductance coefficient can be simplified to

$$\begin{aligned}
 N_{asar} &= N_{asbr} = N_{ascr} = N_{asr} \\
 N_{bsar} &= N_{bsbr} = N_{bscr} = N_{bsr} \\
 N_{csar} &= N_{csbr} = N_{cscr} = N_{csr} \\
 L_{11}^{sr} &= L_{asr} + 0.25L_{bsr} + 0.25L_{csr} \\
 L_{12}^{sr} &= \frac{\sqrt{3}}{4} (L_{bsr} - L_{csr}) \\
 L_{21}^{sr} &= L_{12}^{sr} \\
 L_{31}^{sr} &= 0.5L_{asr} - 0.25L_{bsr} - 0.25L_{csr} \\
 L_{32}^{sr} &= -L_{12}^{sr}
 \end{aligned} \quad (16)$$

$$\mathbf{L}_{qd0}^{rr} = \begin{bmatrix} L_{11}^{rr} & L_{12}^{rr} & L_{13}^{rr} \\ L_{21}^{rr} & L_{22}^{rr} & L_{23}^{rr} \\ L_{31}^{rr} & L_{32}^{rr} & L_{33}^{rr} \end{bmatrix} \quad (17)$$

If rotor is symmetrical and balance, we can get

$$\begin{aligned}
 L_{11}^{rr} &= L_{11}^{rr} = L_{lr} + \frac{N_r^2}{N_s^2} L_m \\
 L_{33}^{rr} &= L_{lr} \\
 L_{12}^{rr} &= L_{13}^{rr} = L_{21}^{rr} = L_{23}^{rr} = L_{31}^{rr} = L_{32}^{rr} = 0
 \end{aligned} \quad (18)$$

$$T_{em} = \frac{3P}{2} (\lambda_d^s i_q^s - \lambda_q^s i_d^s) \quad (19)$$

$$\omega_r(t) = \frac{P}{2J} \int (T_{em} + T_{mech} - T_{damp}) dt \quad (20)$$

where superscript  $s$  is represent stator variable,  $P$  is number of poles,  $J$  motor inertia  $T_{mech}$  and  $T_{damp}$  are mechanical and damping torque respectively. Based on the normal and balance operation as the previous equation, model under short circuit is derived.

### B. Induction motor model under Short Circuit fault

The short circuit occurs in inter turn of *phase-a* winding as shown in Fig.1. [17, 28]. Because of the short circuit case, *phase-a* stator winding is divided into un-shorted turn,  $N_{a1}^s$ , and shorted turn,  $N_{a2}^s$ . The number of shorted turn is equal to  $\mu N_s$ , where  $N_s$  is the number of stator turn.

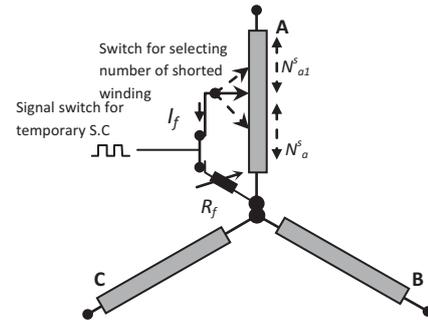


Figure 1 Temporary short circuit case.

Voltage and flux equation in *abc*-reference frame considering the short circuit fault case is expressed as follows.

$$v_{abc}^s = r_{abc}^s i_{abc}^s + \frac{d\lambda_{abc}^s}{dt} + \mu \begin{bmatrix} -r_s \\ 0 \\ 0 \end{bmatrix} i_f \quad (21)$$

$$v_{abc}^r = r_{abc}^r i_{abc}^r + \frac{d\lambda_{abc}^r}{dt} \quad (22)$$

$$\lambda_{abc}^s = L_{abc}^{ss} i_{abc}^s + L_{abc}^{sr} i_{abc}^r + \mu \begin{bmatrix} -r_s \\ 0 \\ 0 \end{bmatrix} i_f \quad (23)$$

$$\lambda_{abc}^r = L_{abc}^{rs} i_{abc}^s + L_{abc}^{rr} i_{abc}^r + \mu \left( -\frac{2}{3} L_m \right) \begin{bmatrix} \cos\theta \\ \cos\left(\theta + \frac{2\pi}{3}\right) \\ \cos\left(\theta - \frac{2\pi}{3}\right) \end{bmatrix} i_f \quad (24)$$

Voltage and flux expression for shorted winding part is shown as follows.

$$v_{a2}^s = r_s \mu (i_a^s - i_f) + \frac{d\lambda_{a2}^s}{dt} = r_f i_f \quad (25)$$

$$\begin{aligned}
 \lambda_{a2}^s &= \mu \begin{bmatrix} L_{asas} \\ L_{asbs} \\ L_{ascs} \end{bmatrix}^T i_{abc}^s + L_{sr} \begin{bmatrix} \cos\theta \\ \cos\left(\theta + \frac{2\pi}{3}\right) \\ \cos\left(\theta - \frac{2\pi}{3}\right) \end{bmatrix}^T i_{abc}^r - \\
 &\mu \left( L_{ls} + \mu \left( \frac{2}{3} L_m \right) \right) i_f
 \end{aligned} \quad (26)$$

Electromagnetic torque of the machine considering fault is obtained using following equation.

$$T_{em} = \frac{P}{2} [i_{abc}^s]^T \frac{d(L_{abc}^{sr})}{d\theta} i_{abc}^r - \mu \frac{P}{2} \left( \frac{2}{3} L_m \right) i_f \left\{ \frac{3}{2} i_a^r \sin\theta + \frac{\sqrt{3}}{2} (i_b^r - i_c^r) \cos\theta \right\} \quad (27)$$

In order to develop the simulation system, machine equation is converting into *qd0* stationary reference frame. Transformation for voltage equation is yields the following formula.

$$\begin{bmatrix} v_q^s \\ v_d^s \end{bmatrix} = \begin{bmatrix} r_{11}^s & r_{12}^s \\ r_{21}^s & r_{22}^s \end{bmatrix} \begin{bmatrix} i_q^s \\ i_d^s \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} \lambda_q^s \\ \lambda_d^s \end{bmatrix} - \frac{2\mu}{3} \begin{bmatrix} r_s \\ 0 \end{bmatrix} i_f \quad (28)$$

$$v_0^s = -\frac{1}{3} \mu r_s i_f + \frac{d\lambda_0^s}{dt} \quad (29)$$

$$\begin{bmatrix} v_q^r \\ v_d^r \end{bmatrix} = \begin{bmatrix} r_{11}^r & r_{12}^r \\ r_{21}^r & r_{22}^r \end{bmatrix} \begin{bmatrix} i_q^r \\ i_d^r \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} \lambda_q^r \\ \lambda_d^r \end{bmatrix} - \omega_r \begin{bmatrix} \lambda_d^r \\ -\lambda_q^r \end{bmatrix} \quad (30)$$

$$v_0^r = 0 \quad (31)$$

$$v_{a2}^s = r_f i_f = \mu r_s (i_q^s + i_0^s - i_f) + \frac{d\lambda_{a2}^s}{dt} \quad (32)$$

Flux linkage equation is transformed as follow.

$$\begin{bmatrix} \lambda_q^s \\ \lambda_d^s \end{bmatrix} = \begin{bmatrix} L_{11}^{ss} & L_{12}^{ss} \\ L_{21}^{ss} & L_{22}^{ss} \end{bmatrix} \begin{bmatrix} i_q^s \\ i_d^s \end{bmatrix} + \begin{bmatrix} L_{11}^{sr} & L_{12}^{sr} \\ L_{21}^{sr} & L_{22}^{sr} \end{bmatrix} \begin{bmatrix} i_q^r \\ i_d^r \end{bmatrix} - \frac{2\mu}{3} \begin{bmatrix} L_{11}^{ss} \\ 0 \end{bmatrix} i_f \quad (33)$$

$$\lambda_0^s = -\frac{1}{3} \mu L_{11}^{ss} i_f \quad (34)$$

$$\begin{bmatrix} \lambda_q^r \\ \lambda_d^r \end{bmatrix} = \begin{bmatrix} L_{11}^{sr} & L_{12}^{sr} \\ L_{21}^{sr} & L_{22}^{sr} \end{bmatrix} \begin{bmatrix} i_q^s \\ i_d^s \end{bmatrix} + \begin{bmatrix} L_{11}^{rr} & L_{12}^{rr} \\ L_{21}^{rr} & L_{22}^{rr} \end{bmatrix} \begin{bmatrix} i_q^r \\ i_d^r \end{bmatrix} - \frac{2\mu}{3} \begin{bmatrix} L_{11}^{sr} \\ 0 \end{bmatrix} i_f \quad (35)$$

$$\lambda_{a2}^s = \mu L_{ls} (i_q^s + i_0^s - i_f) + \mu L_{11}^{sr} (i_q^s + i_q^r - \frac{2\mu}{3} i_f) \quad (36)$$

$$\begin{bmatrix} \lambda_q^s \\ \lambda_d^s \\ \lambda_q^r \\ \lambda_d^r \\ \lambda_{a2}^s \end{bmatrix} = \begin{bmatrix} L_{11}^{ss} & 0 & L_{11}^{sr} & 0 & -\frac{2}{3} \mu L_{11}^{ss} \\ 0 & L_{22}^{ss} & 0 & L_{22}^{sr} & 0 \\ L_{11}^{sr} & 0 & L_{11}^{rr} & 0 & -\frac{2}{3} \mu L_{11}^{sr} \\ 0 & L_{22}^{sr} & 0 & L_{22}^{rr} & 0 \\ \mu L_{11}^{ss} & 0 & \mu L_{11}^{sr} & 0 & -\mu (L_{ls} + \frac{2}{3} \mu L_{11}^{sr}) \end{bmatrix} \begin{bmatrix} i_q^s \\ i_d^s \\ i_q^r \\ i_d^r \\ i_f \end{bmatrix} \quad (37)$$

Electromagnetic torque can be obtained using following equation.

$$T_{em} = \frac{3P}{2} (\lambda_d^s i_q^s - \lambda_q^s i_d^s) - \frac{P}{2} \mu L_{11}^{sr} i_f i_q^r \quad (38)$$

### C. Induction motor model under High Impedance and Temporary short circuit

External resistance is inserted in circuit equivalent, parallel to shorted inductance. The shunt voltage due to the fault resistance is expressed as  $v_q^{ext}$ , and calculated as follow.

$$v_q^{ext} = v_{a2}^s = i_f r_f \quad (39)$$

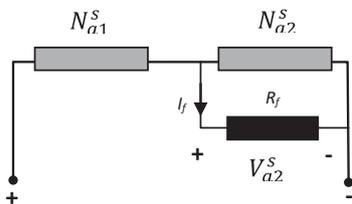


Figure 2 High impedance short circuit.

### III. SIMULATION AND ANALISYS

Based in the mathematical model that has developed above, simulation system is built in Matlab-Simulink system for 2hp, 3 phase and 460 Volt induction motor [28].

#### A. Current pattern under high impedance short circuit

Temporary short circuit is simulated after steady state operation after starting transient. Figure 3 shows the *phase-a* current signal during temporary short circuit in *phase-a*, with 20 turn of winding is shorted in 8 cycle. In this case, fault resistance,  $R_f$ , is to be set a zero or bolted short circuit. The current increase is not a slightly high because it only 8% of winding shorted.

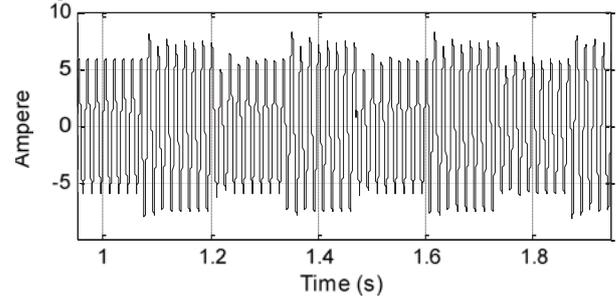


Figure 3 Simulation of temporary short circuit in *Phase-a* stator winding.

Figure 4 shows the transient current spectrum during high impedance fault. As shown in this figure, the magnitude current is decreasing when the resistance is increase. The short circuit cases are difficult to distinguish from normal operation when the current magnitude used as detection variable. However, the starting of short circuit can be noticed based on the transient current when the fault starting occurred. Moreover, short circuit case is produce high frequency that can be shown as low harmonics ripple in the current. Based on these phenomena, the detection system using high frequency signal current is proposed in this paper.

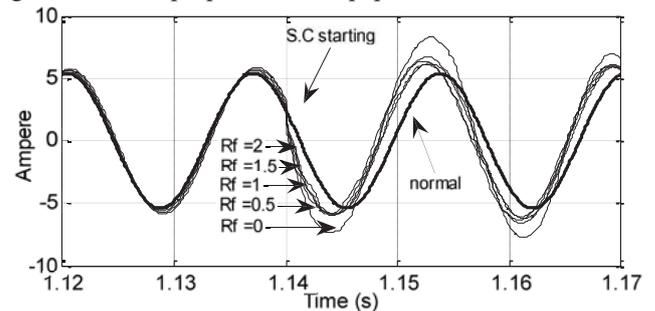


Figure 4 Simulation of temporary short circuit with high impedance fault.

#### B. Fault Detection

In this section, the proposed method of high impedance short circuit detection is discussed. The discrete wavelet transform is used to obtain high frequency signal of motor current. Haar wavelet is selected as wavelet filter because of

simplicity. From the current signal  $I(t)=[i_1 \ i_2 \ \dots \ i_n]$ , the Haar wavelet transformation for high frequency signal,  $HF$ , and low frequency signal,  $LF$ , can be calculated as follows

$$HF = [Wh] I(t) \tag{40}$$

$$LF = [Wl] I(t) \tag{41}$$

$$Wh = \begin{bmatrix} \ddots & \ddots & \ddots & & & & \\ & 0 & \frac{1}{2} & -\frac{1}{2} & 0 & 0 & \\ \dots & 0 & 0 & \frac{1}{2} & -\frac{1}{2} & 0 & \dots \\ & 0 & 0 & 0 & \frac{1}{2} & -\frac{1}{2} & \\ & 0 & 0 & 0 & 0 & \frac{1}{2} & \\ & & & & & & \ddots \end{bmatrix}$$

$$Wl = \begin{bmatrix} \ddots & \ddots & \ddots & & & & \\ & 0 & \frac{1}{2} & \frac{1}{2} & 0 & 0 & \\ \dots & 0 & 0 & \frac{1}{2} & \frac{1}{2} & 0 & \dots \\ & 0 & 0 & 0 & \frac{1}{2} & \frac{1}{2} & \\ & 0 & 0 & 0 & 0 & \frac{1}{2} & \\ & & & & & & \ddots \end{bmatrix}$$

In this method, three level transformation is used to obtain the appropriate signal that clearly to detecting the occurring of fault consist the starting and ending of short circuit. Low and high frequency signal is obtained at first step transformation as  $LF1$  and  $HF1$ , respectively. The next two transformation are used the high frequency signal to be transformed using wavelet filter as shown in Figure 5.

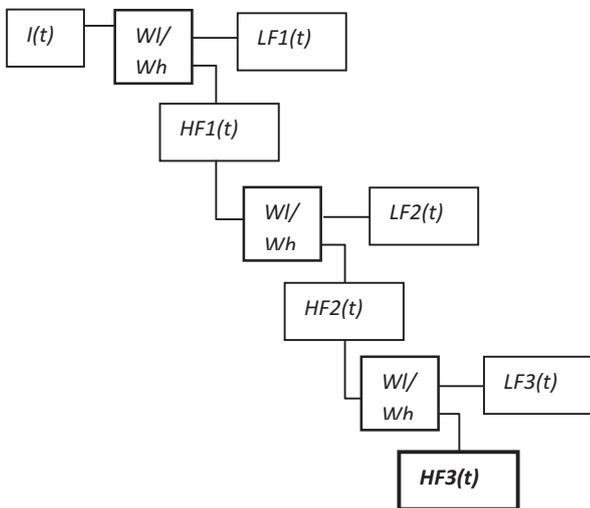


Figure 5 Calculation process of high frequency level-3 (HF3).

Figure 6 shows the current spectrum during temporary high impedance short circuit with 8% of stator winding is shorted and 2 Ohm resistance fault is inserted. In this case, normal

current has magnitude 5.4 Ampere, while a short circuit case is raising current to 6 Ampere or 0.6 Ampere differences. Because of small raising current, the short circuit case is difficult to detect. Figure 7 shows the high frequency current,  $HF3$ , of the current spectrum from Figure 6. The magnitude is very low during the normal operation. While short circuit is starting occur, the magnitude is increasing very high. Moreover, when the fault is cleared, the magnitude is decreasing back to the normal.

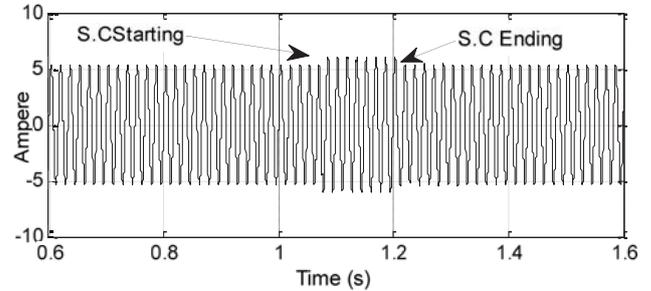


Figure 6 Current spectrum of temporary short circuit current with 20 turn shorted and 2 Ohm of resistance fault.

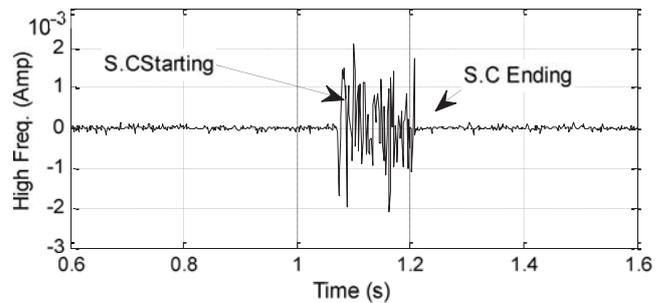


Figure 7 HF3-spectrum of temporary short circuit current with 20 turn shorted and 2 Ohm of resistance fault.

Based on this result, the short circuit fault is clear detecting using high frequency of 3<sup>rd</sup> level Haar transformation. The occurring of fault, including when the fault started and cleared, is easily detected even though the fault has small current magnitude.

#### IV. CONCLUSION

Mathematical model and simulation of induction motor under short circuit fault is presented. The short circuit is specified as temporary and high impedance fault to represent the early stage of winding deterioration. Sensitive short circuit detection is proposed based on the high frequency signal of motor current. High frequency signal is obtained using wavelet transform. Third level transformation of Haar wavelet result is the high frequency signal that suitable to detect high impedance short circuit. As the result, the proposed detection method can detect 8% of shorted turn winding with fault resistance 2 Ohm. This fault only has 11% of current fault magnitude comparing the nominal operating current.

## ACKNOWLEDGMENT

The authors gratefully acknowledge to the Directorate General for Higher Education (DGHE), Ministry of national Education, the Republic of Indonesia for supporting this research under program of "Hibah Penelitian Laboratorium 2013 LPPM ITS".

## REFERENCES

- [1] W. T. Thomson and M. Fenger, "Current signature analysis to detect induction motor faults," *Industry Applications Magazine*, IEEE, vol. 7, pp. 26-34, 2001.
- [2] J. Cusido, J. A. Rosero, J. A. Ortega, A. Garcia, and L. Romeral, "Induction Motor Fault Detection by using Wavelet decomposition on dq0 components," in *Industrial Electronics, 2006 IEEE International Symposium on*, 2006, pp. 2406-2411.
- [3] J. Cusido, L. Romeral, J. A. Ortega, J. A. Rosero, and A. Garcia Espinosa, "Fault Detection in Induction Machines Using Power Spectral Density in Wavelet Decomposition," *Industrial Electronics, IEEE Transactions on*, vol. 55, pp. 633-643, 2008.
- [4] Z. Pinjia, D. Yi, T. G. Habetler, and L. Bin, "A Survey of Condition Monitoring and Protection Methods for Medium-Voltage Induction Motors," *Industry Applications, IEEE Transactions on*, vol. 47, pp. 34-46, 2011.
- [5] M. A. Cash, T. G. Habetler, and G. B. Kliman, "Insulation failure prediction in AC machines using line-neutral voltages," *Industry Applications, IEEE Transactions on*, vol. 34, pp. 1234-1239, 1998.
- [6] G. M. Joksimovic and J. Penman, "The detection of inter-turn short circuits in the stator windings of operating motors," *Industrial Electronics, IEEE Transactions on*, vol. 47, pp. 1078-1084, 2000.
- [7] M. Arkan, D. K. Perovic, and P. Unsworth, "Online stator fault diagnosis in induction motors," *Electric Power Applications, IEE Proceedings -*, vol. 148, pp. 537-547, 2001.
- [8] J. L. Kohler, J. Sottile, and F. C. Trutt, "Condition monitoring of stator windings in induction motors. I. Experimental investigation of the effective negative-sequence impedance detector," *Industry Applications, IEEE Transactions on*, vol. 38, pp. 1447-1453, 2002.
- [9] J. Sottile, F. C. Trutt, and J. L. Kohler, "Condition monitoring of stator windings in induction motors. II. Experimental investigation of voltage mismatch detectors," *Industry Applications, IEEE Transactions on*, vol. 38, pp. 1454-1459, 2002.
- [10] S. M. A. Cruz and A. J. M. Cardoso, "Multiple Reference Frames Theory: A New Method for the Diagnosis of Stator Faults in Three-Phase Induction Motors," *Energy Conversion, IEEE Transactions on*, vol. 20, pp. 611-619, 2005.
- [11] C. S. Kallesoe, R. Izadi-Zamanabadi, P. Vadstrup, and H. Rasmussen, "Observer-Based Estimation of Stator-Winding Faults in Delta-Connected Induction Motors: A Linear Matrix Inequality Approach," *Industry Applications, IEEE Transactions on*, vol. 43, pp. 1022-1031, 2007.
- [12] A. M. da Silva, R. J. Povinelli, and N. A. O. Demerdash, "Induction Machine Broken Bar and Stator Short-Circuit Fault Diagnostics Based on Three-Phase Stator Current Envelopes," *Industrial Electronics, IEEE Transactions on*, vol. 55, pp. 1310-1318, 2008.
- [13] C. H. De Angelo, G. R. Bossio, S. J. Giaccone, M. I. Valla, J. A. Solsona, and G. O. Garcia, "Online Model-Based Stator-Fault Detection and Identification in Induction Motors," *Industrial Electronics, IEEE Transactions on*, vol. 56, pp. 4671-4680, 2009.
- [14] S. Cheng, P. Zhang, and T. G. Habetler, "An Impedance Identification Approach to Sensitive Detection and Location of Stator Turn-to-Turn Faults in a Closed-Loop Multiple-Motor Drive," *Industrial Electronics, IEEE Transactions on*, vol. 58, pp. 1545-1554, 2011.
- [15] W. T. Thomson and M. Fenger, "Case histories of current signature analysis to detect faults in induction motor drives," in *Electric Machines and Drives Conference, 2003. IEMDC'03. IEEE International*, 2003, pp. 1459-1465 vol.3.
- [16] S. Grubic, J. M. Aller, L. Bin, and T. G. Habetler, "A Survey on Testing and Monitoring Methods for Stator Insulation Systems of Low-Voltage Induction Machines Focusing on Turn Insulation Problems," *Industrial Electronics, IEEE Transactions on*, vol. 55, pp. 4127-4136, 2008.
- [17] R. M. Tallam, T. G. Habetler, and R. G. Harley, "Transient model for induction machines with stator winding turn faults," *Industry Applications, IEEE Transactions on*, vol. 38, pp. 632-637, 2002.
- [18] A. Ceban, R. Pusca, R. Romary, and J.-P. Lecoite, "Diagnosis of Inter-turn short circuit fault in Induction machine," *Annals of the University of Craiova, Electrical Engineering series*, vol. 35, pp. 103-110, 2011.
- [19] H. A. Toliyat and T. A. Lipo, "Transient analysis of cage induction machines under stator, rotor bar and end ring faults," *Energy Conversion, IEEE Transactions on*, vol. 10, pp. 241-247, 1995.
- [20] S. Chen and R. Živanović, "Modelling and simulation of stator and rotor fault conditions in induction machines for testing fault diagnostic techniques," *European Transactions on Electrical Power*, vol. 20, pp. 611-629, 2010.
- [21] G. B. Kliman, W. J. Premerlani, R. A. Koegl, and D. Hoeweler, "A new approach to on-line turn fault detection in AC motors," in *Industry Applications Conference, 1996. Thirty-First IAS Annual Meeting, IAS '96., Conference Record of the 1996 IEEE*, 1996, pp. 687-693 vol.1.
- [22] L. Xiaogang, L. Yuefeng, H. A. Toliyat, A. El-Antably, and T. A. Lipo, "Multiple coupled circuit modeling of induction machines," *Industry Applications, IEEE Transactions on*, vol. 31, pp. 311-318, 1995.
- [23] M. Sahraoui, A. Ghoggal, S. E. Zouzou, A. Aboubou, and H. Razik, "Modelling and Detection of Inter-Turn Short Circuits in Stator Windings of Induction Motor," in *IEEE Industrial Electronics, IECON 2006 - 32nd Annual Conference on*, 2006, pp. 4981-4986.
- [24] C. S. Kallesoe, "Model-Based Stator Fault Detection in Induction Motors," in *Industry Applications Society Annual Meeting, 2008. IAS '08. IEEE*, 2008, pp. 1-8.
- [25] C. Xianrong, V. Cocquemot, and C. Christophe, "A model of asynchronous machines for stator fault detection and isolation," *Industrial Electronics, IEEE Transactions on*, vol. 50, pp. 578-584, 2003.
- [26] D. C. Patel and M. C. Chandorkar, "Transient modeling and analysis of induction motors with position effects in stator turn faults," in *Industrial Technology (ICIT), 2010 IEEE International Conference on*, 2010, pp. 1251-1256.
- [27] H. Li, L. Sun, and B. Xu, "Research on transient behaviors and detection methods of stator winding inter-turn short circuit fault in induction motors based on multi-loop mathematical model," in *Electrical Machines and Systems, 2005. ICEMS 2005. Proceedings of the Eighth International Conference on*, 2005, pp. 1951-1955 Vol. 3.
- [28] M. Arkan, D. Kostic-Perovic, and P. J. Unsworth, "Modelling and simulation of induction motors with inter-turn faults for diagnostics," *Electric Power Systems Research*, vol. 75, pp. 57-66, 2005.
- [29] T. A. Kawady, A. A. Afify, A. M. Osheiba, and A. I. Taalab, "Modeling and Experimental Investigation of Stator Winding Faults in Induction Motors," *Electric Power Components and Systems*, vol. 37, pp. 599-611, 2012/04/22 2009.
- [30] S. Lee, M. D. Bryant, and L. Karlapalem, "Model- and Information Theory-Based Diagnostic Method for Induction Motors," *Journal of Dynamic Systems, Measurement, and Control*, vol. 128, pp. 584-591, 2006.
- [31] C. M. Ong, *Dynamic Simulation of Electric Machinery*: Prentice Hall PTR 1998.

## Optimization of Light Pulse Response of CMOS Image-Based Receiver for Spatial Communications

Song Song<sup>a</sup>, Keita Yasutomi<sup>a</sup>, Keiichiro Kagawa<sup>a</sup>, Isamu Takai<sup>b</sup>, Shoji Kawahito<sup>a</sup>

<sup>a</sup> Research Institute of Electronics  
Shizuoka University, Japan  
Tel : (81)0534781342. Fax : (81) 0534125481  
E-mail : song@idl.rie.shizuoka.ac.jp

<sup>b</sup> Toyota central R&D Labs, Inc, Japan  
E-mail : takai@idl.rie.shizuoka.ac.jp

### ABSTRACT

Recently, aiming to the carry out the realization of advanced traffic systems, the optical communication system which is based on LED traffic lights is presently being studied. Devices used to find the area of signal light source, and receive the optical signal are strongly required. This paper investigates CMOS light pulse receiver (LPR) cell for car-to-car and road-to-car spatial optical communication. In present type of pixel, the LPR cell consists of a photodiode with a charge sensing node and charge overflow drain. If fringing field is created, the photodiode capacitance in depletion region is greatly reduced. Therefore the depleted diode implemented with pinned photodiode technology is of great help with regards to enhancing the time response while achieving high-sensitivity. In accordance with the analysis and calculation of SPECTRA simulation, the response to the received light pulse is optimized by considering charge sensing node capacitance of LPR cell in different structural parameters in order to select the most suitable ones.

### Keywords

*Spatial optical communication, CMOS image sensor, Light pulse receiver (LPR) cell, Optimization of response speed, LED-based communication*

# Ultra Wideband Microstrip Antenna Using T-Shaped Stub Fed by Coplanar Waveguide

Rastanto Hadinegoro, Indra Surjati and Yuli Kurnia Ningsih  
 Graduate Program Department of Electrical Engineering  
 Faculty of Industrial Technology Trisakti University  
 Jakarta, Indonesia  
[rastanto@yahoo.com](mailto:rastanto@yahoo.com), [indra@trisakti.ac.id](mailto:indra@trisakti.ac.id) and [yuli\\_kn@yahoo.com](mailto:yuli_kn@yahoo.com)

**Abstract**— A novel design for ultra wideband microstrip antenna using T-shape stub fed by coplanar waveguide is proposed and experimentally studied. The multiband frequencies can be reached by controlling the length of a and b of the T shaped stub. The results shown that the proposed antenna can be achieved multiband frequencies with return loss -21.5 dB at frequency 2.65GHz, return loss -24.5dB at frequency 5GHz, and return loss -35dB at frequency 8.42GHz. Impedance bandwidth of the proposed antenna is 6570 MHz or about 200% (VSWR < 2) with broadside radiation patterns and the antenna gain is about 5.02 dBi.

**Keywords**— Coplanar waveguide, Multiband, T-shaped stub, Ultra Wideband

## I. INTRODUCTION

Recently, wireless communications have been developed widely and rapidly, which leads to a great demand in designing broadband antennas for mobile terminals. Among various forms of planar antennas, coplanar waveguide (CPW) fed printed slot antennas have the simplest structure of a single metallic layer. Because CPW fed wide slot antennas have the advantages of wide bandwidth and easy integration with monolithic microwave integrated circuit (MMIC). And the planar antennas fed by CPW have many advantages such as low profile, low cost, and suitable for integration with active device. The designs of the CPW fed wide slot antennas have recently received much attention [1-2].

A simple CPW fed square slot antenna, the impedance bandwidth can be reached about 30%[3-4]. As reported that CPW-fed slot antennas with strip-loaded [5] or with a widened tuning stub [6] can be reached the impedance bandwidth about 60%. Ultra Wide Band (UWB) technology is one of the most promising solutions for future communication systems due to its high-speed data rate and excellent immunity to multi-path interference. UWB is known as a Radio Frequency (RF) technology that transmits data in binary form, using extremely short duration impulses over a wide spectrum of frequencies. It has a marvelous quality of delivering data over 10 to 100 meters and did not require any kind of dedicated radio frequency, so it is also known as carrier-free, impulse or base-band radio and also transmits information over a large bandwidth (>500 MHz)[7].

It has been well known that the future communication technology pressingly demands integration of more than one

communication system into a limited equipment space. Thus, the future communication terminal antennas will not only be desired to be low profile, lightweight, flush mounted, and single-feed but also need to meet the requirements of multiband operation for sufficiently covering the possible operating bands.

This paper proposed a simple design of T-shaped stub microstrip antenna fed by coplanar waveguide to generate ultra wide band frequencies more than 60%. The proposed antenna design and the simulation results are presented.

## II. ANTENNA DESIGN

Fig. 1 shows the geometry of the proposed antenna. The antenna is excited by 50Ω microstrip line with T-shaped stub. The patch antenna is fabricated on FR4 substrate with the dielectric constant ( $\epsilon_r$ ) = 4.6 and the substrate thickness (h) = 1.6 mm. The coplanar waveguide, having a strip of thickness ( $w$ ) and gap ( $g$ ) between the strip and the coplanar ground plane, is used to excite the T-shape stub.

The structure and dimensions of the proposed antenna ultra wide band can be calculated by equation (1) and (2) for design a microstrip antenna shaped rectangular.

$$L_{eff} = \frac{c}{2f_{10}\sqrt{\epsilon_e}} \quad (1)$$

$$W = \frac{c}{2f_o \sqrt{\frac{(\epsilon_r + 1)}{2}}} \quad (2)$$

$$\epsilon_e = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left( \frac{1}{\sqrt{1 + 12h/W}} \right) \quad (3)$$

The width of the 50Ω microstrip line ( $w$ ) is 3 mm, the gap of the coplanar waveguide line ( $g$ ) is 0.4 mm and the dimension of ground and T-shape stub  $a \times b$  is 12 mm x 6 mm.

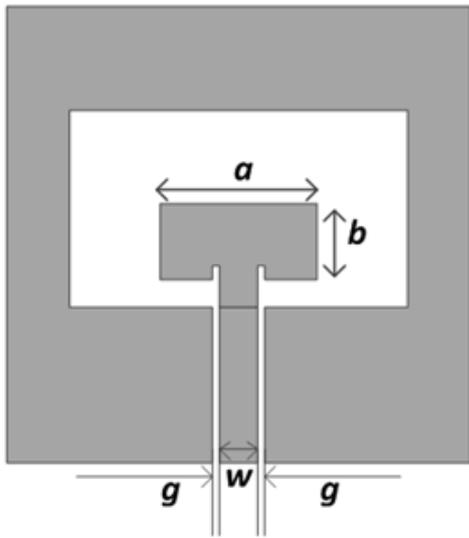


Fig.1. Geometry of the proposed T-shape stub antenna fed by coplanar waveguide

### III. EXPERIMENTAL RESULTS

The analysis and performance of the proposed antenna is explored to get the best impedance matching. The analysis of the antenna carried out by varying parameter. At the first iteration with parameter  $a = 6$  mm and  $b = 3$  mm. The simulation result is shown in Fig.2 with return loss less than -10 dB and the range frequency operation (5.51GHz – 6.68GHz) and (8.78GHz – 9.87GHz) can be generated bandwidth about 2260 MHz.

The second iteration with parameter  $a = 8$  mm and  $b = 4$  mm. From the simulation result, return loss value is shown in Fig.3 with the range frequency operation (3.78GHz – 6.8GHz) and (8.22GHz – 9.48GHz) bandwidth 4280 MHz can be achieved.

The third iteration with parameter  $a = 10$  mm and  $b = 5$  mm and the simulation result is shown in Fig.4. From Fig.4 shows that bandwidth about 5600 MHz can be reached in the range frequency operation of (2.81GHz – 6.94GHz) and (7.76GHz – 9.23GHz).

The fourth iteration with parameter  $a = 12$  mm and  $b = 6$  mm. Bandwidth 6570 MHz can be generated in the frequency operation (2.43GHz – 9GHz) as seen in Fig.5.

Figures (6a) shows the return loss -21.5 dB at frequency 2.65 GHz, return loss -24.5dB at frequency 5GHz, return loss -35dB at frequency 8.42GHz and impedance bandwidth of 6570 MHz or about 200% by adjusting the length of  $a$  and  $b$ . Table 1 shows the iteration parameters  $a$  and  $b$  to generate multiband frequencies. Figure (6b) shows that the proposed antenna using T-shape stub can be achieved wider bandwidth.

TABLE 1 PARAMETERS ITERATION

Iteration	$a$ (mm)	$b$ (mm)	Bandwidth
1	6	3	2260 MHz
2	8	4	4280 MHz
3	10	5	5600 MHz
4	12	6	6570 MHz

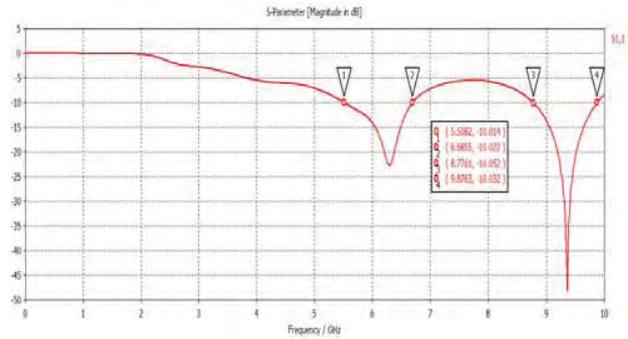


Fig.2. First iteration with parameter  $a = 6$  mm and  $b = 3$  mm

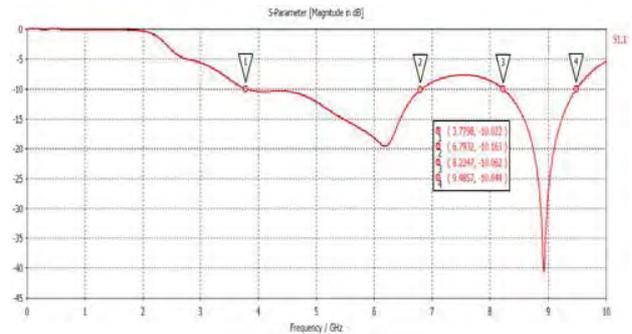


Fig.3. Second iteration with parameter  $a = 8$  mm and  $b = 4$  mm

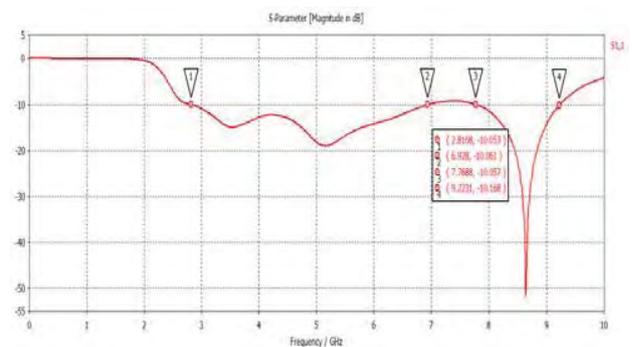


Fig.4. Third iteration with parameter  $a = 10$  mm and  $b = 5$  mm

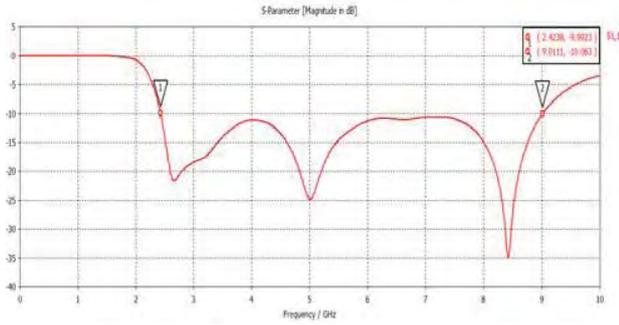
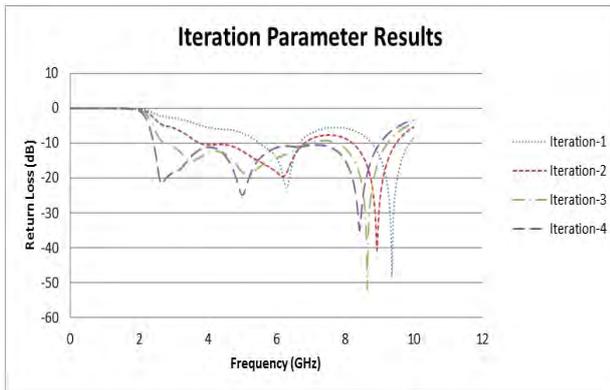


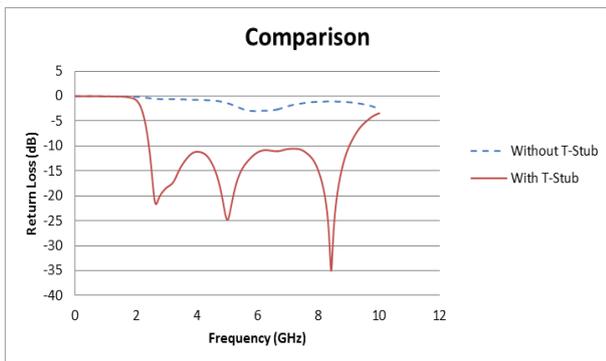
Fig.5.Fourth iteration with parameter  $a = 12$  mm and  $b = 6$  mm

(a)



(a)

(b)



(b)

(c)

Fig. 6. Simulation results from the proposed antenna

Fig.7.Radiation patterns of the proposed antenna at frequency (a) 2.65 GHz, (b) 5 GHz, (c) 8.42 GHz

Figure (7a) until (7c) shows the radiation patterns in the H-plane and E-plane for the three frequencies of the proposed antenna at  $a = 12$  mm and  $b = 6$  mm. The result shows that the antenna has broadside radiation pattern. The antenna gain against frequency is presented in Fig.8 and the antenna gain is about 5.02dBi, with gain variations less than 3 dBi across the operating frequency from 2.42 GHz to 9.01 GHz.

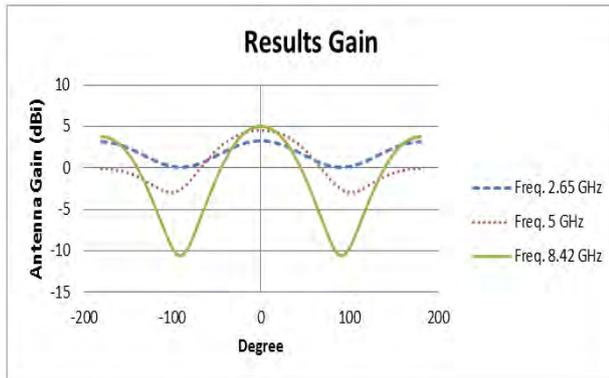


Fig.8. Antenna gain of the proposed antenna

#### IV. CONCLUSION

Rectangular T-shape stub microstrip antenna fed by coplanar waveguide for ultra wide band operation have been designed and experimentally studied. The maximum impedance bandwidth is 6570 MHz or about 200%. The antenna has broadside radiation pattern and gain of about 5.02 dBi is obtained.

#### REFERENCES

- [1] Z. Li, C.-X. Zhang, G.-M. Wang, and W.-R. Su, "Designs on CPW-Fed Aperture Antenna for Ultra-Wideband Applications", *Progress In Electromagnetics Research C*, Vol. 2, 1-6, 2008.
- [2] Q. Chen\*, H.-L. Zheng, T. Quan, and X. Li, "Broadband CPW-Fed Circularly Polarized Antenna with Equiangular Tapered-Shaped Feedline for Ultra-Wideband Applications", *Progress In Electromagnetics Research C*, Vol. 26, 83-95, 2012.
- [3] J.-J. Jiao, G. Zhao, F.-S. Zhang, H.-W. Yuan, and Y.-C. Jiao, "A Broadband CPW-Fed T-Shape Slot Antenna", *Progress In Electromagnetics Research*, PIER 76, 237-242, 2007.
- [4] M. A. Saed, "Broadband CPW-Fed Planar Slot Antennas with Various Tuning Stubs", *Progress In Electromagnetics Research*, PIER 66, 199-212, 2006.
- [5] Chiou, J.-Y., J.-Y. Sze, and K.-L. Wong, "A broad-band CPW-fed strip-loaded square slot antenna," *IEEE Trans. Antennas Propag.*, Vol. 51, No. 4, 719-721, April 2003.
- [6] Chen, H.-D., "Broadband CPW-fed square slot antenna with widened tuning stub," *IEEE Trans. Antennas Propag.*, Vol. 51, No. 8, 1982-1986, August 2003.
- [7] Rahul Malhotra, Tanvi, "UWB Communication Receiver: Review and Design Considerations", *International Journal of Advanced Engineering Sciences and Technologies*. Vol No. 8, Issue No. 2, 197 - 202, 2011.

# Comprehensive Geomagnetic Signal Processings for Successful Earthquake Prediction

Teti Zubaidah, Bulkis Kanata, Cipta Ramadhani  
 Jurusan Teknik Elektro,  
 Fakultas Teknik - Universitas Mataram  
 Jl. Majapahit 62, Mataram 83125, INDONESIA  
 tetizubaidah@te.ftunram.ac.id  
 uqikanata@te.ftunram.ac.id  
 cipta@te.ftunram.ac.id

Budi Irmawati  
 Jurusan Teknik Informatika  
 Fakultas Teknik - Universitas Mataram  
 Jl. Majapahit 62, Mataram 83125, INDONESIA  
 wati@te.ftunram.ac.id

## I. INTRODUCTION

**Abstract**—Previous studies suggested that seismo-electromagnetic signals were generated during earthquake preparation phase. While the anomalous signals in Japan, Russia, and Greece are rather clear; observational results in some regions including America and Indonesian have not conclusive yet, whether the signals are really exist or normal magnetic storm phenomena only. Some problems in measuring instrumentations might also result in anomalous signals. This paper reviews further possibilities by processing a nearly continuous geomagnetic data of INTERMAGNET observatories in three regions (Japan, America, and Indonesia) during the last twelve years (2000–2011). MATLAB ® with digital signal processing and statistical toolboxes is used for night-time data filtering, thereafter processing methods of differentiation and moving average are applied. To get relationship between these anomalous signals and natural processes, tectonic settings of the regions and global geomagnetic conditions are also considered in the analysis.

Fast decreasing of geomagnetic intensities signals are showed prior to earthquakes in Japanese regions, while some little increases of differentiation signals between two adjacent observatories were seen from their moving average values. The anomaly was 10.08 nT, during 8 days started from 32 days prior to the earthquake. Decreasing of geomagnetic intensities prior to earthquakes in American regions occurred rather longer and formerly (during 40 days started from 137 days prior to the earthquake), but the magnitudes are not so high. In Indonesian regions, fast decreasing of geomagnetic signals and increasing of differentiation signals are very clear, especially prior to the giant M9.1 Sumatra earthquake. The anomaly reached extreme magnitude of more than 200 nT during several days prior to the earthquakes. All observational results are back to the normal (base line) values after earthquake occurrences. The distances from the observatories to the epicenters and the magnitudes of earthquakes very affect the results. Elevations of observatories and the tectonic settings of regions may also affect the magnitude of anomalous signals. Some missing data during earthquake days are in fact very valuable to complete the analysis. After all, the geomagnetic signal processing is very valuable in searching appropriate precursors for successful earthquake predictions.

**Keywords**—Geomagnetic; earthquake; precursor; differentiation; INTERMAGNET

Earthquake occurrences are quite often reported to be preceded by some natural anomalous phenomena, among others are increasing or decreasing of regional electric and geomagnetic signals, especially Ultra Low Frequency (ULF) component. Researches on this topic, called as seismo-electromagnetic phenomena, have been conducted in various regions since early nineteenth century. However, [1] has underlined that much of the earliest work was recognized as spurious, because the transient signals were resulted from magnetic variometers (suspended magnets) and other instruments sensitive to ground displacement, acceleration, and rotation common in epicentral regions during the propagation of seismic waves. Only after the mid-1960s, these problems have been avoided through the use of absolute magnetometers installed in regions of low magnetic field gradient to reduce sensitivity to earthquake shaking and by the application of new noise reduction techniques. As a consequence, unambiguous observations of EM variations related to earthquakes and tectonic stress/strain loading, have now been obtained near active faults in many countries (Japan, China, Russia, Italy, Greece, America, and other locations).

Controversies around this crucial topic are still going on. The mostly cited seismo-electromagnetic report is of [2], who accidentally detected extreme ULF geomagnetic signals transient from a ground-based instrument installed at Corralitos, just close (7 km) to the epicentrum of 1989 M7.1 Loma Prieta earthquake in California. They observed increasing of ULF geomagnetic signal amplitudes (in the frequency range of 0.5–2.010 Hz) since one month prior to the earthquake, and detected strong enhancement of the 0.01–0.5 Hz signals from two days before until the occurrence of the earthquake. Conversely, [3] have re-examined all of the available Corralitos data (21 months from January 1989 to October 1990), have found that the reported anomalous geomagnetic signals transient identified by [2] is not related to the Loma Prieta earthquake but is an artifact of sensor-system malfunction.

Another minor opinion against seismo-electromagnetic signal analysis as earthquake precursors is of [4]. They have

concluded that useful prediction of damaging earthquakes seems unlikely using these electromagnetic data, based on the absence of electric and magnetic field precursors for the 2004 M6.0 Parkfield earthquake and other earthquakes with M5–7.3 elsewhere in the San Andreas fault system. Some other authors view the efforts of short term predictions of earthquakes using precursory anomalous signals with strong skepticism, while [5] even called such efforts as a magnetic fraud.

Contrarily, several authors believe that someday people will be able to predict the earthquake occurrences in only a short range of days. They argued that it is just like people being able to fly with airplanes today, which was still a dream before the 19<sup>th</sup> century. These optimistic researchers never give up to search and actively propose the appropriate methods that can be applied for middle-term and even short-term earthquake predictions, which are suitable for regional earthquake early warning system. Among this “optimistic” group members are [6] and [7, 8]. Some of important efforts in searching the methods have been collected by [9] and [10].

In fact, several seismo-electromagnetic satellite-based researches have reported anomalous signal evidences detected from the sky. Changes of ULF and VLF signals in the Ionosphere were detected by the Intercosmos-19 satellite, within 2° latitude and 60° longitude from the epicenter, since 8 hours prior to -until 3 hours after- the 1979 earthquake in Russia [11]. [12] reported that ULF/VLF signals below 450 Hz were detected by COSMOS-1809 satellite, within 6° latitude from the epicenter of the 1988 earthquake in Armenia. Finally, [13] have applied wavelet analysis to investigate if electromagnetic disturbances related to the 2004 M9.2 Sumatra great earthquake could be detected by satellite magnetometers. They have concluded that only a statistical study based on large earthquakes recorded during the CHAMP magnetic mission could bring an answer to such a crucial question.

Regarding all above achievements, searching appropriate methods for seismo-geomagnetic signal processing are still big challenges; because there is no single method appropriate to be applied for every case of earthquake occurrences in different regions over the entire globe. In other words, it is quite possible that each region needs a specific approach to find the most appropriate signal processing method, which depends on its geology and tectonic characteristics.

This paper reports seismo-geomagnetic signal processing by applying differentiation and moving average procedure in the Japanese, American, and Indonesian regions during the last twelve years (2000–2011). Three big earthquakes -two of them are giants- will be analyzed to know whether such earthquakes can generate anomalous geomagnetic signal fluctuations. When the anomalous signals appeared and how large the magnitude of earthquakes will affect the intensity of anomalous geomagnetic signals will also be analyzed. To get relationship between these anomalous signals and natural processes, tectonic settings of the regions and global

geomagnetic conditions are also considered in the analysis. Finally, a fundamental question will be answered, whether seismo-geomagnetic signal processing are really possible to be used as earthquake precursors and applicable for hazard mitigations.

## II. DATA COLLECTIONS AND METHOD

The geomagnetic data from the regions of Japan, USA, and Indonesian are obtained from the INTERMAGNET ([www.intermagnet.org](http://www.intermagnet.org)). The data are of one-minute total intensity (F), which have been initially measured every second, nearly continuously along twelve years during 2000–2011. The data of each region have to be collected from three different observatories, which surround the earthquake locations. To get the reliable data, we use only definitive one and of night time values (i.e. 00:00–06:00 of the local times). MATLAB ® with digital signal processing and statistical toolboxes is used for night-time data filtering, thereafter processing methods of differentiation and moving average are applied. The differentiation procedure was done to reduce signal fluctuations due to diurnal variation, ionospheric as well as magnetospheric disturbances, and to eliminate secular variations. Results will be only variations due to local lithospheric magnetizations, which might be in connection with tectonic activities. To determine how well localization of anomalous signals, observations on global geomagnetic indices were taken by evaluations of the summing of planetary index (Sigma Kp) obtained from ftp site of the *Deutsches GeoForschungsZentrum* (<ftp://ftp.gfz-potsdam.de/pub/home/obs/kp-ap/wdc/>).

The procedure of data processing has been used in [14], which can be shortly described as following: (i) The selected data from the three observatories on one region are daily averaged and plotted individually. (ii) The data are then subtracted each other, to get the differential signals between two observatories in the order of (Obs1-Obs2), (Obs1-Obs3), and (Obs2-Obs 3). (iii) The differential signals are moving averaged to get the low pass filtered (smoothed) signals, with time windows of 7 days (regarding 27 days time interval of the solar cycle). (iv) The signal trends are defined and evaluated over the elapsed times for each moving averaged results, with the focus on the time of earthquake occurrences.

## III. SEISMO-GEOMAGNETIC SIGNALS IN THREE REGIONS

### A. Japanese Region

Data from three INTERMAGNET observatories in Japanese region will be used, i.e. Memambetsu (MMB), Kakioka (KAK), and Kanoya (KNY). The geographical positions of the three observatories and their distances to the earthquake epicenter are listed in Table 1, while Fig. 1 depicts their locations and the epicenter location of studied giant Tohoku Earthquake. The earthquake occurrence is on March 11th 2011 at (38.3°N, 142.37°E) with M9.0 and 29 km depth.

Fig. 2 shows geomagnetic data during October 2010–September 2011 from MMB, KAK, and KNY. Fig. 2(a) shows daily averaged values of the geomagnetic total intensity data, while Fig. 2(b) shows the differentiations between two

observatories and their moving averages. We also show the sigma Kp values to be an indicator for global geomagnetic conditions, especially prior to the earthquake occurrence.

As seen on the parts marked with circles in Fig. 2, some anomalous signal clearly exist with their intensity values as calculated on Table 2. The highest anomalies are in the differentiation signals between KAK and KNY. There were four anomalous signals, with intensities of 9.06 nT on 33 days, 25.74 nT on 10 days, 6.51 nT on 4 days, and 16.8 nT on 1 day prior to the earthquake. Unfortunately, no data recorded on the day of earthquake and three days after, probably because of electrical power failure. Using moving average procedure, we see clear anomalous patterns with magnitude of 10.08 nT during 8 days (DOY 38–45), starting from 32 days prior to the earthquake (from DOY 70). In this case, sigma Kp values are low; means that no geomagnetic storms occurred during the anomalous days. We are, therefore, confident that the anomalous signals were local in the Japanese region and in close correlation to the earthquake occurrence.

### B. American Region

Data from three INTERMAGNET observatories in American region will be used, i.e. Boulder (BOU), Fresno (FRN), and Tucson (TUC). The geographical positions of the three observatories and their distances to the earthquake epicentre are listed in Table 1, while Fig. 3 depicts their locations and the location of studied Colima/Mexico Earthquake. The earthquake occurrence is on January 22<sup>nd</sup> 2003 at (18.77°N, -104.10°E) with M7.6 and 24 km depth.

Fig. 4 shows geomagnetic data during July 2002–June 2003 from BOU, FRN, and TUC. Fig. 4(a) shows daily averaged values of the geomagnetic total intensity data, while Fig. 4(b) shows the differentiations between two observatories and their moving averages



Fig. 1. Three geomagnetic observatories and the location of studied earthquake in Japanese region: MMB, KAK, and KNY with the giant M9.0 Tohoku Earthquake on March 11th 2011.

TABLE I. GEOMAGNETIC OBSERVATORIES IN JAPANESE, AMERICAN, AND CLOSE TO INDONESIAN REGION

Regional	IAGA code	Lat	Long	Elev. (m)	Dist. to EQ (km)
Japan	MMB	43.91°N	144.19°E	42	642
	KAK	36.23°N	140.18°E	36	301
	KNY	31.42°N	130.88°E	107	1295
America	BOU	40.14°N	-105.24°E	2682	2377
	FRN	37.09°N	-119.72°E	331	2541
	TUC	32.18°N	-110.73°E	946	1631
Indonesia	LRM	-22.22°N	144.10°E	4	3452
	KDU	-12.69°N	132.47°E	14	4402
	PHU	21.03°N	105.95°E	5	2246

TABLE II. INTENSITY OF ANOMALOUS GEOMAGNETIC SIGNALS ON MMB, KAK, AND KNY PRIOR TO THE TOHOKU EARTHQUAKE

Anomaly (nT)	Earthquake on 2011.03.11 (DOY 70)			
	DOY 37 (33 days before EQ)	DOY 60 (10 days before EQ)	DOY 66 (4 days before EQ)	DOY 69 (1 day before EQ)
MMB-KAK	9.62	3.38	10.62	1.62
MMB-KNY	10.00	14.00	-3.00	10.00
KAK-KNY	9.06	25.74	6.51	16.8
Sigma Kp	23	29.7	17.3	25.7

TABLE III. INTENSITY OF ANOMALOUS GEOMAGNETIC SIGNALS ON BOU, FRN, AND TUC PRIOR TO THE COLIMA/MEXICO EARTHQUAKE

Anomaly (nT)	Earthquake on 2003.01.22 (DOY 22)			
	DOY 206 (181 days before EQ)	DOY 250 (137 days before EQ)	DOY 277 (110 days before EQ)	DOY 12 (15 day before EQ)
BOU-FRN	7.26	33.86	33.56	30.0
BOU-TUC	-19.26	31.34	21.14	20.0
FRN-TUC	-26.58	-2.57	-12.43	-12.3
Sigma Kp	21.0	33.7	42.0	16.7

We also show the sigma Kp values to be an indicator for global geomagnetic conditions, especially prior to the earthquake occurrence. As seen on the parts marked with circles in Fig. 4, some anomalous signal clearly exist with their intensity values as calculated on Table 3. The highest anomalies are in the differentiation signals between FRN and TUC, but then between BOU and FRN. There were four anomalous signals, with intensities of -26.58 nT on 181 days, 33.86 nT on 137 days, 33.56 nT on 110 days, and 30.0 nT on 15 days prior to the earthquake. The minus signs mean that the signals are lower than normal values.

Unfortunately, no data recorded on some days prior to the earthquake, while anomalous signals were recognized. Nevertheless, by using moving average procedure, we still see the track of anomalous signals during 40 days (DOY 250–290), starting from 137 days prior to the earthquake. In this case, sigma Kp values fluctuate, with some high in between low values. It means that geomagnetic storms probably occurred during some of the anomalous days. Therefore, we considered that not all of the anomalous signals were local in the American region, but due global geomagnetic storms. On the other hand, we are also confident that some anomalous signals were really in close correlation to the earthquake occurrence.

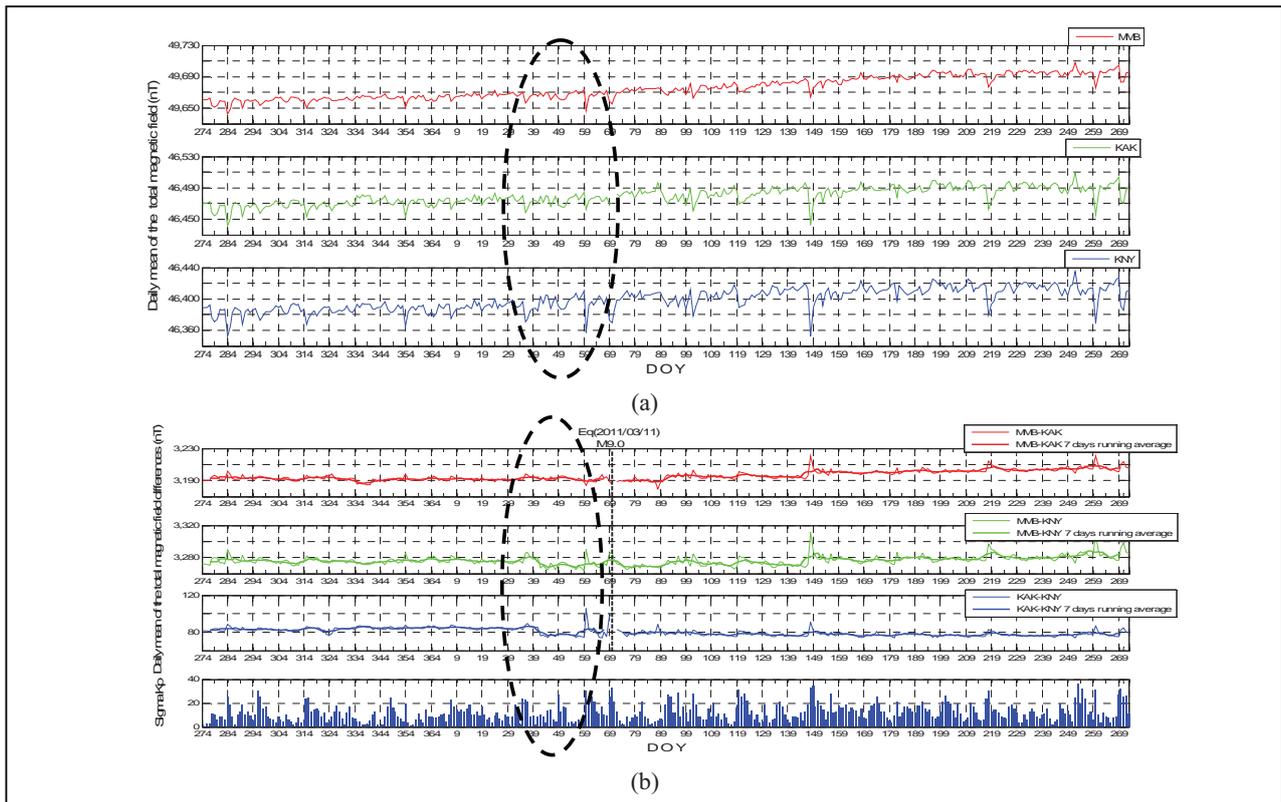


Fig. 2. Geomagnetic anomalous signal related to the M9.0 giant Tohoku Earthquake on March 11th 2011. (a) The daily mean of the total geomagnetic fields observed by three observatories in Japanese region (MMB, KAK, and KNY), and (b) The differentiations signals of two observatories and the moving averages, with sigma Kp values of corresponding days to evaluate the global geomagnetic conditions.

### C. Indonesian Region

Since no INTERMAGNET observatory in Indonesia, data from three INTERMAGNET observatories which are close to Indonesian region will be used, i.e. Learmonth (LRM) in Australia, Kakadu (KDU) in Australia, and Phuthuy (PHU) in Vietnam. The geographical positions of the three observatories and their distances to the earthquake epicenter are listed in Table 1, while Fig. 5 depicts their locations and the location of studied giant Sumatera Earthquake. The earthquake occurrence is on December 26th 2004 at (3.3°N, 95.98°E) with M9.1 and 30 km depth. Another M7.5 earthquake happened before on November 11th 2004 also in Indonesian region will be used as comparison.

Fig. 6 shows geomagnetic data during July 2004–December 2005 from LRM, KDU, and PHU. Fig. 6(a) shows daily averaged values of the geomagnetic total intensity data, while Fig. 6(b) shows the differentiations between two observatories and their moving averages. We also show the sigma Kp values to be an indicator for global geomagnetic conditions, especially prior to the earthquake occurrence.

As seen on the parts marked with circles in Fig. 6, some anomalous signal clearly exist with their intensity values as

calculated on Table 4. Unfortunately, many data were missing on some days prior to and after the earthquakes.



Fig. 3. Three geomagnetic observatories and the location of studied earthquake in American region: BOU, FRN, and TUC with the M7.6 Colima/Mexico Earthquake on January 22nd 2003.

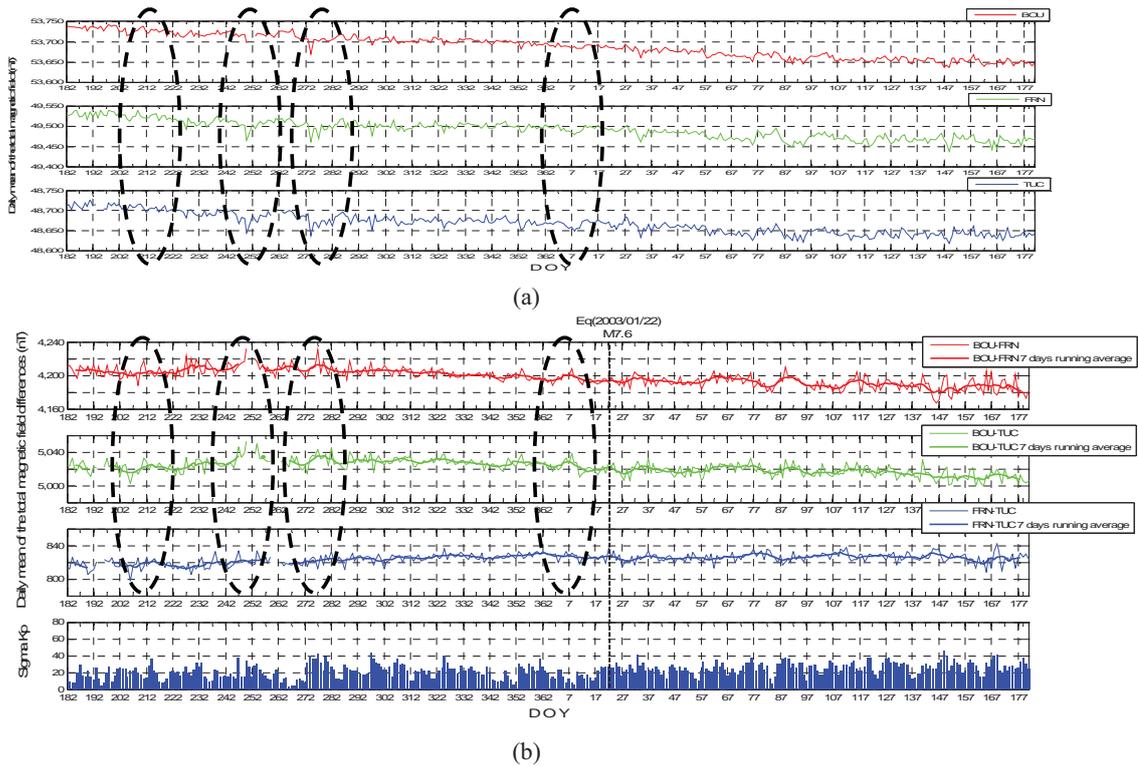


Fig. 4. Geomagnetic anomalous signal related to the M7.6 Colima/Mexico Earthquake on January 22nd 2003. (a) The daily mean of the total geomagnetic fields observed by three observatories in American region (BOU, FRN, and TUC), and (b) The differentiation signals of two observatories and the moving averages, with sigma Kp values of corresponding days to evaluate the global geomagnetic conditions.

Nevertheless, anomalies were clearly seen in the differentiation signal between LRM and PHU. There were four anomalous signals, with intensities of 46.04 nT on 21 (or 66) days, 61.64 nT on 12 (or 57) days, 253.24 nT on 3 (or 48) days, and 286.24 nT on 1 (or 45) days prior to the first (or the second) earthquake. Using moving average procedure, we also see clear anomalous patterns reaching extreme magnitude of more than 200 nT during several days prior to the earthquakes.

On these days, sigma Kp values were also extreme reaching abnormal values of more than 50 nT; but the background sigma Kp values were low. It means that some abnormalities were recorded globally, but we are not quite sure that whether geomagnetic storms occurred during the anomalous days. It is also possible that the anomalous signals were in close correlation to the earthquake occurrences, but they were not only locally detected over Indonesian region, moreover they spread globally due to the giant magnitude of the earthquake. Indeed the anomalies still persisted with approximately magnitude of 100 nT, then gradually decreased and until return to normal values in 112 days after the earthquake.

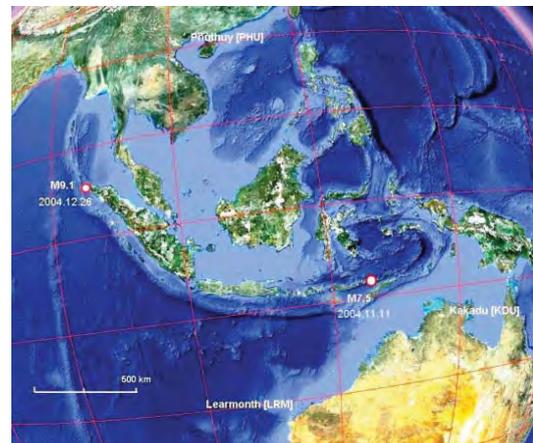


Fig. 5. Three geomagnetic observatories and the location of studied earthquake in Indonesian region: LRM, KDU, and PHU with the giant M9.1 Sumatera Earthquake on December 26th 2004 and of another M7.5 one happened before on November 11th 2004.

TABLE IV. INTENSITY OF ANOMALOUS GEOMAGNETIC SIGNALS ON LRM, KDU, AND PHU PRIOR TO THE SUMATERA EARTHQUAKE

Anomaly (nT)	Earthquake on 2004.11.11 (DOY 316) and 2004.12.26 (DOY 361)			
	DOY 295 (21/66 days before EQ)	DOY 304 (12/57 days before EQ)	DOY 313 (3/48 days before EQ)	DOY 315 (1/45 days before EQ)
LRM-KDU	Not Recorded	Not Recorded	Not Recorded	Not Recorded
LRM-PHU	46.04	61.64	253.24	286.24
KDU-PHU	Not Recorded	Not Recorded	Not Recorded	Not Recorded
Sigma Kp	14.3	25	50	56.3

#### IV. DISCUSSION

Results of study show that big earthquakes generate some anomalous geomagnetic signals prior to the day of occurrences, which can be recorded by the nearby observatories. The highest anomalies mainly in the differentiation signals between two observatories, which one of them located closest to-, and another one located most distant from-, the epicenter. It is possibly because the closest observatory recorded the highest intensity, while the most distant recorded the lowest intensity, so that the

differentiations are of greatest. However, in case of American region, TUC is the nearest to the epicenter and FRN is the farthest, therefore the differentiation signals of FRN-TUC should be the highest. Indeed those occurred more frequent in BOU-FRN signals, probably due to the location of FRN and TUC which are bounded to the epicenter by the same shoreline, while BOU is located on the high altitude (2682 m). Here BOU recorded is much less signals than other two observatories.

Anomalies in American region were less visible rather than ones in Japanese and Indonesian regions. We suggest that it was because larger distances between observatories to the epicenters, while the magnitude of earthquake is smaller. In contrast, the studied earthquake in Indonesian region is giant; therefore we observed anomalies even from rather remote observatories. The elevations of used observatories in Japanese and Indonesian regions are quite low, which one in Australia is only of 4 m above the sea level. We suggest further that observatories which are close to the sea level may more responsive to the earthquake.

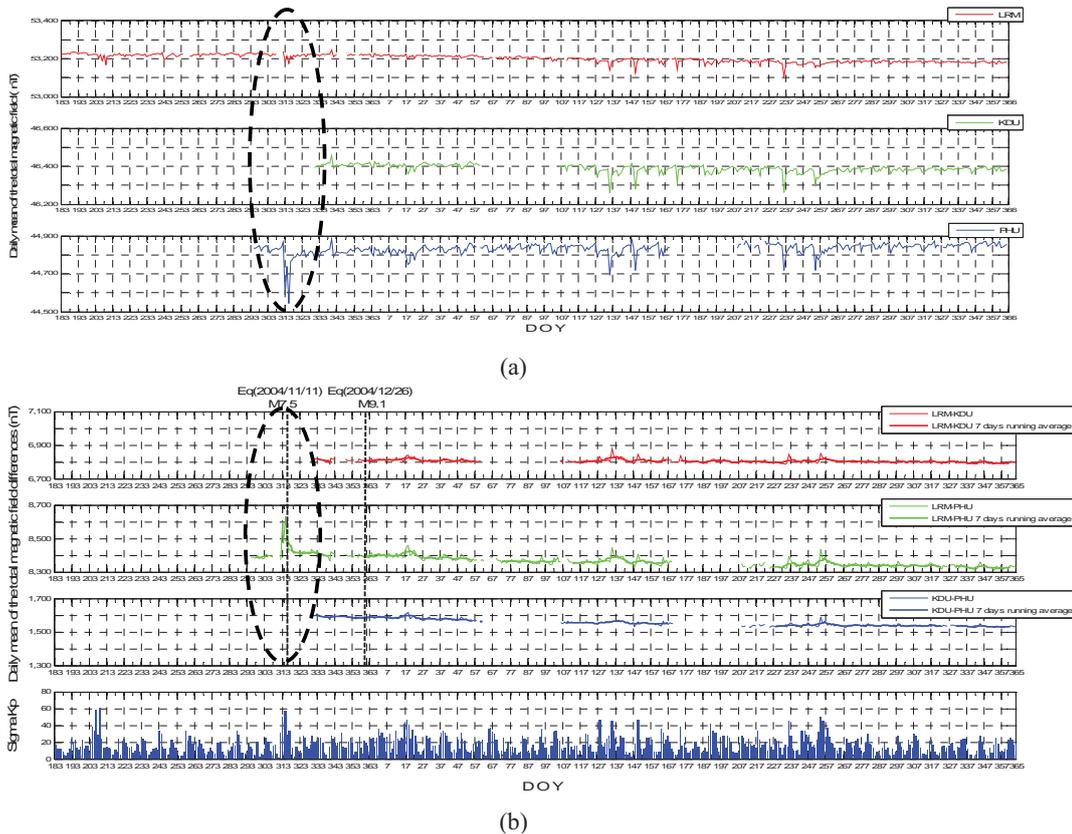


Fig. 6. Geomagnetic anomalous signal related to the M9.1 giant Sumatra Earthquake on December 26th 2004. (a) The daily mean of the total geomagnetic fields observed by three observatories which are the closest to Indonesian region (LRM, KDU, and PHU), and (b) The differentiations signals of two observatories and the moving averages, with sigma Kp values of corresponding days to evaluate the global geomagnetic conditions.

All studied regions have tectonic setting with normal fault mechanisms, which is caused by subduction of oceanic crust into continental crust. However, in American region the subducting Cocos plate is only a very small with a relatively low subduction speed of 44 mm/year, in comparison with the giant subducting Indian oceanic plate with a speed of 75 mm/year.

Further comparison to our previous study [15], we found that for other earthquakes with smaller magnitudes in Japanese region (on September 25<sup>th</sup> 2003 and September 5<sup>th</sup> 2004) anomalies were also clear. They were seen four to five times, from 99 days and 83 days prior to the earthquakes. These clear anomalies were generated due to closer distances from the epicentres to the observatories.

It is quite regret that we have no data of some important dates from the studied observatories in America and Australia, which probably have been filtered out by the national institutions who supplied the data to the INTERMAGNET, because they were quite extreme while no reasonable high sigma Kp values on the days. On the other hand, it is possible that the extreme (filtered out) data are quite valuable for seismo-geomagnetic analysis. There were many of these data losses from LRM and KDU after November 11<sup>th</sup> 2004 earthquake in Indonesia, therefore we could not analyze the most important days just before the giant Sumatera Earthquake on December 26<sup>th</sup> 2004. It will be useful to compare the recent results with data from other nearby observatories, even more to use data from Indonesian observatories for comprehensive analysis. In this case, we also found that for this giant earthquake, the sigma Kp were quite extreme. We therefore need more studies of 27 days of solar cycle, whether or not the anomalous days were on the maxima cycles (as normal geomagnetic storms phenomena, otherwise seismogenic ones). We further suggest studying the Kp cycle within quite longer time interval, e.g. 50–70 years maybe enough.

## V. CONCLUSION

We have processed geomagnetic signals and analyzed their correlations to three large magnitude earthquakes in Japanese, American, and Indonesian regions; and conclude that the geomagnetic signal processing is very valuable in searching appropriate precursors for successful earthquake predictions. Here we re-underline some important aspects:

1. Fast decreasing of geomagnetic intensities signals are showed prior to earthquakes in Japanese, American, and Indonesian regions. All observational results are back to the normal (base line) values after earthquake occurrences.
2. The highest anomalies mainly in the differentiation signals between two observatories, which one of them located closest to-, and another one located most distant from-, the epicentre.
3. The distances from the observatories to the epicentres and the magnitudes of earthquakes very affect the results,

while observatories which are close to the sea level may more responsive to the earthquake.

4. The regional tectonic setting, including size and velocity rate of subductions, may also affect the results.
5. Some missing data (which probably have been filtered out by the national institutions who supplied the data to the INTERMAGNET) during earthquake days are in fact very valuable to complete the analysis.
6. Further studies which will be very useful for Indonesian region are: (i) comparing the recent results with data from other nearby observatories even more to get data from Indonesian observatories, and (ii) studies of 27 days of solar cycle in quite longer time interval (e.g. 50–70 years) to determine whether the extreme sigma Kp values prior to the giant earthquakes are seismogenic phenomena, otherwise normal geomagnetic storms ones.

## ACKNOWLEDGMENT

This research is funded by the Indonesian Directorate of Higher Education under Hibah Penelitian Unggulan Perguruan Tinggi 2012 program entitled “Pengolahan Sinyal Seismo-Geomagnetik untuk Mitigasi Bencana Gempa Bumi Tektonik Regional di Wilayah Indonesia Timur (Seismo-Geomagnetic Signals Processing for Regional Tectonic Earthquake Hazard Mitigations of Eastern Indonesian Regions)”. The results presented in this paper rely on data collected at magnetic observatories. We thank the national institutes that support them and INTERMAGNET for promoting high standards of magnetic observatory practice ([www.intermagnet.org](http://www.intermagnet.org)). MATLAB® license number 863485 is used for data processing. TZ is alumni of Electrical Engineering Dept. of University of Indonesia (0493037152).

## REFERENCES

- [1] Johnston MJS (2007) Seismo-Electromagnetic Effects, Encyclopedia of Geomagnetism and Paleomagnetism, Springer, The Netherlands, 908-910.
- [2] Fraser-Smith AC, Bernardi A, McGill PR, Ladd ME, Helliwell RA, Villard Jr. OG (1990) Low-frequency magnetic field measurements near the epicenter of the Ms 7.1 Loma Prieta earthquake, Geophys. Res. Lett., 17, 1465-1468.
- [3] Thomas JN, Love JJ, Johnston MJS (2009) On the reported Magnetic Precursor of the 1989 Loma Prieta earthquake. Phys. Earthq. Planet. Int., 173, 207-215.
- [4] Johnston MJS, Sasai Y, Egbert GD, Mueller RJ (2006) Seismomagnetic Effects from the Long-Awaited 28 September 2004 M 6.0 Parkfield Earthquake. Bull. Seis. Soc. Am., Vol. 96 (4B): S206–S220, doi: 10.1785/0120050810.
- [5] Campbell WH (2003) Introduction to geomagnetic fields, Second edition, Cambridge University Press, Cambridge. ISBN: 0 521 82206 8.
- [6] Uyeda S, Nagao T, Kamogawa M (2009) Short-term earthquake prediction: Current status of seismo-electromagnetics. Tectonophysics, 470: 205–213, doi:10.1016/j.tecto.2008.07.019.
- [7] Hattori K, Takahashi I, Yoshino C, Isezaki N, Iwasaki H, Harada M, Kawabata K, Kopytenko E, Kopytenko Y, Maltsev P, Korepanov V, Molchanov O, Hayakawa M, Noda Y, Nagao T, Uyeda S (2004a) ULF geomagnetic field measurements in Japan and some recent results associated with Iwateken Nairiku Hokubu earthquake in 1998. Physics and Chemistry of the Earth, 29: 481–494, doi: 10.1016/j.pce.2003.09.019.

- [8] Hattori K (2004b) ULF geomagnetic changes associated with large earthquakes. *TAO*, 15 (3): 329–360.
- [9] Hayakawa M, Molchanov OA (eds) (2002) *Seismo-Electromagnetics: Lithosphere-Atmosphere-Ionosphere Coupling*. TERRAPUB, Tokyo, Japan.
- [10] Hayakawa M (ed) (2009) *Electromagnetic phenomena associated with earthquakes*, Transworld Research Network, Kerala, India. ISBN: 978-81-7895-297-0.
- [11] Larkina VI, Migulin VV, Molchanov OA, Kharkov IP, Inchin AS, Schvetcova VB (1989) Some statistical results on very low frequency radio wave emissions in the upper ionosphere over earthquake zones. *Phys. Earth Planet. Inter* 1989, 57:100–109.
- [12] Serebryakova ON, Bilichenko SV, Chmyrev VM, Parrot M, Rauch JL, Lefeuvre F, Pokhotelov OA (1992) Electromagnetic ELF radiation from earthquake regions as observed by low altitude satellites. *Geophys. Res. Lett.*, 19(2): 91–94, doi: 10.1029/91GL02775.
- [13] Balasis G, Manda M (2007) Can electromagnetic disturbances related to the recent great earthquakes be detected by satellite magnetometers? *Tectonophysics*, 431, 173-195.
- [14] Masci F, Palangio P, Persio MD (2009) Magnetic anomalies possibly linked to local low seismicity. *Nat. Hazards Earth Syst. Sci.*, 9: 1567–1572.
- [15] Kanata B, Zubaidah T, Irmawati B, Ramadhani C (2013) Pengolahan Sinyal Geomagnetik sebagai Prekursor Gempa Bumi di Regional Jepang. *Proceeding (in press)*, Konferensi Nasional Sistem Informasi 2013, Mataram.

# Pi Slot Array Two Elements Multi Wide-band Microstrip Antenna Fed by Tuning Stub

Ambros Magnus Rudolf Mekeng<sup>1</sup>  
 Department of Telecommunication  
 Engineering  
 University of National  
 Jakarta – Indonesia  
 tektel2009@rocketmail.com

Iskandar Fitri<sup>2</sup>  
 Department of Telecommunication  
 Engineering  
 University of National  
 Jakarta – Indonesia  
 tektel2001@yahoo.com

**Abstract**—Achievement multi-wideband with bandwidth 100 MHz of the passive antenna from a resonant frequency 4 GHz is proposed and investigated. Antenna design using two substrates. The upper layer used as an radiation element while the bottom layer is used for the feeding. The feeder of the microstrip line is connected to an electromagnetic proximity coupling with tuning stub technique and two elements of pi slot array so as to obtain multi wideband 3.25-3.35 GHz, 4.40-4.50 GHz, 4.82-4.94 GHz, 7.11-7.45 GHz (VSWR  $\leq 2$ )

**Keywords** — Ultrawideband, Bandwidth, Mikrostrip,

## I. Introduction

Today's in the world The development of telecommunications technology increasingly competitive and inovative, as an example the wireless telecommunications systems , which is in development the wireless technology requires a wide bandwidth. Of this phenomenon is very possible to created or researched antenna has a wide bandwidth with the concept of multi-frequency and wide bandwidth (multi-wideband).

The Researched of microstrip antenna has many uses slot elements type (MSA) and microstrip patch elements (MPA) with rectangles radiator especially for single elements to enhance bandwidths. Several researched has MPA technique to increase bandwidth by proximity coupling fed [1] [2]. In recent years a lot of focus design microstrip antenna to obtain multi-wideband characteristics [3] [4]. But as far as I know is still little research on MPA and MSA array configuration fed by proximity coupling using tuning stub to generate multi-wideband characteristics.

In accordance with the trend and the needed of wide bandwidth, in this research we design *Pi Slot Array Two Elements Multi Wide-band Microstrip Antenna Fed by Tuning Stub*. This study describes the incorporation of proximity coupling techniques and tuning stub techniques. The expectation from this experiments conducted to obtain a prototype microstrip antenna with multi-band characteristics, it is above two operating bandwidth of each

bandwidth >100MHz. More over from this study will support future communication systems with a terabyte capacity.

## II. Antenna Structure and Mechanism

In the process of designing pi slot microstrip patch antenna, we realized that the main parameters are important to determine in a microstrip line is the characteristic impedance ( $Z_0$ ). So that in this researched we did the simulation using impedance characteristic of  $50\Omega$  because  $50\Omega$  is the standart of microwave input impedance.

The initial stage in the design process is to find the value of the approach channel *width* of microstrip antenna ( $w$ ) with corresponding to the characteristic impedance of  $50\Omega$ . We use PCAAD software version 3.0 to do that as shown in the figure below:

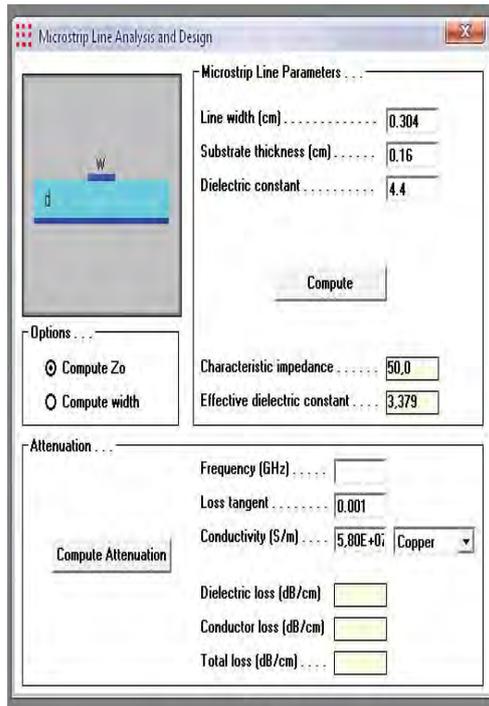


Figure 1. Simulation of line width

From the simulation results obtained PCAAD fed size using width channel (w) corresponding to the characteristic impedance of  $50 \Omega$  is equal to 0.304cm. After getting the value of (w), we look for approaches to obtain value of fed line length (l). In search of value (l) we uses a mathematical approach by first looking for value of  $\lambda_0$ ,  $\epsilon_{eff}$ , and  $\lambda_m$  according to mathematical formulas found in reference [5] that the result is obtained as follows:

$$\epsilon_{r\,eff} = 3,144825833$$

$$fc = 4GHz$$

$$\lambda_0 = 0,00125m$$

$$\lambda_m = \frac{\lambda_0}{\sqrt{\epsilon_{r\,eff}}} = 0,0070487436 \quad cm$$

$$l = \frac{\lambda_m \sqrt{\epsilon_{r\,eff}}}{2}$$

$$0,0070487436$$

After getting the numbers from these approaches as well as the length and width of the fed line channel, then the numbers are included as a reference in the next step of antenna design using the simulator. In the design process we use a simulator HFSS version 10 (High Frequency Simulator Sigh) the materials used FR4 substrate with a thickness of 0.16 mm and dielectric constant values  $\epsilon_r = 4.4$ , and copper (cu) for fed line and patch pi slot.

But in the simulation phase, the length and width numbers of fed line that have been sought was not exactly produce bandwidths that match to the resonance frequency of 4 GHz. Thus, in the simulation process the numbers from PCAAD and

mathematical formulas is altered to get the size of antenna according to the resonance frequency of 4 GHz. After the size of antenna is changed, eventually we get the appropriate size for the antenna to the resonant frequency 4 GHz with multi wide bandwidth (5 MHz) and the value of reflection coefficient is  $\leq -10$  dB and transmission coefficient is  $\leq 2$  that the design fix in the figure below :

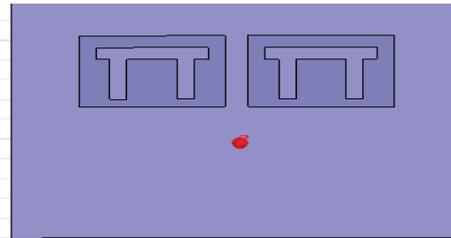


Figure 2. Antenna Dimension

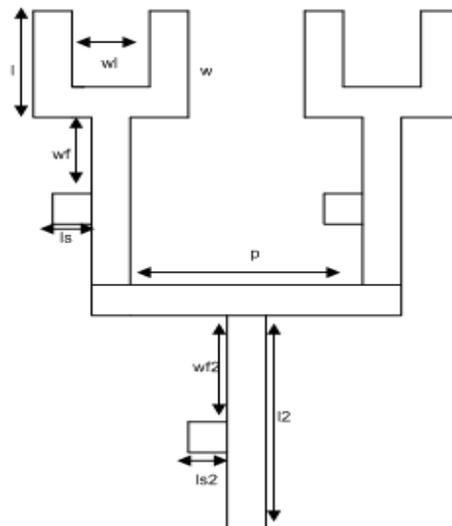


Figure 3. Feeder Antenna Microstrip with tuning stub (wl= 0,9cm. l=1cm. wf= 0,6cm. ls=0,5cm, wf2=1,9 cm. l2=2.5cm. ls2=0,5cm. p=3,3cm)

### III. Simulation Results and Analysis

From the simulation results using the antenna size as shown in figure 2 and (3) we found that the antenna has four operating bandwidths are at 3.25GHz - 3.35 GHz(100 MHz Bandwidth ), 4.40 GHz - 4.50 GHz(100 MHz Bandwidth ), 4.82GHz - 4.94 GHz(120 MHz Bandwidth ) , 7.11GHz - 7.45 GHz(340 MHz Bandwidth ) then  $VSWR \leq 2$  with a resonance frequency of 4 GHz. This report can be seen in figure 4 which intersected at -10dB return loss. From this simulation we show that the best wide bandwidth is obtained at the intersection of at most 340 MHz starting from frequency 7.11GHz - 7.45GHz. From the graph results of these simulations we can be

seen that the best return loss for frequency 7.11 GHz have a return loss value of -44.11 dB.

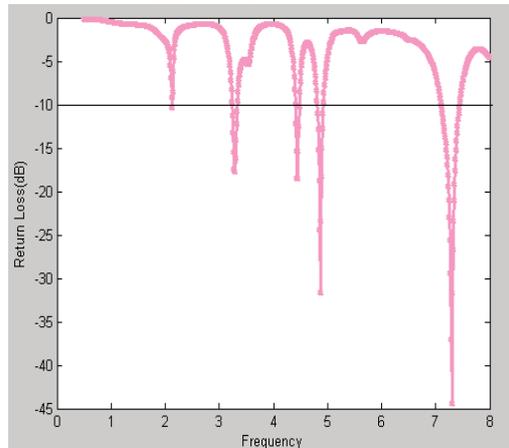


Figure 4. Return loss

In addition to the comparison of bandwidth and return loss, in the simulation we can also see the comparisons between frequencies with VSWR as shown in figure 5 where the value of VSWR  $\leq 2$  is starting from frequency 3.25GHz- 3.35GHz, 4.40GHz – 4.50 GHz, 4.82GHz - 4.94GHz, 7.11GHz – 7.45 GHz with the best VSWR value is 1.3 at a frequency of 7.16GHz.

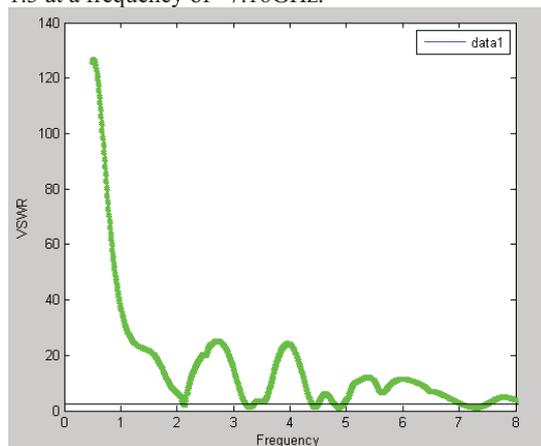


Figure 5. VSWR

Table1. sample of input impedance 50Ω with the frequency operation

No	Frequency	Z <sub>in</sub> Real(Ω)	Z <sub>in</sub> Imaginer(Ω)
1	3.230000	50.910372	42.209039
2	4.440000	50.678324	11.999867
3	7.270000	50.774246	-5.266951
4	7.280000	50.496741	-3.345230
5	7.290000	50.266414	-1.392474
6	7.300000	50.086306	0.592970
7	7.350000	50.0516	13.291308

Input impedance of this experiment is expected to get 50 Ω. From the simulation results in the frequency range from 3.25 GHz – 3.35 GHz, 4.40 GHz – 4.50 GHz, 4.82 GHz - 4.94 GHz, 7.11GHz – 7.45 GHz input impedance obtained were close to the -5 and +5 from the value of 50 Ω. The sample of frequency with 50 Ω input impedance is show in table 1.

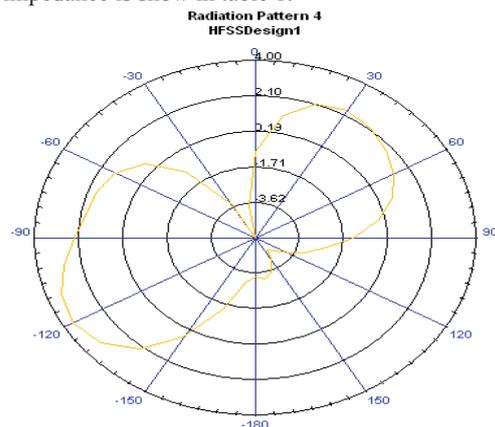


Figure 6. Radiation Patern

The resulting radiation pattern of the antenna design is lead to angle 0°-120° and -30°(-150°). The result of radiation is show in figure 6.

#### IV. Conclusion

Microstrip patch pi slot two element array antenna has been designed with 4 GHz resonance frequency using proximity coupling techniques and multi-tuning stub. The antenna has designed until simulation have frequency operation at 3.25GHz – 3.35GHz , 4.40GHz – 4.50 GHz, 4.82GHz - 4.94GHz, 7.11GHz - 7.45GHz. The antenna have a multi- wide bandwidth with the reflection coefficient  $\leq -10$  and VSWR  $\leq 2$ . This antenna have four bandwidth  $\geq 100$  MHz so that the antenna have multi-wideband characteristics.

#### References

- [1] Akhavan, H.G. & Syahkal, D.M., "A Simple Technique for evaluation of Input Impedance of Microstrip-Fed Slot Antennas", IEEE Confrence Publication, No.407, 1995
- [2] Garg, R.,Bhartia, P.,Bahl,I.,and Ittipiboon,A., "Microstrip Antenna Design Handbook", Artech House, Noorwod,2001
- [3] Karlsson, M.& Gong.S., "Wideband Patch Antena Array For Multiband UWB", Department Of Technology and Natural Scienses-ITN, Linkopig University, SE-601 74 Norrkoping, Sweden, 2005.
- [4] Rakesh Kumar Tripathi., & Rajesh Khanna., "Pi Shape Slot Loaded Patch Antenna fo Wi-Max Applications, " Special Issue of International Journal of Computer Applications (0975 – 8887) on Electronics, Information and Communication Engineering - ICEICE No.6, Dec 2011
- [5] Jean-Francois Zurcher dan Fred E.Gardiol, "Broadband Patch Antenna", Boston : Artech House, 1995.

# Fluid Structure Interaction Simulation in IC Encapsulation Process

Dadan Ramdan\*, Usman Harahap  
Electrical Engineering Department  
Engineering Faculty, Medan Area University  
Medan, Indonesia  
061-7357771, dadan@uma.ac.id

Mohd. Zulkifli Abdillah  
\*School of Mechanical Engineering  
Universiti Sains Malaysia  
Penang, Malaysia  
+604-5996310, mezul@eng.usm.my

**Abstract**— This paper presents three-dimensional (3D) fluid structure interaction (FSI) technique; using Mesh based Parallel Code Coupling Interface (MpCCI), for the visualization of wire sweep during encapsulation. The effects of number of mold cavity outlet vents on the melt flow behavior, wire sweep, and von Mises stress distributions, are mainly studied. 3D model of mold and wire were designed using GAMBIT, simulated fluid flow and structural using FLUENT and ABAQUS. Three types of mold cavity simple model namely Type D1, Type D2 and Type D3 with different outlet vents were studied to analyze wire sweep deformation. Polymer rheology model with curing effect (Castro-Macosko model) have been used in the fluid flow modeling and Volume of Fluid (VOF) technique was applied for melt front tracking for the Epoxy Molding Compound (EMC). In the present study, Type D3 with minimum outlet vent area of mold cavity shows the highest deformation of wire and highest stress distributions. The numerical results of wire deformation pattern were compared with the analytical method and found in good conformity. The strength of MpCCI software in handling FSI problems is proved to be excellent. This present work is expected to be the reference and guideline for microelectronics industry.

**Keywords**— Fluid Structure Interaction, Wire Sweep, MpCCI, Castro-Macosko model, Epoxy Molding Compound (EMC), Volume of Fluid (VOF).

## I. INTRODUCTION

Nowadays, the electronics industry could offer their product in a compact size but also give more functionality, better performance and lower cost. It is widely used in applications including computing, communications, biomedical, automotive, military, and aerospace. They must operate in varying temperature and humidity environments, exposure to moisture and mechanical stresses can be highly detrimental to electronic devices and may lead to device failures [1]. Therefore, it is essential that the electronic devices be packaged for protection from their intended environment. The design, fabrication and encapsulation of the package has become increasingly complex and challenging owing to increased number of components and the need for miniaturization [2]. The major objectives of electronics devices encapsulation are to protect of the device from mechanical and chemical hazards, and thermal path for heat dissipation [1].

Wire bonding is the one principal ways of connecting the silicon device to the lead frame in molded plastic packaging of

encapsulation process [3]. Typical wire bonding process uses gold or aluminum wire to connect the die pads with the leadframe [4]. New packages methods, such as Flip Chip, use Lead-Tin solder bump as interconnection between die and substrates [1]. The purpose of this process is to establish electrical interconnections for signal and power transfer.

During the encapsulation of microelectronic chips by the transfer molding process, the fragile gold wire bonds, which provide electrical connection from the chip to the leadframe, are subjected to flow stresses from the molding compound [5]. The flow stress can cause the leadframe and the wire bond to permanently deform from their original geometry [6]. If the displacement of a bonding wire is too large, it can result in a package failure; either short circuits due to contact between adjacent wires or open circuit due to a broken wire [7]. Even if the displacement is not so severe, wire deformation can result in deteriorated electrical and mechanical performance of the device, which will shorten its lifetime [8]. Hence, it's important to minimize the wire-sweep deformation during encapsulation.

The technique time-dependence and the two-phase aspects of the flow, especially the propagation of the resin front in the mold, and the effect of its impact with the wires, and by introducing the time-dependent material, geometric, and loading variations that exist in the actual phenomenon along wires was introduced [9].

In fact, the wire deflection during encapsulation is a typical fluid-structure interaction (FSI) problem. The drag force resulted from the fluid flow caused the wire sweep or normally known as the wire deformation. The use of finite volume method (FVM) for the flow analysis and the finite-element method (FEM) for the structure analysis, coupled with MpCCI was reported in various works [10-12]. However, as far as the authors are conscious, the use of FSI has not been reported so far in the wire sweep problems.

In the present study, 3D computational analysis is used to predict the wire sweep problems in the simple model of encapsulation process. The FVM-based (FLUENT) and FEM-based (ABAQUS) software with MpCCI coupling software are utilized as tools to perform the FSI for the virtual model of the package. The Castro-Macosko model is used to describe the polymer rheology with curing effect in the viscosity behavior of the epoxy molding compound (EMC). The program is

written in C language has been employed in UDF to calculate the curing kinetics of EMC. The volume of fluid (VOF) technique is also applied to track the flow front of the EMC. Wire sweep profiles are analyzed and presented by ABAQUS. The EMC flow field and wire sweep phenomena can be visualized simultaneously through this FSI simulation. The simulation results are also compared with the analytical results available in literature and found in good agreement.

## II. MATHEMATICAL MODEL

### A. Fluid Flow Analysis

In the simulation model, the encapsulation process material and air are assumed incompressible and the governing equations describing the fluid flow are conservation of mass, conservation of momentum, and conservation of energy [13]. FLUENT normally solves the governing equations using Cartesian spatial coordinates and velocity components.

The conservation of mass or continuity equation is:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i) = 0 \quad (1)$$

Eq. (1) is the general form of the mass conservation equation and is valid for incompressible and compressible flows. Conservation of momentum in  $i^{\text{th}}$  direction in an inertial (non accelerating) reference frame is described by:

$$\frac{\partial}{\partial t}(\rho u_i) + \frac{\partial}{\partial x_i}(\rho u_i u_j) = -\frac{\partial P}{\partial x_i} + \frac{\partial \tau_{ij}}{\partial x_j} + \rho g_i + F_i \quad (2)$$

where,  $P$  is the static pressure,  $\tau_{ij}$  is the viscous stress tensor and  $g_i$  and  $F_i$  are the gravitational acceleration and external body force in the  $i$  direction, respectively.

The energy equation cast in terms of  $h$  (static enthalpy) can be written as,

$$\frac{\partial}{\partial t}(\rho h) + \frac{\partial}{\partial x_i}(\rho u_i h) = \frac{\partial}{\partial x_j} \left( k \frac{\partial T}{\partial x_j} \right) + \eta \dot{\gamma} \quad (3)$$

where  $T$  is the temperature,  $k$  is the thermal conductivity,  $\eta$  is the viscosity and  $\dot{\gamma}$  is the shear rate. The molding compound was assumed to be a generalized Newtonian fluid (GNF).

Several models have been used to predict the relationship between viscosity and the degree of polymerization. The Castro–Macosko model has been applied in encapsulation process [14] and is selected to use in this simulation. It can be described as follows:

$$\mu(T, \dot{\gamma}) = \frac{\mu_0(T)}{1 + \left(\frac{\mu_0(T)\dot{\gamma}}{\tau^*}\right)^{1-n}} \left(\frac{\alpha_g}{\alpha_g - \alpha}\right)^{C_1 + C_2 \alpha} \quad (4)$$

where  $n$  is the power law index,  $\mu_0$  the zero shear rate viscosity,  $\tau^*$  is the parameter that describes the transition region between zero shear rates and the power law region of the viscosity curve,  $\dot{\gamma}$  is the shear rate,  $\alpha$  is the conversion,  $\alpha_g$

is the conversion at the gel point and  $C_1$  and  $C_2$  are fitting constants.

$$\mu_o(T) = B \exp\left(\frac{T_b}{T}\right) \quad (5)$$

$B$  is an exponential-fitted constant and  $T_b$  is a temperature fitted-constant. In addition, Kamal curing kinetics is coupled together with Castro–Macosko model. This model predicts the rate of chemical conversion of the compound as follows:

$$\frac{d\alpha}{dt} = (k_1 + k_2 \alpha^{m_1})(1 - \alpha)^{m_2} \quad (6)$$

$$k_1 = A_1 \exp\left(-\frac{E_1}{T}\right) \quad (7)$$

and

$$k_2 = A_2 \exp\left(-\frac{E_2}{T}\right) \quad (8)$$

where  $\alpha$  is the conversion,  $A_1$  and  $A_2$  are the Arrhenius pre-exponential factors,  $E_1$  and  $E_2$  are the activation energies,  $m_1$  and  $m_2$  are the reaction orders and  $T$  is the absolute temperature. TABLE I summarized the material properties of the EMC considered in the current study.

TABLE I. EMC MATERIAL PROPERTIES [14].

	Parameter	Value	Unit
Castro Macosko Model	$\alpha_g$	0.17	-
	$B$	0.000381	Kg/m/s
	$T_b$	5230	K
	$n$	0.7773	-
	$\tau$	0.0001	N/m <sup>2</sup>
	$C_1$	1.03	-
	$C_2$	1.50	-
	Curing Kinetics	$m_1$	1.21
$m_2$		1.57	-
$A_1$		33530	1/s
$A_2$		30540000	1/s
$E_1$		7161	K
$E_2$		8589	K
$\alpha$		0.05	-
Density		$\rho$	2000
Specific Heat	$C_p$	1079	J/Kg-K
Thermal Conductivity	-	0.97	W/m-K
Reference Temperature	$T$	298	K

The basic idea of the VOF scheme is to locate and evolve the distribution of, say, the liquid phase by assigning for each cell in the computational grid a scalar,  $f$ , which specifies the fraction of the cell's volume occupied by liquid. Thus,  $f$  takes the value of 1 ( $f = 1$ ) in cell which contains only resin, the value 0 ( $f = 0$ ) in cells which are void of resin, and a value between 0 and 1 ( $0 < f < 1$ ) in “interface” cells or referred as the resin melt front. The equation of melt front over time is governed by the following transport equation:

$$\frac{\partial u}{\partial t} = \frac{\partial f}{\partial t} + \nabla \cdot (uf) = 0 \quad (9)$$

### B. Wire Sweep Analysis

To calculate the drag force exerted on the wires by the resin flow, the value of velocities and viscosities have to be determined from the mold filling simulation. The effect of wire density on the resin flow is considered according to their occupied volume in the three dimensional filling simulation. Then, the Lamb's model is utilized to calculate the drag force as follows [5]:

$$D = \frac{C_D \rho U^2 d}{2} \quad (10)$$

where  $D$  is the drag force per unit length,  $\rho$  is the fluid density,  $U$  is the undistributed upstream velocity,  $d$  is the wire diameter and  $C_D$  is the drag coefficient, which can be written as:

$$C_D = \frac{8\pi}{Re[2.002 - \ln(Re)]} \quad (11)$$

where  $Re$  is the Reynold number, which can be defined as:

$$Re = \frac{\rho u d}{\eta} \quad (12)$$

where  $\eta$  is the fluid viscosity.

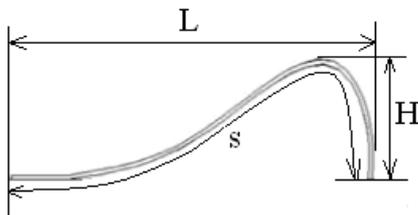


Fig.1: Curved profile of wire.

Wire sweep deflection  $\delta$  can be written as [8]:

$$\delta_{max} = S * D \left( f_B \left( \frac{H}{L} \right) \frac{H^3}{EI} + f_T \left( \frac{H}{L} \right) \frac{L^3}{GI_p} \right) \quad (13)$$

where  $S$  is the length of the wire bond,  $f_B$  is the bending geometry factor for the bending moment,  $f_T$  is the twisting geometry factor for the twisting moment,  $H$  is the height of wire,  $L$  is the length of wire span,  $G$  is the shear modulus of wire,  $E$  is the elastic modulus of wire,  $I$  is the momentum of inertia of the wire,  $I_p$  is the polar momentum of inertia of the wire.

The wire profile is shown in Fig. 1, where  $H$  has a length  $7.3 \times 10^{-4}$  m, the span of wire has a length  $L = 2.2 \times 10^{-3}$  m, and a square cross section of wire is 1 mil x 1 mil (i.e.,  $2.5 \times 10^{-5}$  m x  $2.5 \times 10^{-5}$  m). A square cross section was chosen for this case to simplify the derivation of the analytical solution.

## III. NUMERICAL SIMULATION

### A. Simulation Model and Boundary Conditions in FLUENT

The volume of fluid (VOF) model in FLUENT 6.3.26 is utilized to simulate the process [15]. Outlet vent types are set at different parameters, as shown in TABLE II. In the VOF model, a single set of momentum equations is shared by the fluids, and the volume fraction of each of the fluids in each computational cell is tracked throughout the domain [15]. Air and EMC (EME 6300HN Dynamic Modes) are defined as the phases in the analysis [15]. Implicit solution and time dependent formulation are applied for the volume fraction in every time step. The volume fraction of the encapsulation material is defined as one and zero for air phase.

Besides, viscosity Castro Macosko model and VOF techniques are applied to track the melt front. The mold chip boundary condition and its package model used in the present study are shown in Fig. 2 and 3 respectively. The dimension of mold is  $2.75 \times 1.5 \times 1$  mm. The model is created by using GAMBIT software and average 3500 tetrahedral elements are generated for simulation (Fig 4). Three types of the outlet vent namely Type D1, Type D2, and Type D3 as illustrated in Fig. 3 are considered for simulation. The boundary and initial conditions are used in the calculation are as follows [15]:

- (a) On wall :  $u = v = w = 0; T = T_w, \frac{\partial p}{\partial n} = 0$
- (b) On centre line :  $\frac{\partial u}{\partial z} = \frac{\partial v}{\partial z} = \frac{\partial w}{\partial z} = \frac{\partial T}{\partial z} = 0$
- (c) On melt front :  $p = 0$
- (d) At inlet :  $u = u_{in}(x,y,z); T = T_{in}$

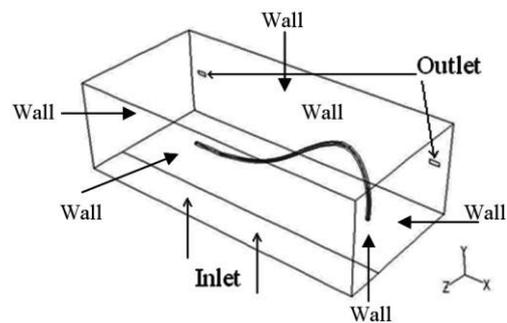
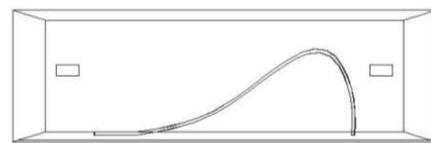
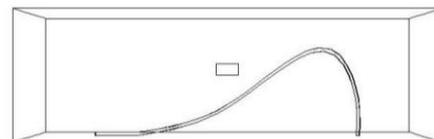


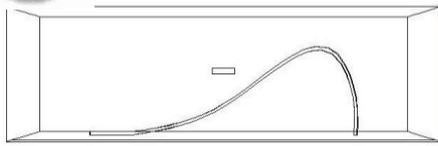
Fig. 2. Boundary condition for FLUENT analysis.



(a) Type D1



(b) Type D2



(c) Type D3

Fig. 3. Models of package.

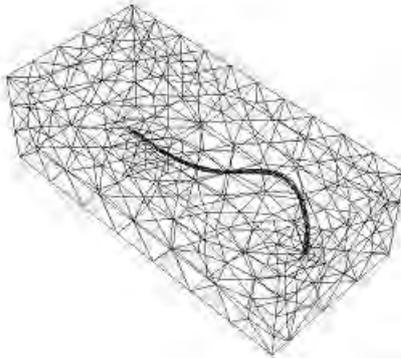


Fig. 4. Meshed model for FLUENT analysis of two outlet vents.

TABLE II. SPESIFICATION OF OUTLET VENT

Type of Mold	Number of outlet vent	Area of outlet vent [mm <sup>2</sup> ]
D1	2	0.04
D2	1	0.02
D3	1	0.01

This research introduce of a new three-dimensional computational technique for prediction of wire sweep in encapsulation process. Wire sweep is the deflection and deformation of wire loop during the encapsulant flow.

#### B. The computational domain and boundary conditions in ABAQUS

Commercial FEM based software; ABAQUS is use in this study to calculate the wire deformation. The structures of the wires are imported from GAMBIT in ACIS '.sat' format. The flow direction is normal to the un-deformed wire axis, and the properties are approximately the same as those used in [11]. The elastic modulus of wire is  $E = 17.73$  GPa; density,  $\rho = 19300$  kg/m<sup>3</sup>; Poisson's ratio,  $\nu = 0.42$ ; and reference temperature,  $T = 175^\circ\text{C}$ . The wire bond is divided into 291 elements as shown in Fig. 5. The shape of the wire also classified as typical J loop wire bond [10]. The ball bond boundary conditions of wire are set as fixed in ABAQUS as shown in Fig. 5.

#### C. Mesh based Parallel Coupling Code Interface (MpCCI)

MpCCI is a software library which enables the exchange of data defined on meshes of two or more simulation codes in the coupling region. Since the meshes need not match point by point, MpCCI performs an interpolation and, in case of parallel codes, keeps track of the distribution of the domains

onto different processes [16]. In this way, the intricate details of the data exchange are hidden behind the concise interface of MpCCI. As a consequence, the simulation codes themselves are changed only moderately when they are prepared for coupling via MpCCI (Fig. 6).

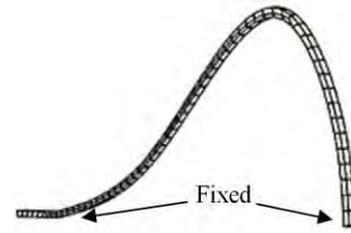


Fig. 5. Boundary condition for ABAQUS analysis

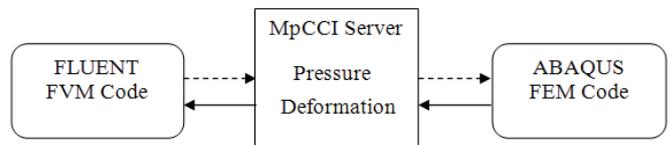


Fig. 6. FLUENT and ABAQUS coupling simulation process [16].

#### IV. RESULT AND DISCUSSION

The wire deformation pattern and the EMC volume is shown in Fig. 7, whereas Fig. 8 to describe of von Misses and displacement of wire in ABAQUS for all types.

The amounts of drag force and wire displacement of each type are shown in Fig. 9. Type D3 shows highest displacement of wire at highest drag force and minimum size of outlet vent.

The comparison of wire displacement of simulation and analytical results of Type D1, D2 and D3 are shown in Fig. 10. The wire deflection is validated with the analytical result that is calculated by using Eq. (13) as proposed by [8]. In the analytical calculation, the values of  $f_B$  and  $f_T$  used are 0.135 and 0.00215 respectively for  $H/L = 0.332$  [8].

Displacement error of analytical and simulation results at 3 s filling time of Type D1, Type D2 and Type D3 are 3.7%, 9.8% and 5.4 % respectively.

#### V. CONGCLUTION

The analysis of wire deformation of encapsulation process with the specific purpose of studying the effects of outlet vent type arrangement is presented. The parameter such as viscosity and curing effect that control the mould quality are also incorporated. Three different arrangements of outlet vent of mould have been investigated. Size, position and type of outlet vent were found affected the encapsulation result in electronics packaging process.

The IC simple packages encapsulation process was investigated numerically using Gambit and FLUENT of FVM

based simulation study. The three dimensional simple IC package was simulated to study the flow visualization and wire sweep in different number of outlet vent of the process.

Three types outlet vent of mold were examined to distinguish the wire sweep of wire bonding and compare with the analytical results and demonstrated that the methodology works very well. From simulation results, the Type D3 of outlet vent showed a highest wire sweep deformation in smaller outlet vent than the Type D1 and D2 of outlet vent. Thus, the strength of MpCCI software in handling wire sweep in encapsulation process is proved to be excellent.

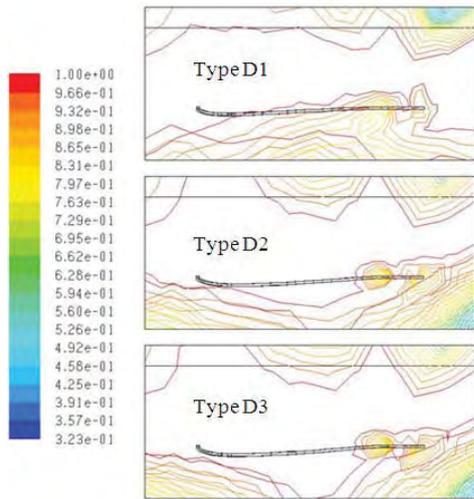
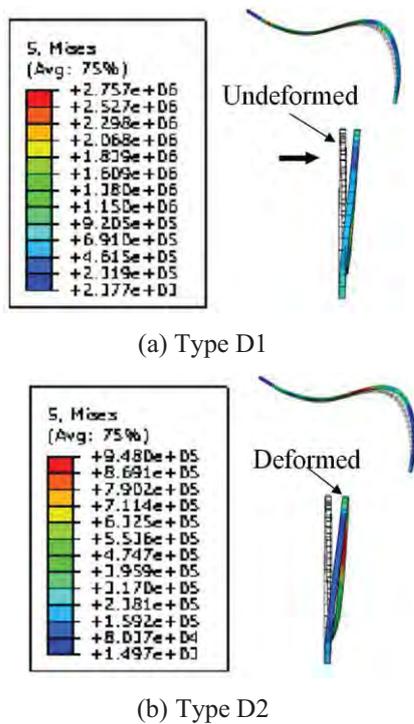
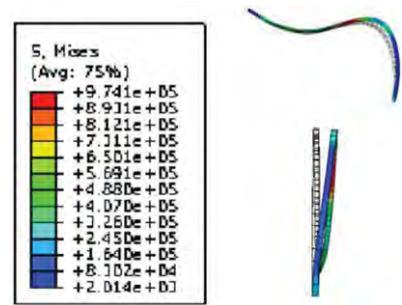


Fig. 7. FSI simulation results for all cases.



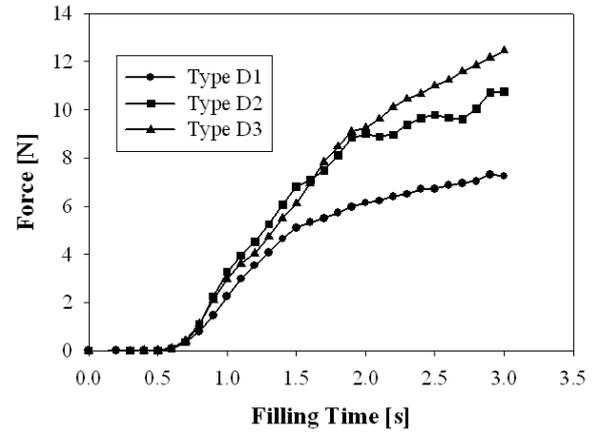
(a) Type D1

(b) Type D2

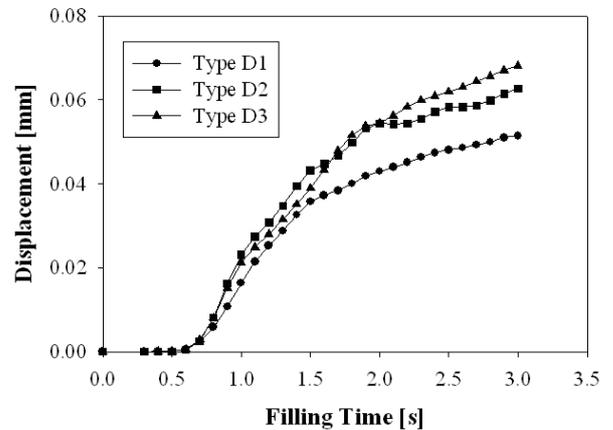


(c) Type D3

Fig. 8. Von Mises and wire deflection in ABAQUS for all cases. (a) Type D1, (b) Type D2 and (c) Type D3.



(a)



(b)

Fig. 9. (a) Drag force of wire for all cases. (b) Wire displacement profile of all cases.

ACKNOWLEDGMENT

The authors gratefully acknowledged the Intel Tech. Sdn. Bhd., Penang for the financial support of this research work. The author would also like to thank DGHE National Education and Culture Department of Republic of Indonesia for the scholarship of PhD Program and Research Found of PHB skin in 2012 FY. Lastly, the author would also like to thank C.Y. Khor for the technical software advices in the present study.

REFERENCES

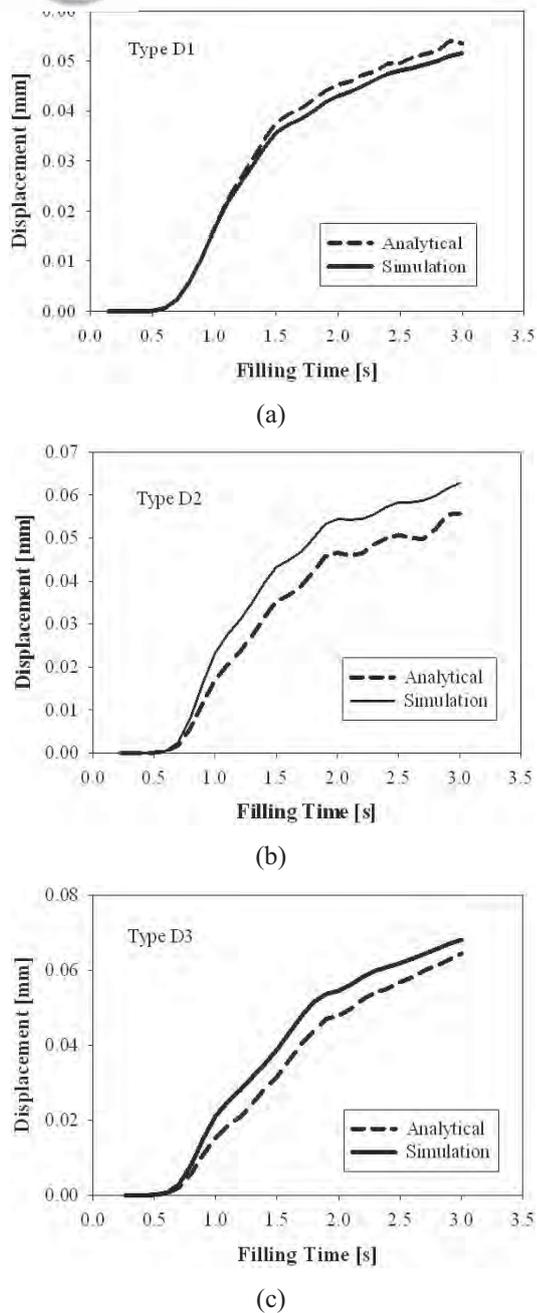


Fig. 10. Comparison wire displacement of simulation with analytical results.

(a) Type D1. (b) Type D2. (c) Type D3.

- [1] H. Ardebiri, M. Pecht, Encapsulation Technologies for Electronic Applications, Linacre House, Jordan Hill, Burlington, USA, Elsevier, 2009, p. 181-188.
- [2] J. M. Brand, S. A. Ruggero, A. J. Shah, "Wire sweep Reduction via Direct Cavity Injection During Encapsulation of Stacked Chip-Scale Packages," J. Electron. Packag., Vol. 130, pp. 011011-1 – 011011-6, March 2008.
- [3] C. C. Pei, S. J. Hwang, "Prediction of Wire Sweep During the Encapsulation of IC Packaging with Wire Density effect," J. Electron. Packag. ASME, vol. 127, pp. 335-339, September 2005.
- [4] M. Ishiko, M. Usui, T. Ohuchi, M. Shirai, "Design Concept for Wire Bonding Reliability Improvement by Optimizing Position in Power devices," Microelectron. J. 37, pp. 262 – 268, 2006.
- [5] J. Su, S. J. Hwang, F. Su, S. K. Chen, "An Efficient Solution for Wire Sweep Analysis in IC Packaging," J. Electron. Packag., ASME, vol. 125, pp. 139-143, March 2003.
- [6] W. R. Jong, Y. R. Chen, T. H. Kuo, "Wire Density in CAE analysis of high pin-count IC packages: Simulation and verification," Int. Commun. Heat and Mass Transfer, vol. 2, pp. 1350-1359, 2005.
- [7] Y. F. Yao, B. Njoman, K. H. Chua, T. Y. Lin, "New Encapsulation Development for Fine Pitch IC Devices," Microelectro. Reliab. vol. 45, pp. 1222-1229, 2005.
- [8] H. K. Kung, J. N. Lee, C. Y. Wang, "The Wire Sweep Analysis Based on the Evaluation of the Bending and Twisting Moments for Semiconductor Packaging," Microelectron. Eng. 83, pp. 1931-1939, 2006.
- [9] H. Q. Yang, S. Bayyuk, S. Mazumder, S. Lowry, A. Krishnan, A. Przekwas, L. Nguyen, "Time-Accurate, 3-D Computation of Wire Sweep During Plastic Encapsulation of Electronic Components," J. Pressure Vessel Tech., ASME, vol. 123, pp.501-509, November 2001.
- [10] S. Yigit, M. Schafer, M. Heck, "Grid movement techniques and their influence on laminar fluid-structure interaction computations," J. Fluids and structures, Vol. 24, pp. 819-832, 2008.
- [11] F. Thirifay and P. Geuzaine, "Numerical simulations of fluid-structure interaction problem using MpCCI," address: <http://citeseerx.ist.psu.edu/viewdoc/download>, 2008.
- [12] B. Gatzhammer, M. Mehl, T. Neckel, "A coupling environment for portioned multiphysics simulations applied to fluid-structure interaction scenarios," Procedia Comput. Science, Vol. 1, pp.681-689, 2010.
- [13] D. Ramdan, M. Z. Abdullah, C. Y. Khor, "Plastic Ball Grid Array Encapsulation Process Simulation on Rheology Effect," TELKOMNIKA, vol. 9, no. 1, pp. 27 – 36, April 2011.
- [14] L. Nguyen, C. Quentin, W. Lee, S. Bayyuk, S. A. Bidstrup-Allen, S. T. Wang, "Computational Modeling and Validation of the Encapsulation of Plastic Packages by Transfer Molding," Trans. of the ASME, vol. 122, pp. 138-146. 2000.
- [15] C. Y. Khor, M. K. Abdullah, M. Z. Abdullah, M. Abdul Mujeebu, D. Ramdan, M. F. M. A. Majid, Z. M. Ariff, "Effect of vertical stacking dies on flow behavior of epoxy molding compound during encapsulation of stacked-chip scale packages," Heat Mass Transfer, vol. 46, pp.1315-1325, 2010.
- [16] MpCCI 3.1.0-1 Documentation part I overview, Fraunhofer Institute for Algorithms and Scientific Computing SCIA, Germany, January 2009.

# Effect of Gauss Doping Profile on Electric Potential of p-n Diode

A.A.N. Gde Saptaka  
 Department of Electrical  
 Politeknik Negeri Bali  
 Badung 80364, Indonesia  
 saptaka@yahoo.co.id

T. Abuzairi and D. Hartanto  
 Faculty of Engineering  
 Universitas Indonesia  
 Depok 16424, Indonesia  
 tomy@ee.ui.ac.id, djoko@eng.ui.ac.id

**Abstract**—This study aimed to determine the effects of Gauss doping profile on electric potential of p-n diode. This effect is studied by simulating PN diodes at equilibrium condition with differences in doping fall-off constant ( $dfc$ ) using MATLAB and COMSOL software. According to the simulation results, it concluded that p-n diode with different Gaussian doping profile, will produce similar built-in voltage ( $V_{Gbi}$ ). But, each p-n diode with different Gaussian doping profile, has different maximum junction voltage ( $V_{jmax}$ ) and minimum junction voltage ( $V_{jmin}$ ). These junction voltages have strong correlation with  $dfc$ . We propose an equation of built-in voltage for Gauss Doping Profile, and also equations of  $V_{jmax}$  and  $V_{jmin}$ .

**Keywords**— Gauss Doping Profile, p-n Diode, Electric Potential.

## I. INTRODUCTION

The study about Gauss doping profile has been done by several researchers. In 1991, K. Suzuki investigated base doping profile, i.e., box, Gaussian, and exponential, which gives the minimum base transit time [1]. He stated that the exponential profile always gives the minimum base transit time at any base width.

J.A. Croon, *et al.* examined the influence of the doping profile on threshold voltage mismatch in 2002 [2]. They compared the calculated threshold voltage mismatch contributions for the case of the Gaussian and uniform profiles. They stated that by using the Gaussian profile, the predicted threshold voltage mismatch due to doping fluctuations is 20-35% smaller and the threshold voltage mismatch due to oxide capacitance fluctuations is 10-25% smaller. The other researchers, G. Zhang, Z. Shao, and K. Zhou proposed a novel surface potential function perpendicular to the channel for an FD SOI MOSFET with vertical Gauss doping profile in 2008 [3].

In 2009, J. Li *et al.* examined A model of Gauss-doped base 4H-SiC bipolar junction transistor (BJT) is simulated by two dimensional device simulator ISE [4]. The result shows Gaussian-doped base can effectively improve the current gain from 16.65 to 44.49, and decrease the output resistance. The

Base with Gaussian-doped SiC BJT also enhance the small signal AC performance.

Sarvesh Dubey, Pramod Kumar Tiwari, and S. Jit in 2010 proposed a two-dimensional 2D model for the threshold voltage of the short-channel double-gate (DG) metal-oxide-semiconductor field-effect transistors MOSFETs with a vertical Gaussian-like doping profile [5]. It is shown that the threshold voltage of a DG MOSFET can be well controlled by controlling only the profile parameters maintaining other device parameters unchanged. The model has been validated by comparing our results with the simulation data obtained from the ATLAS™ simulation software.

This research aims to study the effect of Gauss Doping Profile (GDP) on built-in voltage ( $V_{Gbi}$ ) and also at p-n junction under equilibrium condition with different doping fall-off constant. Here we simulate five GDP of p-n diodes, i.e., GDP 1 with  $dfc = 0.46599 \mu\text{m}$ ; GDP 2 with  $dfc = 0.37279 \mu\text{m}$ ; GDP 3 with  $dfc = 0.27959 \mu\text{m}$ ; GDP 4 with  $dfc = 0.18640 \mu\text{m}$ ; GDP 5 with  $dfc = 0.046599 \mu\text{m}$ .

## II. THEORY

A p-n diode is a two-terminal device. When the impurity concentration in a semiconductor changes abruptly from acceptor impurities  $N_A$  to donor impurities  $N_D$ , one obtains an abrupt junction. In particular, if  $N_A \gg N_D$  (or vice versa), one obtains a one-sided abrupt p<sup>+</sup>-n (or n<sup>+</sup>-p) junction [6]. The built-in potential  $V_{Abi}$ , and diffusion potential for non degenerate semiconductor, are equal to

$$V_{Abi} \approx \frac{kT}{q} \ln \left( \frac{N_D N_A}{n_i^2} \right), \quad (1)$$

$$V(x) = -\frac{q N_A (x + W_{Dp})^2}{2\epsilon_s}, \quad \text{for } W_{Dp} \leq x \leq 0 \quad (2)$$

$$V(x) = V(0) + \frac{q N_D}{\epsilon_s} \left( W_{Dn} - \frac{x}{2} \right) x, \quad \text{for } 0 \leq x \leq W_{Dn} \quad (3)$$

where

$$W_{Dp} = \sqrt{\frac{2\epsilon_s V_{bi} N_D}{q N_A (N_A + N_D)}} \quad (4)$$

$$W_{Dn} = \sqrt{\frac{2\epsilon_s V_{bi} N_A}{q N_D (N_A + N_D)}} \quad (5)$$

The p-type doping of the diode can be accomplished by implantation or diffusion of acceptor atoms. The resulting profile from these two steps is often approximated with a Gauss function. In addition, the transition between the n-type doped substrate and the lower doped n-type epitaxial layer can also be approximated with a Gauss function, because the dopants diffuse from the highly doped substrate during the high temperature step of the epitaxial growth [7]. The Gauss function defined by

$$G_f(x, y, x_1, y_1) = \begin{cases} \exp\left(-\frac{(x-x_1)^2}{dfc}\right) \exp\left(-\frac{(y-y_1)^2}{dfc}\right) & x > x_1, y > y_1 \\ \exp\left(-\frac{(x-x_1)^2}{dfc}\right) & x > x_1, y \leq y_1 \\ \exp\left(-\frac{(y-y_1)^2}{dfc}\right) & x \leq x_1, y > y_1 \\ 1 & x \leq x_1, y \leq y_1 \end{cases} \quad (6)$$

### III. SIMULATION PROCEDURE

We simulate the doping concentration of five GDP of p-n diodes, i.e., GDP 1 with  $dfc = 0.46599 \mu\text{m}$ ; GDP 2 with  $dfc = 0.37279 \mu\text{m}$ ; GDP 3 with  $dfc = 0.27959 \mu\text{m}$ ; GDP 4 with  $dfc = 0.18640 \mu\text{m}$ ; GDP 5 with  $dfc = 0.046599 \mu\text{m}$  using equations (7), (8) and (9). In this study, the p-n diodes have p-type doping  $N_A$  ( $1 \times 10^{18}$ ;  $1 \times 10^{17}$ ;  $1 \times 10^{16}$ ;  $1 \times 10^{15}$ )  $\text{cm}^{-3}$  and n-type doping  $N_D$  ( $1 \times 10^{16}$ ;  $1 \times 10^{15}$ ;  $1 \times 10^{14}$ ;  $1 \times 10^{13}$ )  $\text{cm}^{-3}$ . Here, we set  $N_A$  is 100 times of  $N_D$ . The diodes have different doping fall-off constant ( $dfc$ ) in accordance with Gauss function. The involved parameters are listed in Table I. The relationship between GDP,  $N_A$  and built-in voltage of p-n diode is determined by MATLAB.

Subsequently, we analyzed the result to find the relationship between  $dfc$  with built-in potential ( $V_{Gbi}$ ), and also with maximum junction voltage ( $V_{jmax}$ ) and minimum junction voltage ( $V_{jmin}$ ). The research conducted by means of

simulation of p-n diodes with Gauss doping profile (GDP) using COMSOL. The last step was to determine conclusions obtained from the analysis.

TABLE I. DEFINITIONS AND DESCRIPTIONS OF PARAMETERS

Parameter	Description
$N$	Concentration of free electron ( $\text{cm}^{-3}$ )
$P$	Concentration of free hole ( $\text{cm}^{-3}$ )
$N_A$	Maximum p-type doping ( $\text{cm}^{-3}$ )
$N_D$	Maximum n-type doping ( $\text{cm}^{-3}$ )
$n_i$	Intrinsic concentration for Si = $1.46 \times 10^{10} \text{ cm}^{-3}$
$N$	Doping concentration
$W_p$	Maximum p-type doping thickness ( $\mu\text{m}$ )
$V_{Abi}, V_{Gbi}$	Abrupt built-in potential (V), Gauss built-in potential (V)
$W_{Dp}$	Depletion width in n-type material (cm)
$W_{Dn}$	Depletion width in p-type material (cm)
$V(x)$	Electric Potential (V) at depth $x$
$\epsilon_s$	Relative permittivity for Si = 11.8
$ju$	Junction depth = $-2 \mu\text{m}$
$y_1$	Diode dimension = $7 \mu\text{m}$
$x_1$	Diode dimension = $5 \mu\text{m}$
$ac$	Anode dimension = $2 \mu\text{m}$
$dfc$	Doping fall-off constant ( $\mu\text{m}$ )
$k$	Boltzmann's constant = $1.3 \times 10^{-23} \text{ J/K}$
$T$	Room temperature = $300 \text{ K}$
$q$	Elementary charge = $1.602 \times 10^{-19} \text{ C}$
$V_{jmax}$	Maximum junction voltage (V)
$V_{jmin}$	Minimum junction voltage (V)
$G_f$	Gauss function

### IV. RESULT AND DISCUSSION

Based on (6), the Gauss function is depicted in Fig. 1 using (7) and (8).

$$dfc = -(ju-wp) / \text{sqrt}(-\log(N_D/N_A)) \quad (7)$$

$$y = \exp(-((x-wp)/dfc)^2) \times (x < wp) + 1 \times (x \geq wp) \quad (8)$$

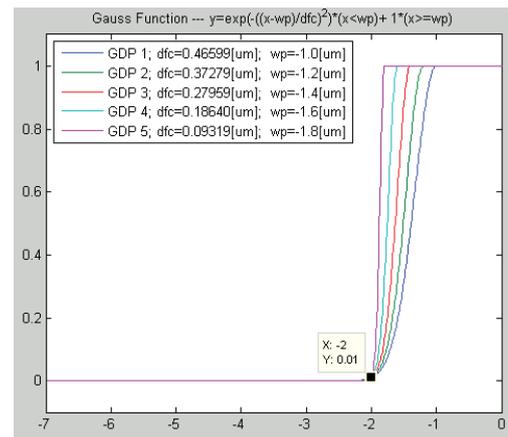


Fig. 1. Gauss Function.

As illustrated in Fig. 1, the junction is set at  $2 \mu\text{m}$  due to  $N$  must be zero here. Equation (9) is used to simulate the GDP in 3-D as shown in Fig. 2 - 6.

$$\begin{aligned}
 N = & ((N_D - N_A \times \exp(-((y-wp)/dfc)^2)) \times (y < wp) \\
 & + (-N_A \times (y \geq wp))) \times (x < ac) \\
 & + ((N_D - N_A \times \exp(-((y-wp)/dfc)^2)) \\
 & \times \exp(-((x-ac)/dfc)^2)) \times (y < wp) \\
 & + (N_D - N_A \times \exp(-((x-ac)/dfc)^2)) \\
 & \times (y \geq wp) \times (x \geq ac)
 \end{aligned}
 \tag{9}$$

The electric potential at thermal equilibrium for GDP 1 of p-n Diodes are depicted in Fig. 7 - 10. The simulation shows that p- region has lower voltage than n-region. In Table II we tabulated built-in voltage ( $V_{Gbi}$ ) of p-n diode using GDP 1, GDP 2, GDP 3, GDP 4, and GDP 5.

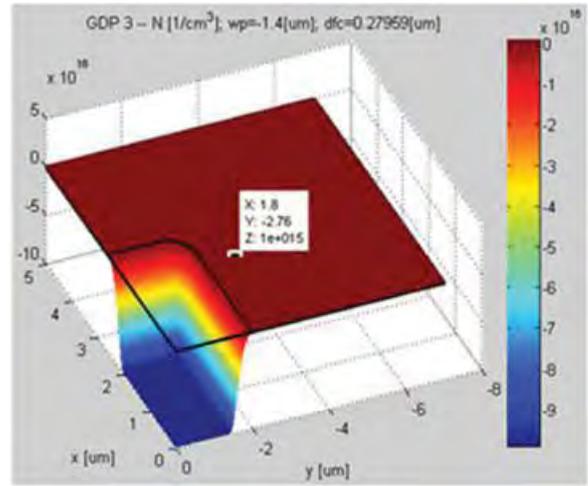


Fig. 4. p-n Diode doping concentration with  $N_A = 1 \times 10^{17} \text{ cm}^{-3}$  and  $N_D = 1 \times 10^{15} \text{ cm}^{-3}$  using GDP 3

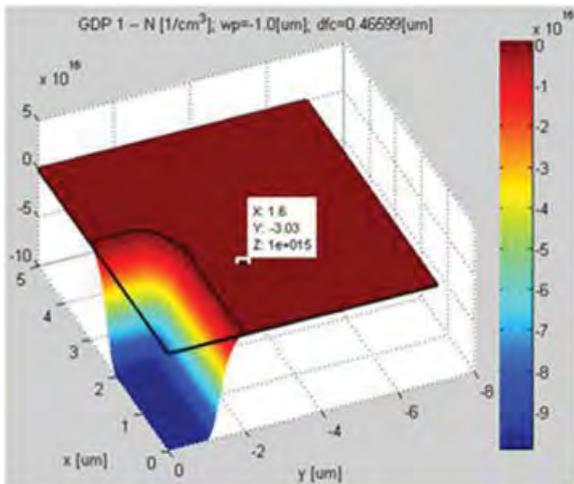


Fig. 2. p-n Diode doping concentration with  $N_A = 1 \times 10^{17} \text{ cm}^{-3}$  and  $N_D = 1 \times 10^{15} \text{ cm}^{-3}$  using GDP 1

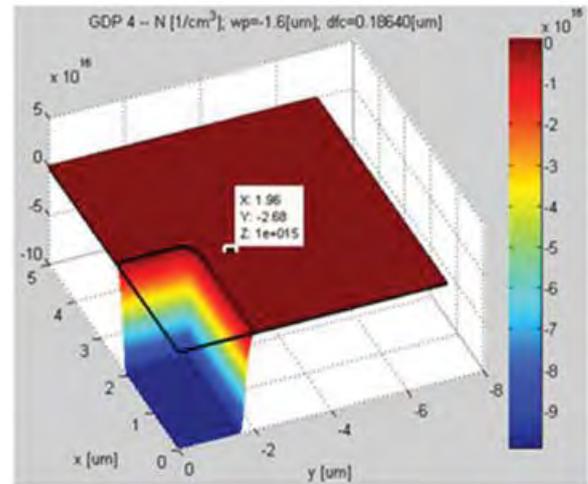


Fig. 5. p-n Diode doping concentration with  $N_A = 1 \times 10^{17} \text{ cm}^{-3}$  and  $N_D = 1 \times 10^{15} \text{ cm}^{-3}$  using GDP 4

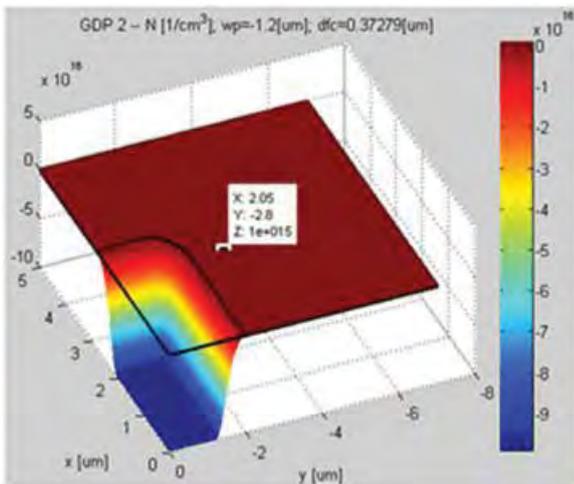


Fig. 3. p-n Diode doping concentration with  $N_A = 1 \times 10^{17} \text{ cm}^{-3}$  and  $N_D = 1 \times 10^{15} \text{ cm}^{-3}$  using GDP 2

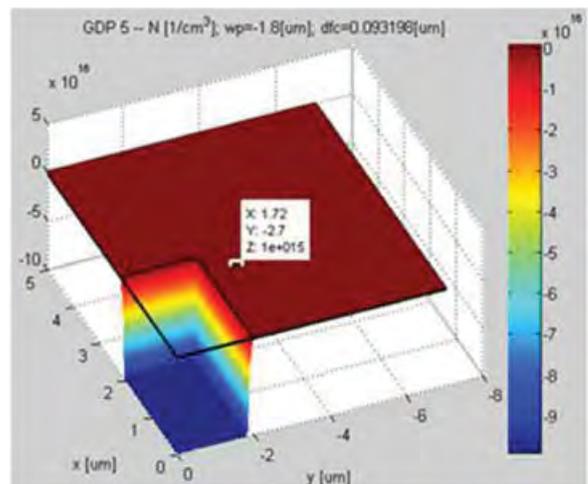


Fig. 6. p-n Diode doping concentration with  $N_A = 1 \times 10^{17} \text{ cm}^{-3}$  and  $N_D = 1 \times 10^{15} \text{ cm}^{-3}$  using GDP 5

TABLE II. GAUSS DOPING PROFILE BUILT-IN VOLTAGE ( $V_{Gbi}$ )

GDP	$dfc$	$N_1$	$N_2$	$N_3$	$N_4$
GDP 1	0.465990	0.813 V	0.695 V	0.575 V	0.456 V
GDP 2	0.372790	0.813 V	0.695 V	0.575 V	0.456 V
GDP 3	0.279590	0.813 V	0.695 V	0.575 V	0.456 V
GDP 4	0.186400	0.813 V	0.695 V	0.575 V	0.456 V
GDP 5	0.093198	0.813 V	0.695 V	0.575 V	0.456 V

where

$$\begin{aligned}
 N_1 : N_A &= 1 \times 10^{18} \text{ cm}^{-3}; N_D = 1 \times 10^{16} \text{ cm}^{-3} \\
 N_2 : N_A &= 1 \times 10^{17} \text{ cm}^{-3}; N_D = 1 \times 10^{15} \text{ cm}^{-3} \\
 N_3 : N_A &= 1 \times 10^{16} \text{ cm}^{-3}; N_D = 1 \times 10^{14} \text{ cm}^{-3} \\
 N_4 : N_A &= 1 \times 10^{15} \text{ cm}^{-3}; N_D = 1 \times 10^{13} \text{ cm}^{-3}
 \end{aligned}$$

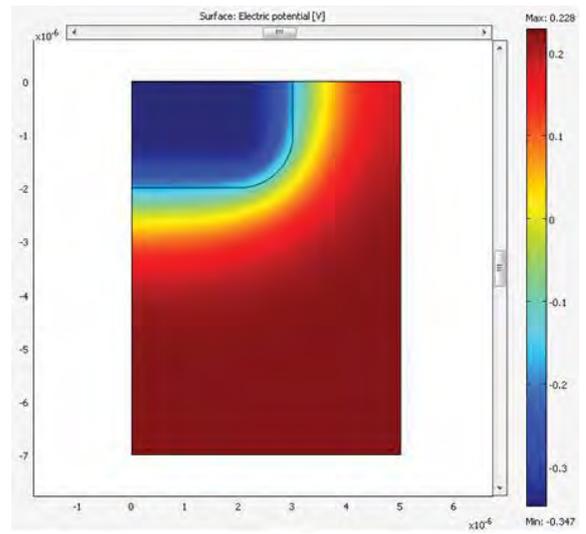


Fig. 9. Electric Potential of GDP 1 with  $N_A = 1 \times 10^{16} \text{ cm}^{-3}; N_D = 1 \times 10^{14} \text{ cm}^{-3}$

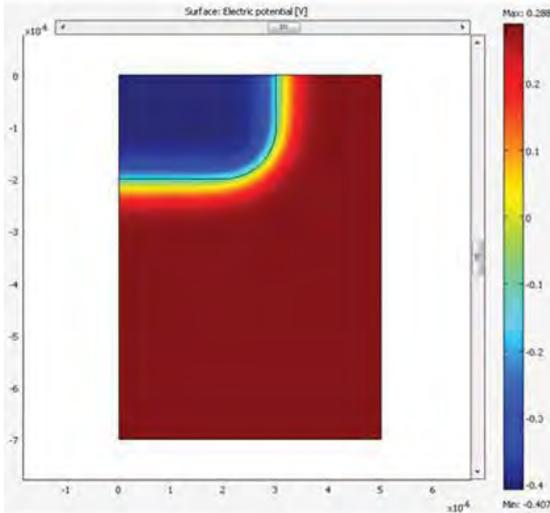


Fig. 7. Electric Potential of GDP 1 with  $N_A = 1 \times 10^{18} \text{ cm}^{-3}; N_D = 1 \times 10^{16} \text{ cm}^{-3}$

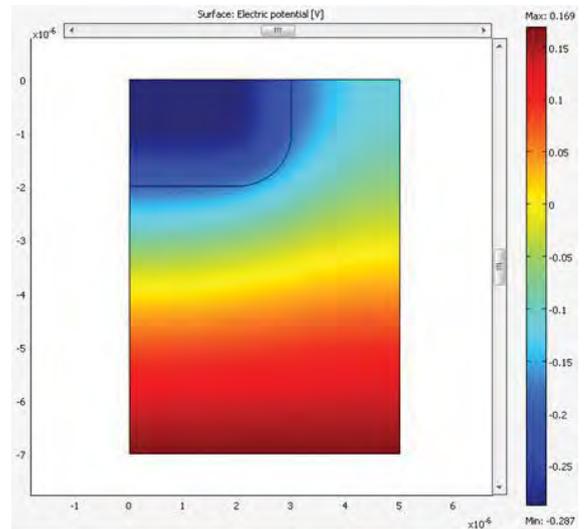


Fig. 10. Electric Potential of GDP 1 with  $N_A = 1 \times 10^{15} \text{ cm}^{-3}; N_D = 1 \times 10^{13} \text{ cm}^{-3}$

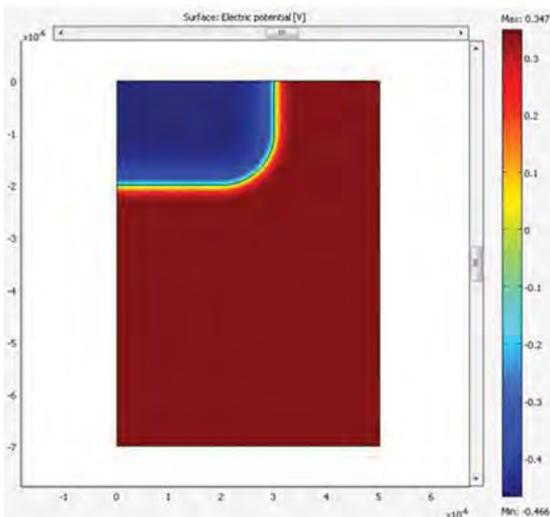


Fig. 8. Electric Potential of GDP 1 with  $N_A = 1 \times 10^{17} \text{ cm}^{-3}; N_D = 1 \times 10^{15} \text{ cm}^{-3}$

According to Table 2, we achieve the relationship between  $dfc$ ,  $N_A$ , and  $V_{Gbi}$  by simulations as shown in Fig. 11. In particular concentration composition  $N_1, N_2, N_3, N_4$  with different doping profiles ( $dfc$ ), we find similar  $V_{Gbi}$ . The built-in voltage of Gauss Doping Profile using pattern as shown in Fig. 1 at thermal equilibrium is determined by  $N_A$ . The higher  $N_A$  will get higher  $V_{Gbi}$ .

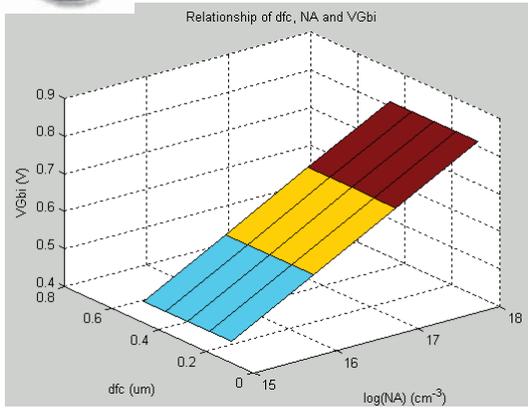


Fig. 11. Relationship of  $dfc$ ,  $N_A$  and  $V_{Gbi}$ .

We propose an equation of built-in voltage for Gauss Doping Profile as a function of  $\log(N_A)$ ,

$$V_{Gbi} \approx 0.1191 \log(N_A) - 1.3304 \text{ V} \quad (10)$$

Equation (10) shows a linear relationship between the  $N_A$  and  $V_{Gbi}$  with gradient of  $0.1191 \text{ V.cm}^3$  and constant term of  $-1.3304 \text{ V}$ . Referring to the built-in voltage equation for abrupt junction (1), we determined the percentage difference of built-in voltage for abrupt junction with built-in voltage for Gauss doping profile as shown in Table III.

TABLE III. BUILT-IN VOLTAGE COMPARISON

$N_A$	$N_D$	$V_{A_{bi}}$	$V_{G_{bi}}$	% diff
$1 \times 10^{18}$	$1 \times 10^{16}$	0.8135	0.8130	0.06
$1 \times 10^{17}$	$1 \times 10^{15}$	0.6945	0.6950	0.07
$1 \times 10^{16}$	$1 \times 10^{14}$	0.5747	0.5750	0.08
$1 \times 10^{15}$	$1 \times 10^{13}$	0.4565	0.4560	0.11

We also investigate the electric potential at p-n junction, especially the maximum junction voltage ( $V_{jmax}$ ) and the minimum junction voltage ( $V_{jmin}$ ). The junction voltage parameters are plotted in Fig. 12.

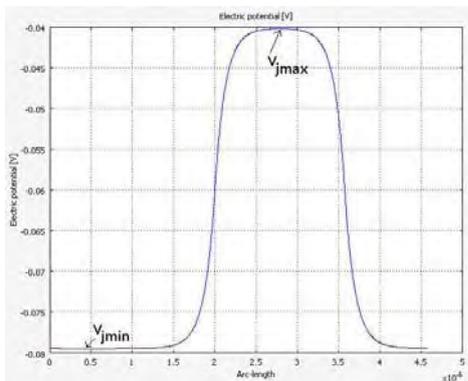


Fig.12. Junction voltage of GDP 1 using  $N_A = 1 \times 10^{18} \text{ cm}^{-3}$ ;  $N_D = 1 \times 10^{16} \text{ cm}^{-3}$

In Table IV we tabulated junction voltage of p-n diode using GDP 1, GDP 2, GDP 3, GDP 4, and GDP 5. The maximum junction value ( $V_{jmax}$ ) and the minimum junction value ( $V_{jmin}$ ) as stated in Table 4. Under thermal equilibrium condition and doping profile according to Fig. 2- 6, we acquire that  $V_{jmax}$  and  $V_{jmin}$  are the function of  $dfc$  and  $\log(N_A)$ . The higher  $dfc$  will produce higher  $V_{jmax}$  and also higher  $V_{jmin}$ . Similarly, the higher the  $N_A$  will produce higher  $V_{jmax}$  and also higher  $V_{jmin}$  as shown in Fig. 13-14.

TABLE IV. JUNCTION VOLTAGE  $V_{jmax}$  AND  $V_{jmin}$

GDP	dfc	$N_1$		$N_2$	
		$V_{jmax}$	$V_{jmin}$	$V_{jmax}$	$V_{jmin}$
GDP 1	0.465990	-0.0402 V	-0.0794 V	-0.0709 V	-0.1344 V
GDP 2	0.372790	-0.0468 V	-0.0925 V	-0.0813 V	-0.1516 V
GDP 3	0.279590	-0.0565 V	-0.1122 V	-0.0955 V	-0.175 V
GDP 4	0.186400	-0.0734 V	-0.1445 V	-0.1185 V	-0.2078 V
GDP 5	0.093198	-0.1109 V	-0.2082 V	-0.1615 V	-0.2590 V
GDP	dfc	$N_3$		$N_4$	
		$V_{jmax}$	$V_{jmin}$	$V_{jmax}$	$V_{jmin}$
GDP 1	0.465990	-0.1095 V	-0.1778 V	-0.1541 V	-0.1946 V
GDP 2	0.372790	-0.1207 V	-0.1924 V	-0.1606 V	-0.2034 V
GDP 3	0.279590	-0.1360 V	-0.2102 V	-0.1686 V	-0.2134 V
GDP 4	0.186400	-0.1570 V	-0.2329 V	-0.1784 V	-0.2255 V
GDP 5	0.093198	-0.1885 V	-0.2641 V	-0.1909 V	-0.2419 V

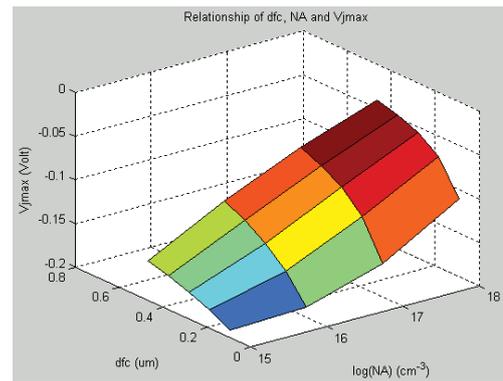


Fig. 13. Relationship of  $dfc$ ,  $N_A$ ,  $V_{jmax}$

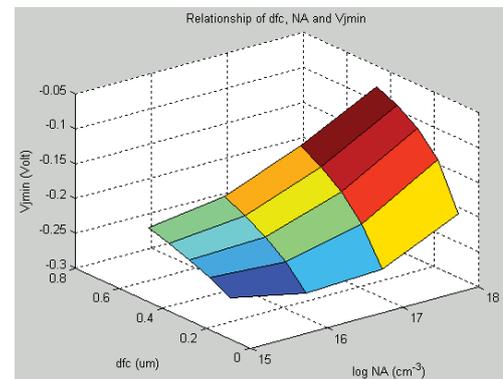


Fig. 14. Relationship of  $dfc$ ,  $N_A$ ,  $V_{jmin}$

We propose equations for  $V_{jmax}$  and  $V_{jmin}$  as a function of  $dfc$  and  $\log(N_A)$ , as stated in equation (11) and (12).

$$V_{jmax} \approx A \times dfc^3 + B \times dfc^2 + C \times dfc + D \quad (11)$$

where

$$A = -0.22470 \log(N_A)^3 + 11.0231 \log(N_A)^2 - 179.1617 \log(N_A) + 965.70$$

$$B = 0.22670 \log(N_A)^3 - 11.0645 \log(N_A)^2 + 178.7741 \log(N_A) - 957.70$$

$$C = -0.06670 \log(N_A)^3 + 3.1952 \log(N_A)^2 - 50.6149 \log(N_A) + 265.50$$

$$D = 0.00420 \log(N_A)^3 - 0.1899 \log(N_A)^2 + 2.7964 \log(N_A) - 13.77$$

$$V_{jmin} \approx A \times dfc^3 + B \times dfc^2 + C \times dfc + D \quad (12)$$

where

$$A = 0.01710 \log(N_A)^3 - 0.5772 \log(N_A)^2 + 5.8160 \log(N_A) - 14.80$$

$$B = 0.01490 \log(N_A)^3 - 0.9966 \log(N_A)^2 + 19.7647 \log(N_A) - 122.88$$

$$C = -0.02795 \log(N_A)^3 + 1.4316 \log(N_A)^2 + 23.9822 \log(N_A) + 132.22$$

$$D = 0.00555 \log(N_A)^3 - 0.2589 \log(N_A)^2 + 3.9822 \log(N_A) - 20.47$$

## V. CONCLUSION

We achieve the relationship between  $dfc$ ,  $N_A$ , and  $V_{Gbi}$  of p-n Diode with Gauss Doping Profile in which  $N_A$  is 100 times of  $N_D$  as stated in (10) using MATLAB and COMSOL software. We also propose equations for  $V_{jmax}$  and  $V_{jmin}$  as a function of  $dfc$  and  $\log(N_A)$ , as stated in (11) and (12).

## ACKNOWLEDGMENT

We would like to thank to *Pusat Komputer FT UI* for their permission to use MATLAB software version R2012 and also to the reviewers for their suggestions and improvements.

## REFERENCES

- [1] K. Suzuki, "Optimum Base Profile for Minimum Base Transit Time", *IEEE Trans. On Electron Devices*, vol. 38, no. 9, 1991.
- [2] J.A. Croon, E. Augendre, S. Decoutere, W. Sansen, H.E. Maes, "Influence of Doping Profile and Halo Implantation on the Threshold Voltage Mismatch of a 0.13  $\mu\text{m}$  CMOS Technology", *ESSDERC*, 2002.
- [3] G. Zhang, Z. Shao, and K. Zhou, "Threshold Voltage Model of Short-Channel FD-SOI MOSFETs With Vertical Gaussian Profile", *IEEE Trans. On Electron Devices*, vol. 55, no. 3, 2008.
- [4] J. Li, Y. Zhang, Y. Zhang, X. Tang, "The Simulation Study of Gaussian-doped Base 4H-SiC Bipolar Junction Transistor", *IEEE International Conference of Electron Devices and Solid-State Circuits*, pp. 318 – 321, 2009.
- [5] Sarvesh Dubey, Pramod Kumar Tiwari, and S. Jit, "A two-dimensional model for the potential distribution and threshold voltage of short-channel double-gate metal-oxide-semiconductor field-effect transistors with a vertical Gaussian-like doping profile", *Journal of Applied Physics*, vol. 108, 2010.
- [6] S. M. Sze and Kwok K. Ng, *Physics of Semiconductor Devices*, 2007, John Wiley & Sons, Inc., Hoboken, New Jersey, ch.2, pp. 79-133.
- [7] Comsol AB, *COMSOL Multiphysics Model Library*, Stockholm, 2008, ch. *Semiconductor Device Models*, pp. 499-513.

# ColorDetection on CarComponent Knock Down using MicrocontrollerPIC 16F877A and a Photodiode as a Sensor

Syahril Ardi, Akhid Amin Rohayat  
 Manufacturing Production and Process Department  
 Politeknik Manufaktur Astra  
 Jakarta 14330, Indonesia  
 Email: syahril.ardi@polman.astra.ac.id

**Abstract-** The automotive manufactures company has Packing Vanning Division, which acts to process components or parts needed for assembly of four-wheeled vehicle products. To ensure components are delivered in accordance with customer demand, we check in accordance with standard components. However, there are some problems, complaint of the customer, such as errors of color according to customer demand. The problem was due to a predetermined color samples have almost the same color so it is difficult to be distinguished by the operator. In this research, we designed the color detector that will be used to facilitate the work of an operator. The detector uses photo diode as a sensor which is controlled by the microcontroller PIC16F877A. Error color checking manually for Component Knock Down in automotive manufacturing companies can be overcome by using color detection as a tool for checking. The result of the use of color detector is the operator job can be simplified and reduce operator eye fatigue. The problem of complaint miss-color part can be reduced from an average of 30 pieces to 0 piece.

**Keywords** -color detecto;, photodiode; Component Knock Dow; Microcontroller PIC16F877A.

## I. INTRODUCTION

The automotive manufactures company has Packing Vanning Division, which acts to process components or parts needed for assembly of four-wheeled vehicle products. To ensure components (especially Component Knock Down) are delivered in accordance with customer demand, we check in accordance with standard components. However, there are some problems, for instance complaint of the customer, such as errors of color according to customer demand. The problem was due to a predetermined color samples has almost the same color so it is difficult to be distinguished by the operator. It occurs because the color samples that have been determined are the same color.

To facilitate the operator in distinguishing colors, hence made tools for color detection. This tool uses a photo diode (photo diode) as sensors and controlled using PIC16F877A microcontroller. Color detector can facilitate operators in CKD colored checks so as to reduce problems complaints (claim) of the customer. In this paper, we will discuss about how to cope the problems with error checking manually for component

CKD and how to design and create a color detector control system CKD. Previously, we have researched about the application of Microcontroller PIC 16F877A that related with this research [1, 2, and 3].

## II. METHODOLOGY

In 2011 there were a reported claim by the importer country to Quality Control Engineering. Claims data were obtained from Quality Control Engineering in August to October 2011. Figure 1 shows the data and the external party claim pareto diagrams claim average August-October 2011. Problems that occur are sortage, eg parts, and quality. Explanation of the three types of problems are as follow:

- Sortage is the claim due to lack of quantity or number of components of demand.
- Mis part is the claim due to improper component passes to the customer.
- Quality is the claim due to the quality standard does not pass to the customer.

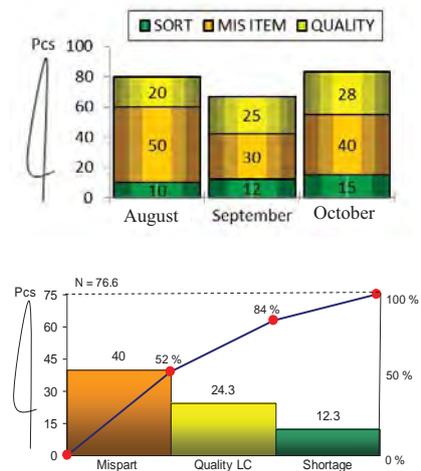


Figure 1. External claim and Pareto average data from August-October 2011

To find the most dominant type of claim, then from the above data was made pareto diagram. From the

analysis of Pareto diagram, it can be seen that the most dominant type of claim is a claim mis part. Mis part happens there are two types of mis color and mis item. Figure 2 shows the data of parts between March to May 2011. Mis part most is mis color or color errors, as many as 30 cases.

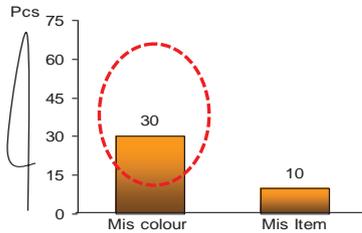


Figure 2. Mis part data from March-May 2011

### A. Problem Analysis

Based on existing problems, in general it can be concluded that the problem of frequent claim is mis color. Then be analyzed to determine the problems and get the solutions to problems that occur to reduce mis color.

Based on the process flow Vanning Packing Division, which is tasked to check the color quality is a process of receiving and auditing case. In the process, the operator checked limit sample components and Key Point Part Inspection. Figure 3 shows the process of checking the components based on color samples and Key Point Part Inspection.

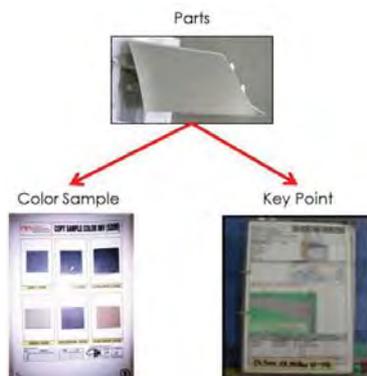


Figure 3. Checking components based on color samples and Key Point Part Inspection

In the process of checking, analysis is performed to determine the cause of the frequent occurrence of mis color. Based on the analysis it can be concluded that the cause is that the operator is difficult to distinguish the color sample limit is almost the same (similar). It is caused by the ability of the eyes of the operator is not able to check the colors similar to many times. From the analysis above, it is a necessary tool for color checking. A tool that can be color-checking tool to distinguish colors is nearly the same components.

### B. The Concept of Color Detector

The concept is that the tools needed to help the operator to distinguish the component colors easily. Figure 4 shows an example of CKD components are checked. These components include: garnish pillar lwr, cover seat track, box assy console, shield fr seat cushion, panel assy quarter, and cover rr seat.



Figure 4. Examples of CKD components are checked

The colors those distinguished are Grey, Mid Grey, Dark Grey, Grege, Ash Brown, Sand Beige, and Light Grey. The colors of these components if at first glance will look the same or similar, but each color will reflect light at different intensities. Figure 5 shows the concept of the color detection.

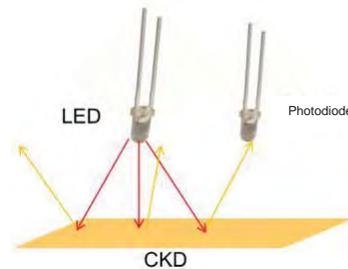


Figure 5. The concept of the color detection

From Figure 5 can be explained that the LED light serves to illuminate the CKD components. The reflection of CKD components will reflect the intensity of light according to the color components of CKD. To detect the color of CKD components are used photodiode. Photodiode has a working principle can stream analog signal voltage be comparable to the value of the intensity of light received. Furthermore, the voltage signal must be converted into digital data. To convert analog signals into digital data, then use a microcontroller which has a facility analog to digital conversion (Analog-to-Digital Converter (A / D)). The working principle is that each ADC input voltage change; it will change the value of output in the form of digital numbers. Voltage changes that can be distinguished by an ADC (Analog Digital Converter), depending on the resolution of the ADC. In this research, we used a 16F877A PIC microcontroller with 10-bit ADC, the input voltage range of 0 to 5 volts.

### III. DESIGN

Based on the concept of the tool in the section above, it was made the workings of the desired device. Figure 6 shows the color detector CKD components. The ways of the device works are as follow:

- First there is the selection of the operating mode, i.e. the mode checking and detection modes. Mode checking is intended to check the mode of a single color, which has been pre-selected by the operator. Mode detection is a menu aimed to find out the name of the color of CKD components is checked.
- If you select the operation mode checks, then it will go to the color selection menu. In this menu, it has to be checked to choose the color components. There are seven colors available, i.e. Grey, Mid Grey, Dark Grey, Grege, Ash Brown, Sand Beige, and Light Grey.
- After selecting the color, it will go into the checking mode.
- The operator will put a sensor on the component to be checked.
- When the button is pressed to detect, the microcontroller will read the input from the sensors and compare with the data that has been programmed.
- If the appropriate comparisons, shows the words "RIGHT" on the LCD. But if the results do not match, it will display "WRONG" and turn rotary lamp.
- If the main menu selects the detection mode, it will go into the detection mode.
- The operator will put a sensor on the component to be checked.
- When it had gone into the detection mode and presses the button to detect pressed, the microcontroller will read the input from the sensors and compare with the data that has been programmed.
- After comparing the data, the LCD will display the name of the color component detected.

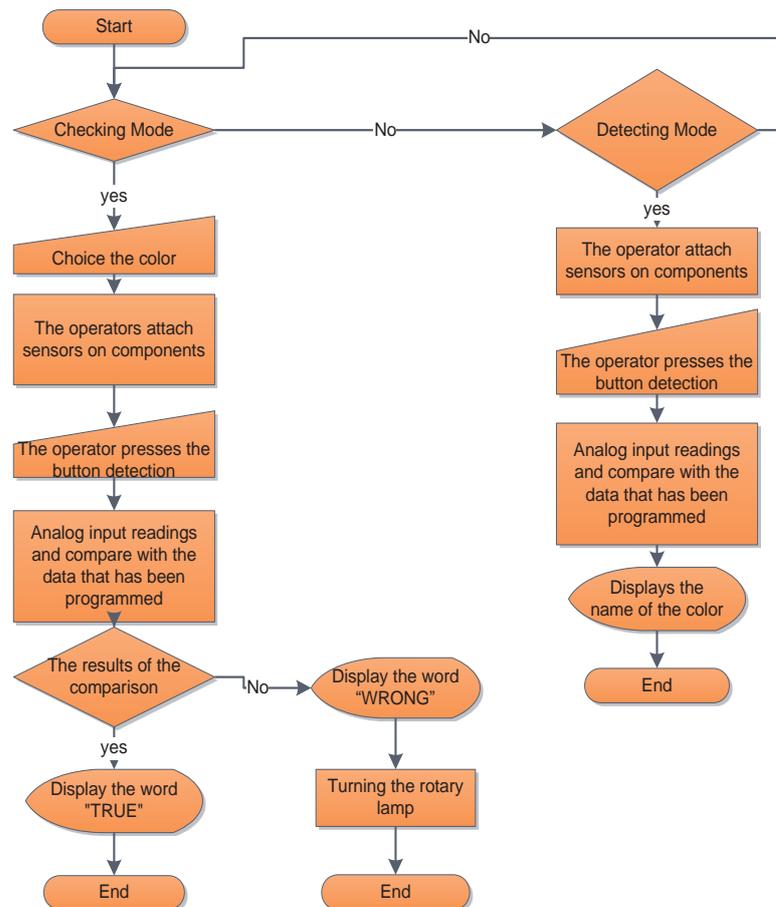


Figure 6. The working principle of the color detector

Based on the concept of the overall device, then be made to the design of the control system components of the color detector CKD. Figure 7 shows a block diagram of the control system components of the color detector CKD.

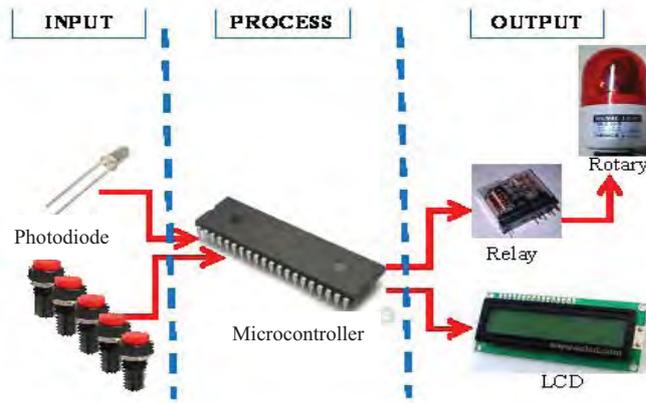


Figure 7. Block diagram of the control system components of the color detector CKD.

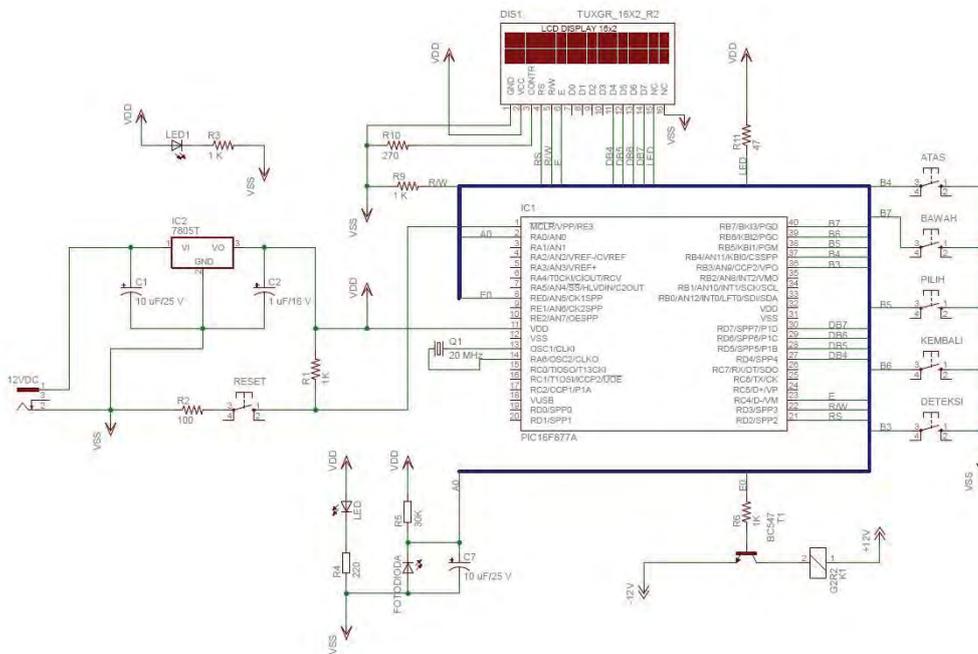


Figure 8. Electric circuit schematic of color detector

The workings of each block of the circuit are as follow:

- Photodiode, serves as analog input to the microcontroller
- Button, functioning as a digital input to the microcontroller. Keys are used there are five that have functions such as shown in the following table.
- Microcontroller, serves as a central data processor, change the analog input into digital output mengandalkan LCD and relays.
- 16x2 LCD, serves to display the program and the results of the detection.
- Relay, Rotary works to turn on the lamp.
- Rotary lamp, serves as a check mark if the component is wrong.

#### A. Realization of the Electric Design

Figure 8 shows the schematic of electric circuit color detector that fulfills the concept and support to the design. From this figure, we divide the circuit into five circuits. It because of this equipment can be inserted into the casing. Those circuits are microcontroller circuit, relay circuit, LCD circuit, push button, and sensor circuit.

#### B. Realization of Creation

To realize a design that has been made, then the design is divided into two types: the realization of the electrical design and realization of the program design. Sensor and the detection circuit incorporated into a flashlight casing. It aims to be easy to use by operators. Distance from the photodiode to the end of the hole is 1 cm flashlight. Figure 9 shows the overall physical color detector.



Figure 9. The overall physical color detector.

### C. Realization of The Programming

Microcontroller will be able to work after downloading the program. Before making a program, the first step is to create a flowchart as a reference for the manufacture of program listings. To make the program a PIC microcontroller 16F877A, the authors use Microcode Studio Plus software as a compiler. The

programming language used in the software is the Basic language.

## IV. THE TESTING AND ANALYSIS

### A. Input and Output Testing

At this stage the microcontroller which has been programmed, the input and output tested. This test is intended to ensure that the input and output of the microcontroller to function properly. This test includes testing the buttons, LCD, photodiode sensors, and relay.

### B. Testing of Input Sensor Photodiode

Photodiode sensor connected to port A0 on the microcontroller. To pass the test, firstly, it must provide a program to send a digital value via serial communication on mikrokontrolernya. After that, by using the Serial Communicator Microcode Studio Plus software, can be seen the value of the photodiode sensor readings. The value will change if the sensor is held to the body with different colors as well.

Tests performed are using the color sample. From these test results obtained digital value of each color. Table 1 shows the results of the tested sensor readings into color samples available are Grey, Mid Grey, Dark Grey, Grege, Ash Brown, Sand Beige, and Light Grey, that performed ten times.

TABLE I. Results of the tested sensor readings into colour samples

Testing	Grey	Mid Grey	Dark Grey	Grege	Ash Brown	Sand Beige	Light Grey
1st	608	780	865	366	765	483	281
2nd	603	776	860	361	760	476	276
3th	609	780	863	364	764	485	281
4th	605	779	864	369	764	483	279
5th	608	780	861	366	761	484	281
6th	611	783	865	364	764	482	281
7th	607	780	868	366	762	479	281
8th	608	780	870	366	764	484	285
9th	613	785	870	371	769	488	286
10th	608	777	865	368	764	483	281

From the above values, it was made the upper and lower limits of each color, as shown in Table 2. These values are used for programming the microcontroller programming realization.

TABLE II. Value of each color

No.	Color	Decimal Value
1	Grey	603-613
2	Mid Grey	775-780
3	Dark Grey	860-870
4	Grege	361-371
5	Ash Brown	759-769
6	Sand Beige	478-488
7	Light Grey	279-286

### C. Testing of LCD Output

LCD is controlled by the microcontroller through the Port C4, D2 Port-Port D7. To pass the test, the first giving the program the microcontroller. Figure 10 shows the LCD that has managed to display text.



Figure 10. LCD display the text

### D. Testing of input Pushbutton

The buttons those located on the tool are: up, down, select, back, and detection. The buttons are connected to a port on the microcontroller B3-B7. To pass the test, the first giving the program the microcontroller. When the button is pressed it will change the display on the LCD or in writing in accordance with the program. Table 3 shows the function of the input. Figure 11 shows the control buttons on the color detector.

TABLE III. The function of the input

No	Button	Functions
1	Up	Shifting to the next menu option

2	Down	Shifting to the previous menu option
3	Choice	Selecting a menu option displayed
4	Back	Return to the previous menu
5	Detection	Displays sensor readings



Figure 11. The buttons on the color detector

#### 4.5 Testing of Relay

To control relay, used E0 port on the microcontroller. To Perform testing, use mode sensor placed on the checks and the wrong color. If the detection button is pressed, the rotary light lamp is lit as a sign that the relay has been triggered. Figure 12 shows that the relay is functioning properly. Table 4 shows the results of the test input and output.

Based on the input-output microcontroller testing shows that LCD, keypad, photodiode sensors, and relays are functioning properly in accordance with the indicators shown each input and output.



Figure 12. Relay turn on the rotary lamp

TABLE IV. The Results of input-output testing

No	Testing	Result	Indicator
1	LCD	Ok	Showing the text
2	Buttons	Ok	Change the display on the LCD when pressed
3	Photodiode Sensor	Ok	Sending color values detection
4	Relay	Ok	Rotary Lamp on

#### V. DISCUSSION

Comparison before and after the use of tools, can be viewed from four factors. These factors are safety, quality, cost, and productivity.

- In terms of the safety factor, the previous operator got eye fatigue because they had to check it manually. After using the tool, operator can reduce eye fatigue because it has been aided by

the color detector. Figure 13 shows the checks before and after using the tool.

- In terms of the quality factor, the wrong color break-out part of the suppliers can be reduced from an average of 30 pieces to 0 piece. Figure 14 shows the decline in break-part color chart. From Figure 13 can be explained that after the discovery of the problem, then do temporary action in the form of additional man power to check the color of CKD and investigation to address the problem. After a color detector is completed and implemented, it can reduce the man power.
- In terms of cost factors, companies can reduce expenses for claims caused by mis part financing of Rp 650.000 per month.
- In terms of factor productivity, the operator can check faster. Before, it has taken an average of 32 seconds to do the checking. After using the tool, a check can be reduced to an average of 18 seconds. So the total time reduction obtained an average of 15 seconds per component.

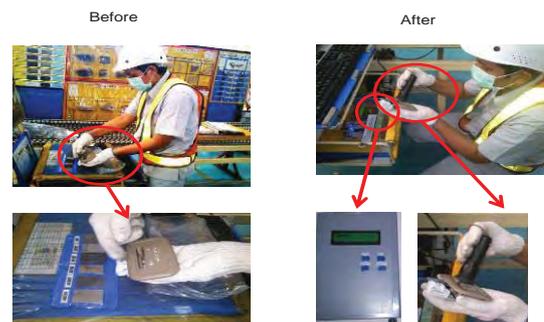
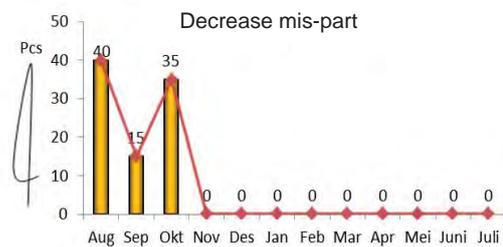


Figure 13. Comparison of the process of checking the color components of CKD



- adding manpower to check the color components of CKD
- implementation detector component colors CKD
- reducing the manpower to check the color components of CKD

Figure 14. Graph reduction claim mis part color.

## VI. CONCLUSION

In this paper, we have discussed the design and testing of the detector component colors CKD automobile. The control system detector CKD component colors are using PIC 16F877A microcontroller, which has facilities ADC (Analog-to-Digital Converter). The facility can alter the form of analog input voltage signal from the photodiode circuit to digital. While the output relay to power the LCD and rotary lamp. From this study, it was found that the error checking manually for the component colors that CKD can be overcome by using color detection as a tool for checking. Mis color part can be reduced from an average of 30 pieces to 0 piece, and checking time can be reduced from an average of 32 seconds to an average of 18 seconds.

## REFERENCES

- [1] S. Ardi, T. S. Rahmandanu, "DESIGN OF DUMP TRUCK SIMULATION CONTROL AREA NETWORK USING THE SPI CAN MODULE, A PIC 18F452 AND PIC 16F877", *Technologic* Vol.3 No.1, ISSN 2085-8507, Halaman 1-7, 2012.
- [2] S. Ardi, D. Prasetyo, "Design of Inspection Tool for Checking The Existence and Position of Hole Stopper Piston 5D9 Using Sick Inspector Camera at Automation Center Bosh Cutting & Engraving Machine", Halaman C-77 – C-80, *Proceeding SNEEMO 2011, Tahun 2011*, ISBN 978-602-19043-0-5
- [3] S. Ardi, A. S. Hudoyo, "Instrumen Kendali Produksi pada Unit Produksi Mesin Injeksi Plastik Menggunakan Mikrokontroler PIC16F877, *Prosiding Seminar Nasional Pengkajian dan Penerapan Teknologi Industri (SNPPTI 2010)*, pp.1-4, ISSN: 2086-2156, Universitas Mercu Buana, Jakarta, Indonesia, 2010.

# Effects of Growth Temperature on Crystal Structure, Electrical, and Photoluminescence of ZnO Thin Films

Iwan Sugihartono  
 Jurusan Fisika FMIPA  
 Universitas Negeri Jakarta,  
 Jakarta 13220, Indonesia  
*Iwan-Sugihartono@unj.ac.id*

PPS Ilmu Material  
 FMIPA Universitas Indonesia,  
 Jakarta 10430, Indonesia

S. Bambang, M. Hikam, E. Handoko  
 PPS Ilmu Material  
 FMIPA Universitas Indonesia

Jakarta 10430, Indonesia  
*bambangsg11@yahoo.com*

H.M. Fan  
 Department of Physics  
 National University of Singapore  
 Singapore

S.T. Tan, X.W. Sun  
 School of Electrical and Electronic Engineering  
 Nanyang Technological University  
 Singapore

**Abstract**— ZnO thin films have been deposited on Si (111) substrate by ultrasonic spray pyrolysis (USP) with various growth temperatures. The polycrystalline of ZnO thin films have preferred plane (002) and relatively low donor concentrations comparing with GaN. Optically, photoluminescence (PL) spectra show the UV emission increased with increasing growth temperature. Nevertheless, green emission does not increase monotonically with increasing temperature. We believed that the ZnO thin films quality improved by increasing growth temperature.

**Keywords**— ZnO thin films, Growth temperature, XRD, Hall measurement, PL

## I. INTRODUCTION

Recently, ZnO has been received much attention for optoelectronics application due to its superior advantages over GaN.[1] Instead of wide band gap energy (3.36 eV) and large exciton binding energy of 60 meV, the quality of ZnO thin film also believed to be improved optoelectronic devices such as UV LEDs and light diodes (LDs) at room temperature.[2] The ZnO thin film quality generally depends on crystallinity, degree of preferred orientation, grain size, morphology, and surface roughness.[3] Some substrates with different lattice constants also used to improve crystalline film quality.[4] However, ZnO suffers from the doping-asymmetry problem, in that the n-type conductivity can be obtained rather easily, but p-type doping proved to be formidable challenge.[5] This doping-asymmetry problem of the wide band gap semiconductors is still the main challenge at the present research. In order to realize applications in optoelectronics technology, a lot of efforts to growth ZnO films on top of a variety of substrates as p-type, such as GaN, Si, SiC, SrCu<sub>2</sub>O<sub>2</sub> and CuGaS<sub>2</sub>. [Error! Bookmark not defined.] Among these

attempts, ZnO thin film on top of Si have stirred-up considerable interest for integrating ZnO onto Si technology.

In this paper, the ZnO thin films grown on Si (111) substrate using ultrasonic spray pyrolysis (USP) technique by various growth temperatures. USP is chosen, due to low cost for fabricating thin films comparing with other technique. X-ray diffraction (XRD), Hall effect, and photoluminescence (PL) measurements were employed to investigate structure, electrical, and optical properties of ZnO thin films.

## II. EXPERIMENTAL METHODS

Undoped ZnO was deposited on p-type silicon (111) substrate using USP. The Zinc acetate dehydrate (Zn(CH<sub>3</sub>COO)<sub>2</sub>·2H<sub>2</sub>O) was chosen as precursors for undoped ZnO. The Zinc acetate 0.02 mol/ml diluted in de-ionized water. The aerosol of precursor's solution was generated by commercial ultrasonic spray pyrolysis (USP). Then it was transported to the heated Si substrate. Each substrate heated at various growth temperature 400 °C, 450 °C, up to 500°C. Heated substrate is intended to increase the density of atom on film deposition, minimize the oxidation, govern the preferred growth orientation, and generally improve the mechanical properties of film.[6] After deposition the ZnO thin film thickness of about 200 nm were characterized by XRD, Hall measurement, and photoluminescence (PL) spectrometer.

## III. RESULTS AND DISCUSSION

X-ray diffraction (XRD) was performed to characterize crystal structure of the ZnO thin films.

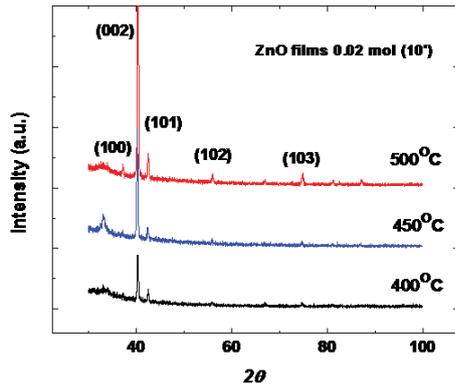


Fig. 1. XRD pattern of ZnO thin films at various growth temperatures

Fig. 1. XRD pattern of ZnO thin films at various growth temperatures

Fig. 1 shows the typical XRD patterns of as grown ZnO films at various different temperatures which ranging from 400°C to 500°C with the increment of 50°C. There is no shifting peak of 2θ angles when growth temperature increases. Nevertheless, the peak (002) of 2θ angles increases by increasing growth temperature.

By using Scherrer's formula, the grain size for crystallographic plane at (002) can be estimated.[7]

$$D = \frac{0.9\lambda}{B\cos\theta} \quad (1)$$

Where  $D$ ,  $B$ ,  $\lambda$ , and  $\theta$  are the average grain size, the full width at half maximum (FWHM), wavelength, and Bragg diffraction angle, respectively. Furthermore, the grain size estimation for crystallographic plane (002) can be seen in the table 1. The grain size increased monotonically with temperature. Nevertheless, other reported that the grain size does not increase monotonically with temperature.[7]

Table I. The ZnO thin films grain size estimation for crystallographic plane (002) at various growth temperatures

Growth Temperature (°C)	Grain size (nm) in Crystallographic plane (002)
400	10.57
450	13.63
500	15.49

In general the electrical properties of bulk ZnO are excellent. Figure 2 show the room temperature Hall measurement of ZnO thin films. Hall measurement predicted that the conduction type is  $n$ .

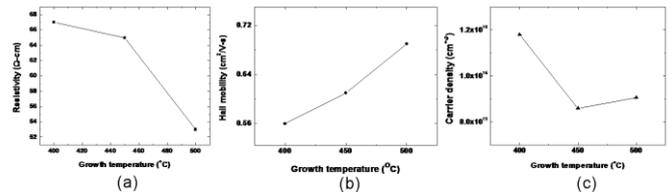


Fig. 2. The room temperature Hall measurement of ZnO thin films (a) resistivity, (b) Hall mobility, (c) Carrier density

As can be seen from the fig. 2 (a), the resistivity of the films decreased with increasing temperatures. It indicates that ZnO thin films relatively have high resistivity which is predicted due to the presence of higher concentration of O vacancies.[8] On the other hand, figure 2 (b) shows that Hall mobility increased with increasing growth temperatures. The Hall mobility of ZnO thin films generally are influenced by scattering from the ionized impurities ( $\mu_i$ ) and grain boundaries ( $\mu_g$ ). Therefore, linearly Hall mobility increased with growth temperatures, mainly due to the grain boundary scattering.[9] Meanwhile, figure 2 (c) shows that the carrier density values are  $1.18E+16$ ,  $8.59E+15$ , and  $9.06E+15$  at temperatures 400°C, 450°C, and 500°C, respectively. It is proper with other reports that the ZnO films have relatively low donor concentrations comparing with GaN.[10] Normally, the dominant donor in ZnO is usually assigned to oxygen ( $O^{-2}$ ) vacancy or zinc (Zn) interstitial atoms.[10]

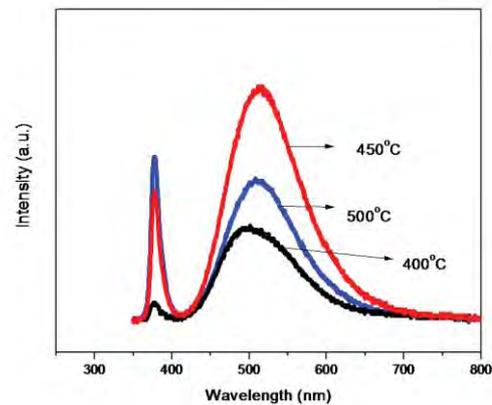


Fig. 3. PL spectrum of ZnO thin films at various growth temperatures

Fig. 3 shows the room-temperature photoluminescence (PL) spectrum of ZnO thin films deposited on to Si (111) substrat. In undoped ZnO thin film the ultraviolet (UV) emission peak which is ascribed to the free exciton emission observed around 375 nm. Then, the strong green band due to the presence defect which originates from deep level emission (DLE) observed as broad peak at 530 nm. The intensity of UV emission increased distinctly with the increasing the growth temperatures (400-500°C). Nevertheless, the others claimed that the UV emission of ZnO thin films which was grown by laser ablation increased by increasing substrate temperature. While, the green band emission are not be uniform and the

estimated value of the intensities may not be linear with increasing temperature.[11]

#### IV. CONCLUSIONS

In conclusions, we have deposited ZnO thin films on Si (111) substrate by ultrasonic spray pyrolysis (USP) with various growth temperatures ranging from 400 °C, 450 °C, and 500°C. The polycrystalline of ZnO thin films have preferred plane (002) and relatively low donor concentrations comparing with GaN. The UV emission increased with increasing growth temperature. Nevertheless, green emission does not increase monotonically with increasing temperature.

#### ACKNOWLEDGMENT

Financial support from Beasiswa Program Pasca-sarjana (BPPS) Direktorat Jenderal Pendidikan Tinggi (DIKTI) Kementerian Pendidikan dan Kebudayaan (KEMENDIKBUD) Republik Indonesia and Science and Engineering Research Council of Agency for Science, Technology and Research of Singapore (Nos. 0921010057 and 0921510088) are gratefully acknowledged.

#### REFERENCES

- 
- [1] T. Aoki, Y. Hatanaka, and D.C. Look, "ZnO diode fabricated by excimer-laser doping", *Appl. Phys. Lett.*, no. 76, 3257, 2000.
- [2] X.W. Sun, S. F. Yu, C. X. Xu, C. Yuen, B. J. Chen, and S. Li, "Room temperature ultraviolet lasing from ZnO microtubes", *Jpn. J. Appl. Phys.*, Part 2 42, L1229, 2003.
- [3] J. Yoo, J. Lee, S. Kim, K. Yoon, I.J. Park, S.K. Dhungel, B. Karunakaran, D. Mangalaraj, J. Yi, "High transmittance and low resistive ZnO:Al films for thin film solar cells", *Thin Solid Films*, no. 480, p.213, 2005.
- [4] Bo Hyun Kong, Sanjay Kumar Mohanta, Dong Chan Kim, Hyung Koun Cho, "Optical and structural properties of ZnO thin films grown on various substrates by MOCVD", *Physica B: Physics of Condensed Matter* 401-402, p. 399-403, 2007.
- [5] V.Avrutin, N. Izyumskaya, U. Özgür, D. Silversmith, H. Morkoç, *Proceeding of the IEEE*, no. 98, 7, 2010.
- [6] P. Patsalas, C. Charitidis, and S. Logothetidis, "The effect of substrate temperature and biasing on the mechanical properties and structure of sputtered titanium nitride thin films", *Surface and Coatings Technology* 125, 335-340, 2000.
- [7] S.T. Tan, B.J. Chen, X.W. Sun, W.J. Fan, H.S. Kwok, X.H. Zhang and S.J. Chua, "Blueshift of optical band gap in ZnO thin films grown by MOCVD", *J. Appl. Phys.* 98, 013505, 2005.
- [8] X. L. Xu, S. P. Lau, J. S. Chen, Z. Sun, B. K. Tay, J. W. Chai, "Dependence of electrical and optical properties of ZnO films on substrate temperature", *Materials Science in Semiconductor Processing* 4, p. 617-620, 2001.
- [9] S. Ghosh, A. Sarkar, S. Chaudhuri, A. K. Pal, "Grain boundary scattering in aluminium-doped ZnO films", *Thin Solid Films*, Vol. 205, 1991.
- [10] D.C. Look, "Recent advance in ZnO Materials and Devices", *Materials Science and Engineering*, B80, 2001.
- [11] X.M. Fan, J.S. Lian, Z.X. Guo, H.J. Lu, "Microstructure and photoluminescence properties of ZnO thin films grown by PLD on Si(111) substrate", *Appl. Surface Science*, 239, 2005.

## Direction Detection of Radioisotopes by Energy Spectra of Compton Scattering in flat CdTe Radiation Recorder

Toru Aoki<sup>a,b</sup>, Akifumi Koike<sup>b</sup>, Hidenori Mimura<sup>a,b</sup>

<sup>a</sup>Research Institute of Electronics, Shizuoka University  
3-5-1 Johoku, Naka-ku, Hamamatsu 432-8011 Japan  
Tel & Fax: +81 (53) 4781321  
E-mail : rtaoki@ipc.shizuoka.ac.jp

<sup>b</sup>ANSeeN Inc.  
3-5-1 Johoku, Naka-ku, Hamamatsu 432-8011, Japan  
Tel & Fax: +81 (53) 5227708  
E-mail : koike@anseen.com

### ABSTRACT

We developed a pocket gamma-ray radiation recorder with CdTe sensor. This radiation recorder has an energy-compensated CdTe gamma-ray sensor but also GPS position sensor, three-axis geomagnetism sensor, three-axis acceleration sensor, and temperature and pressure sensor with SD-memory. Therefore, we can know the accurate dose rate with absolute position and direction of the recorder. We can estimate Radioisotope(RI) direction because the CdTe sensor has directivity. However, the directivity is not so sharp, therefore it is difficult to detect an accurate position of RI. In this research, we used 8-CdTe radiation recorders for detection of RI direction. Moreover, we used the changing of the gamma-ray energy spectra of Compton scattering in CdTe sensor for assistance of estimation calculation because the CdTe radiation recorder can obtain gamma-ray energy spectrum. In this research, we will like to apply this system to measure at Fukushima areas, Cs137 single RI was used for the estimation.

### Keywords

*Radiation detector, Compton Scattering, Gamma-ray, CdTe, Direction Detection*

## OPTIMALIZATION OF MULTI TUNNING STUB PROXIMITY COUPLED E-SLOT MICROSTRIP PATCH ARRAY ANTENNA FOR ENHANCE MULTI-WIDEBAND

<sup>[1]</sup>Binsar Erick L Girsang  
 Telecommunication Engineering  
 Faculty of Communication and Information Technology  
 National University  
 Jakarta, Indonesia  
[ritchieerick36@gmail.com](mailto:ritchieerick36@gmail.com)

<sup>[2]</sup>Iskandar Fitri  
 Telecommunication Engineering  
 Faculty of Communication and Information Technology  
 National University  
 Jakarta, Indonesia  
[tektel2001@yahoo.com](mailto:tektel2001@yahoo.com)

**Abstract--** Current trends and future sharing of communication that needs to be done in a mobile communication device. On the other hand, the creation of a mobile communication device multi-function communication will encourage the creation of such devices will become cheaper and mass production is compared to one with a single communication function of mobile devices. One of the components to support a dream antenna is characterized by compact and lightweight. Microstrip antenna is an antenna types is possible to support mobile communication devices. In this paper is propose a design of microstrip antenna that can receive and send information from several different communications systems operating frequency allocation (multiband) and large information capacity (wideband). The design of the antenna is made using a new technique which combines multi tuning fork-shaped to fed the patch for produce a wideband characteristic and narrow slot technique a modified form of E at 6 patch element in the array to produce multiband characteristics. The configuration of an antenna design in this study is proximity coupling technique by using two layers of epoxy substrate FR-4 with a thickness of 1.6 mm and a dielectric constant of 4.4. From simulation acquired three operating in the frequency band of 1.05 - 7.96 GHz (return loss <-10 and VSWR <2). These frequency band are; 1.05 to 1.96 GHz, 2.65 - 2.80 GHz, and 7.76 to 7.96 GHz.

**Keywords:** multi-wideband, tuning, stub, E-slot, proximity coupled

### I. INTRODUCTION

The development of communication technology in the modern world is getting faster and variety, so many of the new emerging technology standards and increasingly sophisticated. Antenna was instrumental in the development of telecommunications, particularly

telecommunications with radio waves. In its recommendation that have enlightened bandwidth's requirement to wideband case goes to in a few frequency allocation which is [Akhavan, 1995] Manatu Ohanga, 2005] ; bandwidth 10 MHz to frequency distance of 30 MHz until 1 GHz, 50 MHz to 1 GHz until 3 GHz, 100 Mhz to 3 GHz until 10 GHz, 250 MHz to 10 GHz until 15 GHz, and 500 MHz to frequency distance upon 15 GHz. At plays favorites state [Nakano et. al., 2002] there are some frequency allocation alternative for ultrawideband's application as American As and European allocates for radar system with a brass band frequency under 900 MHz, 1.9 – 10.6 GHz and 3.1 – 10.6 GHz. Both of for vehicular is system's radar on 22 – 29 GHz, 24 – 24.25 GHz and 23.6 – 24 GHz. Third for application on communication system without cable which operating on 3.1 – 10.6 GHz. Multiband characteristics appear in many communication systems that can be applied. Wideband characteristics seen in the width of each frequency band communication systems. For example, the mobile phone functions can be used two operators / two cellular systems such as GSM or CDMA-GSM-GSM is also coupled with the function of wireless fidelity (WIFI / Wi-MAX), Global Positioning System, bluetooth all of which are integrated in a single device communication moves.

The purpose of this research is microstrip antenna patch E - slot six elements made with the technique of multituning stub to Enlarge the bandwidth can be applied to a multi-service wireless communication device that works on a frequency of 1-10 GHz. the benefit of double-layer microstrip antenna design is expected to anticipate the

needs of the technology in large capacity and fast, and economical and practical for its users.

## II. DESIGN AND SIMULATION MICROSTRIP ANTENNA

In the design of microstrip antenna substrate materials used have the following specifications:

- Material Dielectric: FR-4 epoxy Konstanta dielektrik ( $\epsilon_r$ ) = 4,4
- dielectric layer thickness ( $h$ ) = 0,0016 m = 1,6 mm
- Loss tangent = 0,02
- upholstery material substrate (conductor) conductivity copper copper ( $\sigma$ ) =  $5.80 \times 10^7$  mho m-1
- 1-10 GHz Frequency Range
- line characteristic impedance = 50  $\Omega$

### 2.1 Planning Feeding Channel

Feeding channels are used in the design is expected to have or at least close to the input impedance of 50  $\Omega$ . To get the value of the impedance is done setting the width of the channel by using the software pncatu PCAAD. For value  $Z_0 = 50 \Omega$ ,  $r = 4.4$  (FR-4 Epoxy) and  $h = 0.16$  cm, the width feeding is obtained 0.3 cm, as shown in figure 6

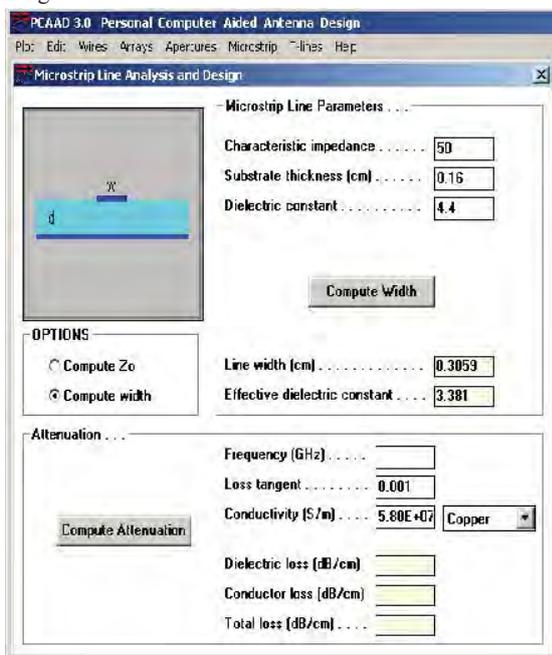


Figure 1. Fed width calculations

Finding width and length patch antenna Rectangle (Rectangular) can use a mathematical method to Determine equation Patch width (W):

$$W = \frac{c}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}}$$

The length L is defined as follows:

$$\Delta L = 0.412h \frac{(\epsilon_{reff} + 0.3) \left( \frac{W}{h} + 0.264 \right)}{(\epsilon_{reff} - 0.258) \left( \frac{W}{h} + 0.8 \right)}$$

For the resonance frequency  $f_0$  indicated the effective length is given as:

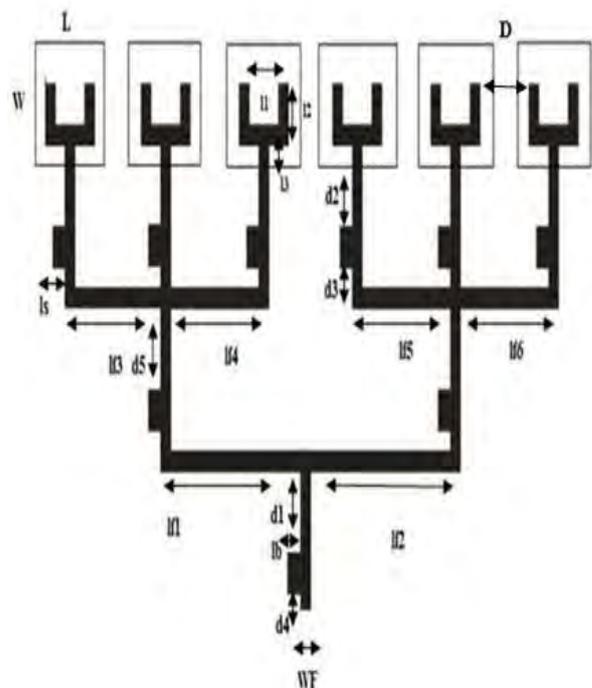
$$L_{eff} = \frac{c}{2f_0 \sqrt{\epsilon_{reff}}}$$

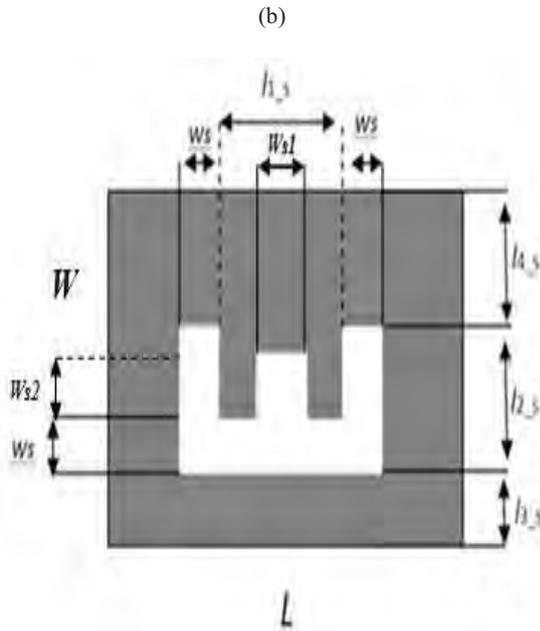
So the length of the field L is:

$$L = L_{eff} - 2 \Delta L$$

From the calculation of the dimensions of the antenna is obtained as follows.

(a)





**Figure 2.** Dimension slot microstrip antenna array element 6 (a) Dimensions designing feeding (b) dimensions of the patch radiator design with E slot

Table 1. The size of the antenna radiator element E-slot double layer

No	Dimension Radiator and E-Slot Patch	Design (cm)
1	$W$	1.6
2	$L$	2.3
3	$W_s$	0.3
4	$W_{s1}$	0.2
5	$W_{s2}$	0.5
6	$l1\_s$	0.6
7	$l2\_s$	0.9
8	$l3\_s$	0
9	$l4\_s$	1.4

Table 2. Size feeding the antenna E-slot double layer

No	Dimension Feeding	Size (cm)
1	$W_f$	0,3
2	$L_{f1}$	4.43
3	$L_{f2}$	4.575
4	$L_{f3}$	3
5	$L_{f4}$	3
6	$L_{f5}$	3
7	$L_{f6}$	3
8	$l_b$	0.4
9	$D$	1.5
10	$d1$	1.2
11	$d2$	1.2
12	$d3$	0.375
13	$d4$	0.4
14	$d5$	1.2
15	$l_s$	0,3
16	$l1$	0.9
17	$l2$	0.9
18	$l3$	0.3

### III. SIMULATION RESULTS

#### A. Return Loss Dan VSWR

The results of the simulation design antenna E-6 slot double layer can be analyzed with graph element Return Loss and VSWR values resulting from the simulation design and presented through the charts to be declared as a result of good design is where the value of return loss  $< -10$  dB and VSWR  $< 2$ . Representation of the simulation results can be seen through the following graph:

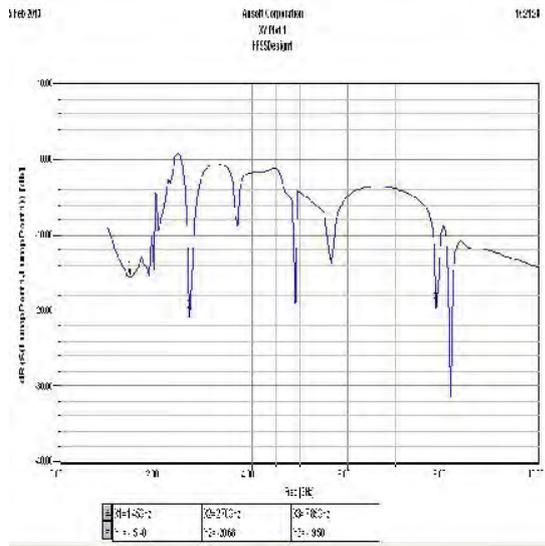


Figure 3. Graph the results of the simulation return loss

value-10dB return loss over the frequency range obtained at 1.05 - 1.96 GHz, 2.65 - 2.80 GHz and 7.76 - 7.96 GHz. Resulting in a wide bandwidth of the return loss for microstrip slot array antenna for 910 MHz, 150 MHz and 200 MHz. From the results I observed in the resonance frequency range on the graph above produces multi bandwidth because it has three resonance frequency and wide bandwidth wideband meet the criteria for having a wide bandwidth of over 100 MHz.

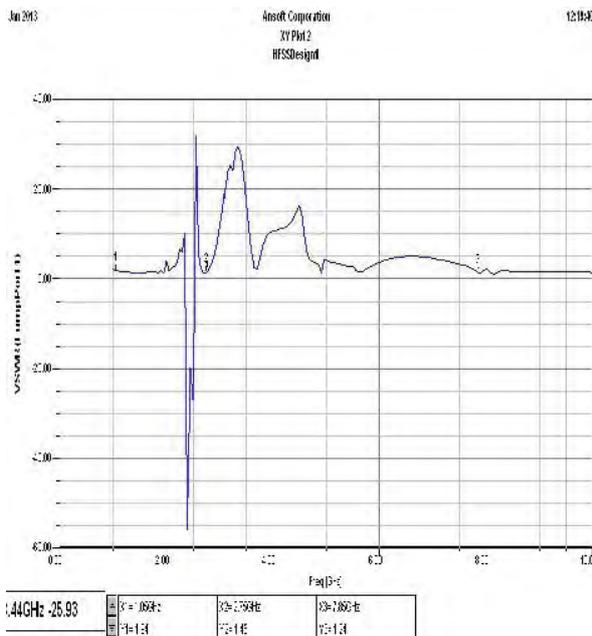


Figure 4. results Graphics simulation VSWR

From the results shown in the chart above, that the value of the frequency tolerance  $VSWR < 2$  During the simulation, the above-10dB VSWR values obtained at 1:05 frequency 1.64 GHz VSWR values obtained, the frequency of 2.75 GHz VSWR values obtained frequency of 7.85 GHz 1:45 and VSWR values obtained 1:24 .

### B. Radiation Pattern

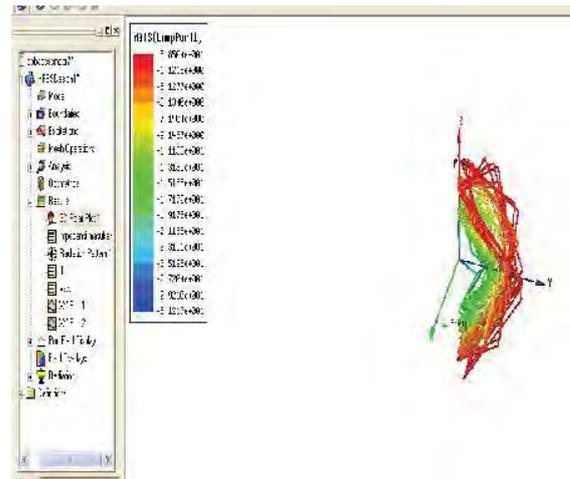


Figure 5. 3D Radiation Pattern Polar Plot

Can in clay of the radiation pattern of the image 8. that red is the radiation pattern of the most powerful and the most blue the weakest radiation pattern. can be inferred from the radiation pattern of microstrip antenna radiation pattern is circular.

### CONCLUSION

Several theories microstrip antenna design techniques in literature by previous researchers as evidenced in the design of microstrip patch antenna wake phi-slot 2 uses proximity coupled elements are; the more slots on the radiation pattern of the antenna on an antenna also will not even become good radiation pattern. Stub connected in shunt at feeding system to affect a wide bandwidth. Position stub on microstripline be able to produce a wide tuning for optimal bandwidth. Forms patch, slot shape, and position of the slots on the patch can affect the amount of the resulting band operation. Slot on the patch, in this case E-slot, capable of producing multiple operating bands (multiband characteristic).

## REFERENCES

- [Ban, Leong Ooi], " A Double II Stub Proximity Feed U-Slo Patch Antenna ", IEEE Transaction On Antennas and Propagation, Vol. 52, No. 9, September 2004
- [Wang, H., Huang, X.B. & Fang, D.G.], "A single Layer Wideband U-Slot Microstrip Patch Antenna Array", IEEE Transaction on Antennas and Wireless Propagation, Vol. 7, 2008.
- [Kidder, Chad., Li, Ming-yi & Chang., Kai], "Broad-band U-Slot Patch Antenna With a Proximity-Coupled Double II-Shaped Fedd Line for Array", IEEE Transaction on Antennas and Wireless Propagation Letter, Vol. 1, 2002.
- [Qu, Shi-Wei & Xue, Quan.], "A Y-Shaped Stub Proximity Coupled V-Slot Microstrip patch Antenna", IEEE Transaction on Antennas and Wireless Propagation Letter, Vol. 6, 2007.
- [Manatu Ohanga] (Ministry of Economic Development), "An Engineering Discussion paper on Spectrum Allocations for Ultra Wide Band Devices", Radio Spectrum Policy and Planning Resources and Networks Branch.
- [Sze, J.Y., & Wong, K.L.], "Bandwidth enhancement of a printed wide slot antenna fed by a microstripline with a fork-like tuning stub," *Proceeding of ISAP*, Japan, 2000, pp.1159-1162.
- [Akhavan, H.G. & Syahkal], D.M., "A Simple Technique for Evaluation of Input Impedance of Microstrip-Fed Slot Antennas", *IEE Conference Publication*, No. 407, April 1995.

## Investigation about Pr-effective concentration and influence of Al-addition on the luminescence properties of SrTiO<sub>3</sub>:Pr<sup>3+</sup>,Al phosphors

O.M.Marchylo<sup>1</sup>, Y.Nakanishi<sup>2</sup>, L.V.Zavyalova<sup>1</sup>, G.S.Svechnikov<sup>1</sup>, A.E.Belyaev<sup>1</sup>,  
H.Kominami<sup>2</sup> and K.Hara<sup>2</sup>

*1) Institute of Semiconductor Physics, National Academy of Science of Ukraine  
41, pr. Nauki, 03028 Kiev, Ukraine*

*2) Research Institute of Electronics, Shizuoka University  
3-5-1 Johoku, Naka-ku, Hamamatsu 432-8011, Japan*

### ABSTRACT

Red-emitting SrTiO<sub>3</sub>:Pr<sup>3+</sup>,Al phosphors were synthesized by sol-gel method. In this study, dependence of luminescent properties of SrTiO<sub>3</sub>:Pr<sup>3+</sup> phosphor on Pr<sup>3+</sup> concentration has been investigated. Moreover, the influence of Al addition for the luminescent and structural properties of the phosphor has also been investigated. It was found that the effective concentration of Pr<sup>3+</sup> for luminescence intensity of SrTiO<sub>3</sub>:Pr<sup>3+</sup> under low-energy electron and UV light excitation is around 0.2 mol%. It was shown that both luminescence intensity and crystallinity of the phosphors were deteriorated by Al addition up to 15 mol%. This result is different from that synthesized by solid phase reaction. It is suggested that the SrTiO<sub>3</sub>:Pr<sup>3+</sup> phosphor can be synthesized by sol-gel method without Al. The high luminance of 1840 cd/m<sup>2</sup> from SrTiO<sub>3</sub>:Pr<sup>3+</sup> phosphor without Al was obtained under excitation with anode voltage of 10 kV and current density of 60 μA/cm<sup>2</sup>.

### Keywords

*SrTiO<sub>3</sub>:Pr<sup>3+</sup>, Al, phosphor, photoluminescence, cathodoluminescence, sol-gel method*

# 5G Key Technologies: Identifying Innovation Opportunity

Cantika Felita<sup>1</sup>, Muhammad Suryanegara<sup>2</sup>  
Department of Electrical Engineering  
Faculty of Engineering, Universitas Indonesia  
Depok, Indonesia  
cantika.felita@ui.ac.id<sup>1</sup>, m.suryanegara@ui.ac.id<sup>2</sup>

**Abstract**—The “not yet officially defined” 5G standard leads to the consequence that its relevant technological innovation is still widely open. For identifying innovations opportunity, we should discover the specific technical area to contribute to the technological development of 5G. This paper discusses a framework answering the main question: In which technological area one may contribute to the innovation? The answer shall benefit countries, firms, universities and research institute which intends to contribute to the formulation of official 5G standard.

First, we reviewed the key technologies of 5<sup>th</sup> generation mobile communication technology (5G). Ubiquitous and interoperability of the network are main technical focus. A flat IP-based network concept was reviewed, as well as cognitive radio technology to reach the terminal which have artificial intelligence. BDMA technology was proposed to help achieving system efficiency in terms of multiple access system. Second, we identified technological challenges, focusing on the issues related to security and problems to deal with limited frequency spectrum resources. Subsequently, we mapped the innovation opportunity based on technical area which is recently published in research article. We concluded that innovation opportunities lies on the research regarding security, network, technological implementation and applications issues.

**Keywords**—5G; innovation; standard

## I. INTRODUCTION

Today, changes in the realm of telecommunication technology have occurred and will remain happening. Mobile telecommunication grows from first generation, known as 1G, to 2G, 3G, and now to the fourth generation that still in implementation stage in several countries, 4G. Every generation of technology have several differences and innovations.

5G is a terminology that is used for the 5th generation mobile technology. Telecommunication companies or standardization bodies of telecommunication such as 3GPP, WiMax Forum, or ITU-R haven't issued the official standard for 5G [1]. The absence of official standard makes the 5G have limitless possibilities. However several expectations have been raised about how 5G should and will be.

The 5G technology is expected to complete the 4G technology and provide solutions to the shortage arising from 4G technology. This technology will be a new technology that makes users able to access different Radio Access Technologies (RATs) using one mobile [2]. 5G has been proposed to assemble the existing wireless and wired communication techniques into an all IP (Internet Protocol) high performance world wide network [3]. 5G technology will help perfecting World Wide Wireless Web (WWWW) [4]. WWW itself is an attempt to create a circumstance where subscriber can savor the great quality and quick access of internet, dynamic movement, favorable Bit Error Ratio (BER) and great security as on wired communications in their wireless communication devices. Limitations of frequency resources making 5G shall have a technical development, which uses other resources than frequency/time resources in order to increase a capacity of the system [1].

In this paper, we try to identify innovation opportunity of the 5G technological development. It explored the fundamental literature framework to answer a question: in which technological area one may contribute to the innovation? The answer shall benefit countries, firms, universities and research institute which intends to contribute to the formulation of official 5G standard.

The second section of this paper provides the review of the key technologies of 5th generation mobile communication technology (5G). The third section presents our identification of technological challenges, focusing on the issues related to security and problems to deal with limited frequency spectrum resources. In the fourth section, we mapped the innovation opportunity based on technological area which is recently published in research article.

## II. REVIEW OF 5G KEY TECHNOLOGIES

There are several key technologies which are expected to help fulfilling the need of improvement for 5G. Those are Flat IP Based Network and Cognitive Radio (CR).

### A. Flat IP Based Network

Previous works by Toni Janevski from University Sv Kiril I Metodij define the basic concept of 5G mobile network which

is seen as user-centric concept instead of operator-centric as in 3G or service-centric concept as seen for 4G. The 5G mobile phone is designed as an open platform on different layers, from physical layer up to the application [5].

The network layer at 5G networks will be divided into several sub-layers to provide all-IP connectivity anywhere and anytime. The use of the Internet Protocol (IP) in the network layer is inevitable, given the IP system is the best and most used system to support and expand the network layer nowadays. All IP Network (AIPN) system has started well since the development of LTE.

All IP Network (AIPN) system has started well since the development of LTE as an evolution of the 3GPP system. Flat IP Network is a key concept that is expected to make 5G acceptable to all kinds of technology [1]. Flat IP architecture provides a way to identify each device using symbolic names, unlike the hierarchical architecture commonly used in the usual IP address [1]. With the shift to flat IP architectures, mobile operators will be able to [1]:

- Reduce the number of network elements in the data path, thereby reducing operations costs and capital expenditure.
- Splitting the cost of service delivery from the amount of data that is sent to equate infrastructure capabilities to the requirements of emerging applications
- Minimize system latency and enable applications with a lower tolerance for delay; upcoming latency enhancements on the radio link can also be fully realized.
- Evolve radio access and packet core networks independently of each other to achieve greater development and make better flexibility in network planning and deployment.
- Develop a flexible core network that can be the basis of innovative services for mobile and generic IP access network.

Create a platform that will enable mobile broadband operators to be competitive with wired networks in terms of price and performance.

IPv6 is the best possible system that can support a flat IP network for technology implementation 5G later. IPv6 is the latest revision of the IP system is expected to overcome the shortcomings of the predecessor version of IPv4. Each device will then have a fixed IPv6 address, and multiple addresses Care of Address (CoA). The number of CoA for the device is according to the number of access networks where device is connected. There are 3 sub-layers of the network layer, the lower network layer, middleware layer and the upper network layer. Lower network layer use CoA, middleware network layer translates CoA into IPv6 so the upper network layer using IPv6 addresses.

Device is expected to be provided by a variety of options in order to get the best wireless connection in accordance with the type of device and current network conditions. QoS parameters such as delay time, jitter, bandwidth, reliability and so on will

be stored in a database that can be used for training intelligent algorithms in a mobile terminal, thus the 5G technology can choose the best connections for the device at the given time and condition.

### B. Cognitive Radio

For mobile and wireless communications technologies, since the 4G, interoperability was an important thing, as it is also applied for 5G. Interoperability system means any system with different technologies can work together and communicate with each other. The network architecture for 5G mobile system consists of a user terminal and a number of independent, autonomous radio access technologies [6]. Within each of the terminals, each of the radio access technologies is seen as the IP link to the outside Internet world [6]. With the use of cognitive radio terminal, 5G can achieve interoperability and still have a good quality of service. In the cognition system, the system recognizes the location, position and condition to determine the best option for network. With this system, users can choose a suitable network for communication and different wireless networks will be able to integrate and communicate with each other via cognitive radio devices.

Cognitive radio is an intelligent communication system that is aware of its surrounding environment (i.e., outside world), and uses the methodology of understanding-by-building to learn from the environment and adapt its internal states to statistical variations in the incoming RF stimuli by making corresponding changes in certain operating parameters (e.g., transmit-power, carrier-frequency, and modulation strategy) in real-time, with two primary objectives in mind: highly reliable communication whenever and wherever needed; efficient utilization of the radio spectrum [7].

By that definition, the cognitive terminal is a smart terminal with intelligence to choose the proper network from all the existing wireless networks [5]. The choice is based on some information such as time, demand, and resource. The 5G technology proposes a universal terminal, which should include all of the radio predecessors features into a single device [5]. This terminal convergence is strongly sustained by the users' needs and demands; therefore, cognitive radio becomes the ideal 5G terminal candidate [5].

## III. TECHNOLOGICAL CHALLENGES

By understanding the key technologies of 5G, we identified the technological challenges which mainly lie on the problems concerning security as well as limited frequency resources.

### A. Security

Being able to scan the available spectrum, select from a wide range of operating frequencies, adjust modulation waveforms, and perform adaptive resource allocation— all of these in real-time— these new Cognitive Radio technology will be able to adapt to a wide variety of radio interference conditions and adaptively select the most efficient communication mechanisms [8]. However, in addition to the advantages and potential of the cognitive radio technology, there are a number of challenges related to security, especially in cognitive radio terminals. The paradigm of cognitive radio

systems poses a new threat on security, such as selfish misbehaviors, harmful interference, licensed user emulation, competition between licensed users and eavesdropping [9].

There is an opportunity and need to develop a system that able to prevent the misuse in the highly open and granular control which is provided to the radio interface. One of them was proposed by [8] with a framework known as TRIESTE which is short term for Trusted Radio Infrastructure for Enforcing SpecTrum Etiquettes. TRIESTE will be able to ensure that radio devices are only able to access and use the spectrum in a manner that conforms to their privileges [8].

### B. Limited Frequency Spectrum Resources

Limited spectrum resources yielded a major challenge for mobile and wireless technologies. Those limited frequency and time are divided to be used among multiple users. Due to this condition, it is expected to improve efficiency in order to enhance the capacity and quality of the system. To achieve this, several multiple access techniques used today, for example, Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Division Multiple Access (OFDMA), etc. However, in all of multiple access system that are used nowadays, the capacity of a mobile communication system depends on time and frequency. This generates a challenge to develop a multiple access system which is able to resolve the dependencies of capacity to the limited frequency spectrum. Korean research and development has suggested BDMA as a radio interface for 5G, which is not depended on frequency/time resources [1].

The BDMA technique of the present invention divides an antenna beam according to locations of the mobile stations to allow the mobile stations to give multiple accesses, thereby significantly increasing the capacity of the system [1]. In such a concept, mobile stations and a base station are in a Line of Sight (LOS) state, so they exactly know each other's positions. In this condition they will be able to transmit beams which direct to each other's position to communicate without interfering with mobile stations at cell edge [1].

For adapting the BDMA system into 5G, the development of the phase array antenna is required. The smart antenna with the ability to switch its beam is needed. Switched beam antennas support radio positioning via Angle of Arrival (AOA) information collected from base and mobile stations. The use of adaptive antenna arrays is one area that shows opportunity for improving the capabilities.

## IV. INNOVATION OPPORTUNITIES

Opening up innovations opportunity means to discover the technical area as the guidance to conduct research work on such particular technological agenda. We monitored the spread of technical issues related to 5G in various scientific and engineering journals. There are 18 research articles which have stated 5G as the main corresponding topic in their research work. Those publications include 7 conference papers, 7 journal papers, 3 conference reviews and 1 document review.

Subsequently, we map the technical area based on 40 keywords mentioned in those 18 research articles. Table 1 lists the keywords and the corresponding number of research articles. In general, it mainly indicates that technical area is not yet heavily concentrated on certain technological agenda. However, more researches were conducted concerning topics of relay selection, mobile ad hoc network and one hop cooperative MAC, while other topics are equally distributed.

We identified that the keywords are likely relevant to three technological agenda, i.e. security, network, and technological implementation and applications issues.

TABLE I. KEYWORDS ON 5G RESEARCH PUBLICATIONS

Keyword on the research articles	Number of research publications
Relay selection	4
Mobile Adhoc Networks (MANETS)	3
One-hop cooperative MAC	3
Ad hoc On-Demand Distance Vector (AODV)	2
Architecture for humanity	2
Blacklisting	2
Dynamic Source Routing (DSR)	2
Error Vector Magnitude (EVM)	2
GNU Radio	2
Multihop wireless network	2
Orthogonal space time codes	2
Prognoses	2
Remote monitoring	2
Two-hop cooperative communication	2
Universal Software Radio Peripheral (USRP)	2
Wireless optics	2
All IP networks	1
Collision avoidance	1
Constellation sizes	1
Cooperative protocols	1
Core networks	1
Denial of Service (Dos)	1
Dense network	1
Heterogeneous networking	1
Linear complexity	1
MIMO channels	1
Modulation technique	1
Multi-hops	1
Network achitecture	1
OFDM systems	1
Packet delivery ratio	1
Parallel transmission	1
Piraeus	1
Service oriented architecture	1
Space diversity	1
Space time code	1
Spatial diversity	1
Spectrum efficiency	1
Throughput improvement	1
Ubiquitous and pervasive computing	1

Security technological agenda spreads over collision avoidance, Denial of Service (DoS), blacklisting, etc. Meanwhile, network technological agenda consists of protocol, all IP network, ad hoc network, etc. Some other technological agenda that remain being the most researched topic are frequency hopping topic, MIMO system, space time codes, relay selection techniques, multi hop systems, etc. There are also a few of topics other those main topics, which are covering about implementation of the proposed 5G applications, such as implanted medical devices, remote monitoring and telemedicine.

Based on those findings, we may formulate the concept to exploit opportunity on certain technological agenda. Researchers may work on those specific areas, which can lead to new innovation on 5G. Such a concept is mainly benefit the developing country which intends to increase their innovation and technological competitiveness. For example, since relay selection has been frequently researched, a new researcher may establish the cooperative work with other researchers working on that field. As in the future, wireless network is forecasted will able to support the relay-based communication, where the relay node is well-placed to receive messages from the source node, process it, and then forward it to the node of its intended destination [10]. Alternatively, developing country can put more concentration on another topic such as spatial diversity, AODV, or technique to improve collision avoidance, since the works on those fields are relatively less conducted.

As the continuous upgrading of wireless technologies, the basic concept of 5G is to open up all the doors of possible methods, technologies and techniques used to leverage telecommunication for human life. Combining with the perspective of 5G key technologies, in particular about flat-based IP and cognitive radio, any researchers may contribute to the development of relevant standard. Such research activities are not only to improve faster data access, but also to create innovation on many technical areas as shown in Table 1.

Finally, it is commonly known that technological development of preceding standards (1G, 2G and 3G) were dominantly controlled by developed countries such as USA, Japan and some European countries. Therefore, in current and future time, developing countries should contribute to 5G technological development by utilizing innovation opportunities. Results of research works on 5G can be made into technical submission to the international standardization bodies, such as ITU. Meanwhile, developing countries can also push their national industries to develop patents and to create innovation on relevant 5G technical areas. It is believed that those schemes may influence the global standards development and increase the country's competitiveness.

## V. CONCLUSIONS

Key technologies in the seam of 5G has been reviewed, i.e. Flat IP Based Network and Cognitive Radio. The key technologies help us to spot the 5G technological challenges. The challenges mainly exist in the security area and the limited frequency resources problem.

We have identified innovation opportunity regarding the technological development of 5G standards from understanding technological challenges and exploring fundamental literature framework. There is an opportunity and demand to develop a system that will be able to prevent the misuse of control, maintain the security and enhance the capacity of system. As the result of exploring literature framework, we conclude three technological agenda in which one may contribute to, i.e. security, network, and technological implementation and applications issues. Accordingly, researchers can make new research focusing on those technical area and make new innovation for the 5G technological development. It is expected that research works may result a relevant submission to the international standardization bodies. On the other hand, innovation can be also made by pushing national industries to develop patents and to create innovation on such relevant 5G technical areas.

## REFERENCES

- [1] S. Patil, V. Patil, and P. Bhat, "A Review on 5G Technology" *International Journal of Engineering and Innovative Technology*, vol 1 Issue 1, January 2012.
- [2] A.Tudzarov, and T.Janevski, "Design for 5G Mobile Network Architecture" *International Journal of Communication Networks and Information Security*, vol 3 No 2, August 2011.
- [3] C.I. Badoi, N. Prasad, V. Croitiru, and R. Prasad, "5G Based on Cognitive Radio" *Wireless Pers Communication*, 2011.
- [4] A.K. Pachauri, and O. Singh, "5G Technology – Redefining Wireless Communication in Upcoming Years" *International Journal of Computer Science and Management Research*, vol 1 Issue 1, August. 2012.
- [5] T. Janevski, "5G Mobile Phone Concept" *IEEE 6th Consumer Communications and Networking Conference*. 2009.
- [6] A. Tudzarov, and T. Janevski, "Functional Architecture for 5G Mobile Networks" *International Journal of Advanced Science and Technology*, vol 32, August 2011.
- [7] K.C. Chen and R. Prasad, *Cognitive radio networks*. New York: Wiley. 2009.
- [8] W. Xu, P. Kamat, W. Trappe, TRIESTE: A Trusted Radio Infrastructure for Enforcing SpecTrum Etiquettes. *Networking Technologies for Software Defined Radio Networks*, 2006. SDR '06. 1<sup>st</sup> IEEE Workshop pp.101-109, 25-25 September. 2006.
- [9] G.A. Safdar and M. O'Neill, "Common Control Channel security Framework for Cognitive Radio Networks" *IEEE 69th Vehicular Technology Conference*. 2009.
- [10] C.K. Lo, R.W.Heath, and S. Vishwanath, "The Impact of Channel Feedback on Opportunistic Relay Selection for Hybrid-ARQ in Wireless Networks" *Vehicular Technology*, *IEEE Transactions* vol.58, no.3, pp.1255-1268, March 2009.

# Vulnerability and Economic Considerations in Designing Network Topology

Antonius Suhartomo

Study Program of Electrical Engineering, Faculty of Engineering,  
 President Univeristy Kota Jababeka, Bekasi 17550, Indonesia  
 Email: [asuharto@president.ac.id](mailto:asuharto@president.ac.id) , [asuharto77@yahoo.com](mailto:asuharto77@yahoo.com)

**Abstract**—Technological developments change the way of life of all people in interacting with each other, regardless of distance and time. One such interaction is the activity of the exchange of information through communication networks, which are either one-way or two-way with a variety of information, such as voices, images, and data, with the desire to have a fast and reliable delivery. If  $G(V,E)$  represents a graph or a network with a number of nodes,  $V = n$ , and the number of links,  $E = e$ , then assume the nodes are reliable and the links can fail. We investigate new parameter of connectivity called “k-component order edge-connectivity” or “component order edge-connectivity”, denoted by  $\lambda_c^{(k)}$ , in which within each type of topology is then compared such as in the topology of path, cycle, star, complete, and wheel networks, then choose the best selection in vulnerability and economic point of views.

**Keywords**— edge-connectivity, component order edge-connectivity, component edge- failure set, component edge-failure state, minimum degree.component;

## I. INTRODUCTION

If there is a communication from one station to another station the communication network can be represented by a graph  $G(V, E)$  where  $V$  is a station node and link  $E$  is a bidirectional link between these two stations. This link is not limited between the two stations and within a limited distance, but it can be in the form of a complex network and an unlimited distance. Thus a communications network topology form that is built will determine the level of vulnerability and the cost of construction of the communication network.

A communications network that forms a particular network topology with the same number of stations will have level of vulnerability and cost of construction cost that is different from one topology to another topology. Both of these considerations will be the focus of further discussion.

In the discussion that will be conveyed in writing this paper is that the consideration of the reliability of a network topology is one of them will be determined by its level of vulnerability. The mentioned vulnerability in a topology is an edge connectivity,  $\lambda(G)$  or  $\lambda$ , assuming that the node is reliable and links can be disconnected, such as the amount of links that should be removed so the remaining network becomes disconnected [1]. The author examines the new edge connectivity within his dissertation [3] that is called component order edge - connectivity,  $\lambda_c^{(k)}(G)$  or  $\lambda_c^{(k)}$ , which

is when a network is removed as much as  $k$  link so the remaining network will be disconnected if all remaining components of subnetwork have a number of nodes as  $\leq k - 1$ . Value of  $k$  is deterministic value with the amount of  $2 \leq k \leq n$ , where  $n$  is the number of nodes of a particular network topology.

However, the economy aspect will be seen from how many links it takes to establish a communications network topology and then compared from several possibility topologies with the same number of nodes, including network topology path, circle, complete, star and wheel. In calculating the economic aspects to form a network topology is assumed that every link that connects two nodes needs funds one unit cost. Thus, the more links required to form a communication network, the greater the economic value or the cost of investment.

## II. CONNECTIVITY MODEL OF A COMMUNICATION NETWORK

Graph theoretic techniques provide a convenient tool for the investigation of the vulnerability of a communication network to damage from natural or enemy – induced damage. Thus, a network communication system can often be represented as interconnection of stations and links. The assumption is that the system is subject to natural failure or enemy attack aimed at isolating stations from each other. The problems of determining the vulnerability and designing communication network which are invulnerability to enemy attack are of paramount importance. As yet, neither the analysis nor synthesis problems have been completed proved, although a number of practical results have been discovered. One difficulty immediately encountered in vulnerability studies is lack of a completely appropriate vulnerability criterion.

## III. RESULTS

In 1966, Chartrand [1] has defined that the vulnerability of a communication network represented by a graph  $G(V, E)$  if the node is assumed to be reliable and link can fail, which is called edge connectivity,  $\lambda(G)$  or  $\lambda$ . In this classical model, a network is considered to be operating when every station can communicate with every other station via some path of stations and operating links. If the failure of some links results in some pair of stations no longer able to communicate, then the network has failed. When this occurs, we say that the network

has become disconnected. The traditional vulnerability parameter for this model is the minimum number of links required to be removed so that the surviving graph is disconnected [1,3,4]. Clearly, if all the links emanating from a particular station fail, then that station is unable to communicate with any other station, and the network has become disconnected. It is easily seen that the value of the traditional vulnerability parameter is at most the minimum number of links to any station. However, it may be possible that a network may become disconnected when fewer links have failed. Chartrand [1] proved that if each station has a link to at least half of the other stations, then the network could not be disconnected if fewer than minimum number of links to any station fail, i.e., the network is invulnerable to failure if fewer than the minimum number of links to any station fail. Since that time considerable attention has been given to the study of this traditional vulnerability parameter.

In the traditional edge-failure model it is assumed that nodes are perfectly reliable but edges may fail. When a set of edges  $F$  fail we refer to  $F$  as an edge-failure set and the surviving subgraph  $G - F$  as an edge-failure state if  $G - F$  is disconnected.

**Definition 3.1**[3]. The edge connectivity of  $G$ , denoted by  $\lambda(G)$  or simply  $\lambda$ , is defined to be  $\lambda(G) = \min\{|F|: F \subseteq E, F \text{ is an edge-failure set}\}$ , i.e.,  $G - F$  disconnected.

Before you begin to format your paper, first write and save the content as a separate text file. Keep your text and graphic files separate until after the text has been formatted and styled. Do not use hard tabs, and limit use of hard returns to only one return at the end of a paragraph. Do not add any kind of pagination anywhere in the paper. Do not number text heads- the template will do that for you.

Back to the traditional model of edge failure is that the graph  $G - F$  is said to be edge - failure state if the graph is disconnected and no consideration is given whether or not a subnetwork have a lot number of stations connected one to another that can still communicate properly. So in this discussion paper will be introduced edge - failure new model called the component order edge connectivity failure model.

Frank Boesch made significant contributions to this body of knowledge. Then, in 2006, Boesch et al. [2] considered a new network model in which a network is considered operating as long as there is a predetermined number of stations, say  $k$ , that can still communicate, regardless of whether the network

Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

#### A. New Edge Connectivity Model [2,3,5]

Classical link connectivity models above have limitations that if there are  $N$  nodes and only one node apart from the original network nodes and form two sub-networks, but the network is said to be disconnected already. Even as many as  $N - 1$  nodes can still communicate to each other well.

Conventionally the parameters connectivity and edge connectivity have been used to measure a network's vulnerability to disconnection due to failure of nodes or edges, respectively. One deficiency of these measures of vulnerability is that they do not take into account the orders of the resulting components, such that no distinction in a case where of links results in two components of equal order and the case where one of the component is an isolated node [2,3].

For the entirely network communication system, it may be enough that a certain number of stations can maintain communication after link failure for the network to be considered operational, even if the network is disconnected.

Under the supervision of Frank Boesch as a leader among others: Charles Suffel, Daniel Gross, John Saccoman, and L.W. Kazmierczak, I have the opportunity to study a new network parameter model of vulnerability, called component order edge - connectivity, denoted by  $\lambda_c^{(k)}(G)$  or  $\lambda_c^{(k)}$ , to address this notion. In this model, says that a network is considered operating as long as there is a predetermined number of a station, say  $k$  that could still communicate regardless of whether the entirely network is disconnected.

In the occasion that has given the author has defined new edge connectivity model [3].

It is reasonable to consider a model in which it is not necessary that the surviving edges form a connected subgraph as long as they form a subgraph with a component of some predetermined order. Thus we introduce a new edge-failure model, the  $k$ -component order edge-failure model, which is called component order edge connectivity. In this model, when a set of edges  $F$  fail we refer to  $F$  as a  $k$ -component edge-failure set and the surviving subgraph  $G - F$  as a  $k$ -component edge-failure state, if  $G - F$  contains no component of order at least  $k$ , where  $k$  is a predetermined threshold value. So the component of each separate communications subnetwork could still be said operational because each subnetwork can do his internal relation with minimum  $k$  orders.

**Definition 3.2.** Let  $2 \leq k \leq n$  be a predetermined threshold value. The component order edge connectivity of  $G$ , denoted by  $\lambda_c^{(k)}(G)$  or simply  $\lambda_c^{(k)}$ , is defined to be  $\lambda_c^{(k)}(G) = \min\{|F|: F \subseteq E, F \text{ is } k\text{-component edge-failure set}\}$ , i.e., all component of  $G - F$  have order  $\leq k - 1$ .

**Definition 3.3.** A set of edges  $F$  of graph  $G$  is  $\lambda_c^{(k)}$ -edge set if and only if it is a  $k$ -component order edge-failure set and  $|F| = \lambda_c^{(k)}$ .

Next we compute  $\lambda_c^{(k)}(G)$  for specific type of graphs.

The first type of graph we consider is the **star**,  $K_{1,n-1}$ . To build communications network of star-shaped with the number of nodes  $n$ , it requires an investment cost of links construction, which is different from the cost of the nodes, for the number of links that allow all the nodes can be connected either directly or through intermediaries of other nodes in the network star. If the assumed cost of each link that connects the two nodes is a unit

cost, then the star to form a star communications network needs  $n-1$  unit cost.

In terms of any vulnerability, deletion of any set of  $m$  edges results in a subgraph consisting of  $m+1$  components, one isomorphic to  $K_{1, n-m-1}$  and the remaining components isolated nodes. Therefore a  $k$ -component edge-failure state exists if the component  $K_{1, n-m-1}$  contains at most  $k-1$  nodes. Thus  $n-m \leq k-1$  or  $n-k+1 \leq m$ . Since component order edge connectivity is the minimum number of edges whose removal results in a  $k$ -component edge-failure state we obtain the following result:

**Theorem 3.1:** Given  $2 \leq k \leq n$ ,  $\lambda_c^{(k)}(K_{1, n-1}) = n - k + 1$

The next type of graph we consider is the **path** on  $n$  nodes,  $P_n$ . In addition, the investment cost of the links construction of the path model network is the same as the form of star network, which is equal to  $n-1$  unit cost.

As for the analysis vulnerability, starting at a pendant edge label the edges consecutively from 1 to  $n-1$ . Let  $F$  be the set of edges whose label is divisible by  $k-1$ . The deletion of the edges in  $F$  creates  $|F|+1$  components, the first  $|F|$  having order exactly  $k-1$  and the last order at most  $k-1$  (but at least 1). We also note that if fewer edges are removed then there will be fewer components and thus by the Pigeonhole Principle, there must be at least one component of order at least  $k$ . Since  $|F| = \left\lfloor \frac{n-1}{k-1} \right\rfloor$  we have:

**Theorem 3.2:** Given  $2 \leq k \leq n$ ,  $\lambda_c^{(k)}(P_n) = \left\lfloor \frac{n-1}{k-1} \right\rfloor$ .

The next type of graph considered is the **cycle** on  $n$  nodes,  $C_n$ . For the cycle network model with the number of nodes  $n$ , it requires an investment cost of link construction as  $n$  unit cost. Thus the formula for  $\lambda_c^{(k)}(C_n)$  can be derived in a similar manner to that of  $\lambda_c^{(k)}(P_n)$ . When one edge of the cycle is removed, it becomes the path with  $n$  nodes,  $P_n$ . Thus  $\lambda_c^{(k)}(C_n) = \lambda_c^{(k)}(P_n) + 1$ , and since  $\left\lfloor \frac{n-1}{k-1} \right\rfloor + 1 = \left\lfloor \frac{n}{k-1} \right\rfloor$  we have the following result:

**Theorem 3.3 [3]:** Given  $2 \leq k \leq n$ ,  $\lambda_c^{(k)}(C_n) = \left\lfloor \frac{n}{k-1} \right\rfloor$ .

The next type of graph considered is the **complete graph** on  $n$  nodes,  $K_n$ . The complete network model is an ideal network that requires an expensive investment cost link construction, because each node must be connected to all existing nodes in the network. So the cost of link construction requires an investment as much as  $n(n-1)/2$  unit cost. The mentioned ideal shape is hardly found in the field because of the complexity and expensive construction, so it is considered less economical.

For vulnerability analysis this network, let  $F \subseteq E(K_n)$  be a  $\lambda_c^{(k)}$ -edge set. We can compute  $|F|$  by calculating the maximum number of edges that can remain in the  $k$ -component edge-failure state  $K_n - F$ . It is easy to see that any edge in  $F$  must have its endpoints in two different components of  $K_n - F$ ; thus each component of  $K_n - F$  must itself be complete.

**Lemma 3.4.** Given  $2 \leq k \leq n$ , let  $n = \left\lfloor \frac{n}{k-1} \right\rfloor (k-1) + r$

where  $0 \leq r < k-1$ . Let  $H$  be a graph on  $n$  nodes consisting of  $\left\lfloor \frac{n}{k-1} \right\rfloor$  copies of  $K_{k-1}$  and if  $r > 0$ , one copy of  $K_r$ . Then  $H$  has the maximal number of edges among all  $k$ -component edge-failure states of order  $n$ .

**Proof:** Consider the class  $F$  of all  $n$  node  $k$ -component edge-failure states and let  $H \in F$  be such that  $e(H)$ , the number of edges in  $H$ , is maximum over all graphs in  $F$ . Let  $C_1, C_2, \dots, C_m$  be the components of  $H$ ,  $1 \leq m \leq n$ , and let  $n_i$  be the order of  $C_i$ . It follows that  $\sum_{i=1}^m n_i = n$  and, since  $H$  is a failure state,  $n_i \leq k-1, \forall i$ . In addition, since  $H$  has the maximal number of edges, each component  $C_i$  is complete, i.e.  $C_i = K_{n_i}$ . We claim that there is at most one component of order  $< k-1$ . If not then there exists components  $C_i$  and  $C_j$ , with  $1 \leq n_i \leq n_j \leq k-2$ . Let  $H'$  be the failure state obtained by deleting the components  $C_i$  and  $C_j$  from  $H$  and replacing them with  $C'_i = K_{n_i-1}$  and  $C'_j = K_{n_j+1}$  (In the case that  $n_i = 1$  we only add the component  $C'_j$ ). Then

$$2[e(H') - e(H)] = [(n_i - 1)(n_i - 2) + (n_j + 1)n_j] - [n_i(n_i - 1) + n_j(n_j - 1)] = 2(n_j - n_i + 1) > 0$$

Hence  $e(H') > e(H)$ , which contradicts that  $e(H)$  is maximum over all graphs in  $F$ . Thus we can have at most one  $n_i < k-1$ . Thus if we write  $n = \left\lfloor \frac{n}{k-1} \right\rfloor (k-1) + r$  where  $0 \leq r < k-1$ ,  $H$  has the prescribed form. ■

From this it immediately follows that a maximum size  $k$ -component edge-failure state of  $K_n$  consists of  $\left\lfloor \frac{n}{k-1} \right\rfloor$  complete components each of order  $k-1$  and possible one additional component of order less than  $k-1$ . Thus we have the following:

**Theorem 3.5.** Given

$$2 \leq k \leq n, \lambda_c^{(k)}(K_n) = \binom{n}{2} - \left\lfloor \frac{n}{k-1} \right\rfloor \binom{k-1}{2} - \binom{r}{2},$$

where  $n = \left\lfloor \frac{n}{k-1} \right\rfloor (k-1) + r, 0 \leq r \leq k-2$ .

The final type of graph considered in this section is the **wheel graph** on  $n$  nodes,  $W_n$ . This network is likely suitable for use metropolitan area network (MAN). The investment cost of the link construction is  $2(n-1)$  unit cost.

In order to find vulnerability for wheel graph we will draw back some investigations that have been discussed in [3] to consider many steps.

Since we do not have a formula or an algorithm that computes  $\lambda_c^{(k)}(G)$  of an arbitrary graph  $G$ . Therefore we want to find bounds (both lower and upper) that may be applied to establish a range of possible values of  $\lambda_c^{(k)}(G)$ . Before we introduce a set of bounds we need to establish some notation and terminology.

First we consider the value of  $\lambda_c^{(k)}(H)$ , where  $H$  is a subgraph of  $G$  but  $H$  is not spanning or not connected. If  $H$  is a graph on  $m$  nodes, and  $m < k$ , then every component of  $H$  has order  $\leq k-1$ , so it follows that  $\lambda_c^{(k)}(H) = 0$ . If  $H$  is disconnected and  $H_1, H_2, \dots, H_p$  are the components of  $H$ , then  $\lambda_c^{(k)}(H) = \sum_{i=1}^p \lambda_c^{(k)}(H_i)$ .

**Definition 3.4. [3.5]** If  $F \subseteq E$  is a set of edges,  $G[F]$  denotes the subgraph of  $G$  with node set  $V$  and edge set  $F$ , i.e.  $G[F] = G - (E - F)$ .

**Definition 3.5. [3.5]** If  $U, W \subseteq V$  with  $U \cap W = \emptyset$ ,  $[U, W]$  denotes the set of all edges with one endpoint in  $U$  and the other endpoint in  $W$ .

Now we start with the basis theorem of our lower bound.

**Theorem 3.6. [3.5]** If  $E_1 \cup E_2$  is a partition of  $E$ , then  $\lambda_c^{(k)}(G[E_1]) + \lambda_c^{(k)}(G[E_2]) \leq \lambda_c^{(k)}(G)$ .

**Proof:** Let  $D \subseteq E$  be a  $\lambda_c^{(k)}$ -edge set and let  $D_i = E_i \cap D, i=1,2$ . Since  $E_i - D_i \subseteq E - D$ , each component of  $G[E_i] - D_i$  is contained in a component of  $G - D$  and thus is of order  $\leq k-1$ . It follows that  $\lambda_c^{(k)}(G[E_i]) \leq |D_i|$ . Therefore

$$\lambda_c^{(k)}(G[E_1]) + \lambda_c^{(k)}(G[E_2]) \leq |D_1| + |D_2| = |D| = \lambda_c^{(k)}(G).$$

Therefore we obtain the following lower bound:

$$\lambda_c^{(k)}(G[E_1]) + \lambda_c^{(k)}(G[E_2]) \leq \lambda_c^{(k)}(G), \text{ where } E_1 \cup E_2 \text{ is a partition of } E.$$

In particular if  $u$  is a node of full degree, then  $(n-k+1) + \lambda_c^{(k)}(G-u) \leq \lambda_c^{(k)}(G)$ .

Now let  $U \subseteq V$  be a set of nodes with  $|U| = k-1$ . We construct a  $k$ -component edge-failure set as follows: Delete all edges that connect  $U$  to the rest of the graph, and then delete edges from  $\langle V-U \rangle$  until all components have order  $\leq k-1$ . Thus we obtain the following upper bound:

$$\lambda_c^{(k)}(G) \leq |[U, V-U] + \lambda_c^{(k)}(\langle V-U \rangle), \text{ where } U \subseteq V \text{ with } |U| = k-1.$$

We will apply these bounds to compute  $\lambda_c^{(k)}(G)$ , when  $G$  is  $W_n$ , the wheel of order  $n$ .

**Definition 3.6. [3.5]** The wheel of order  $n$ ,  $W_n$ , is the graph formed by connecting a single vertex to all the vertices of a  $C_{n-1}$ .

The picture below is an example of a network wheel,  $W_n$ , with  $n$  nodes.

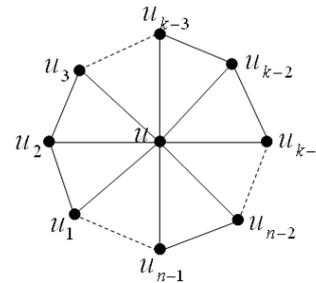


Figure 3.1 A wheel network,  $W_n$ , with  $n$  nodes

Let  $G = W_n$  and let  $u$  be the full degree node. Then  $G - u = C_{n-1}$  and the **lower bound** implies

$$\lambda_c^{(k)}(W_n) = \lambda_c^{(k)}(G) \geq (n-k+1) + \lambda_c^{(k)}(C_{n-1}) = (n-k+1) + \left\lfloor \frac{n-1}{k-1} \right\rfloor \quad (3.1)$$

Now if  $U = \{u, u_1, \dots, u_{k-2}\}$ ,  $V - U = \{u_{k-1}, \dots, u_{n-1}\}$ , then  $|[U, V-U]| = (n-1) - (k-2) + 2 = n-k+3$  and  $\langle V-U \rangle = P_{n-k+1}$ .

Thus the **upper bound** implies

$$\lambda_c^{(k)}(W_n) \leq (n-k+3) + \lambda_c^{(k)}(P_{n-k+1}) \leq (n-k+3) + \left\lfloor \frac{n-k}{k-1} \right\rfloor \quad (3.2)$$

Inequalities (3.1) and (3.2) together yield the following bounds on  $\lambda_c^{(k)}(W_n)$ :

$$(n-k+1) + \left\lceil \frac{n-1}{k-1} \right\rceil \leq \lambda_c^{(k)}(W_n) \leq (n-k+3) + \left\lceil \frac{n-k}{k-1} \right\rceil \quad (3.3)$$

We will find a formula for  $\lambda_c^{(k)}(W_n)$  by comparing the lower and upper bounds.

$$(n-k+1) + \left\lceil \frac{n-1}{k-1} \right\rceil \leq (n-k+3) + \left\lceil \frac{n-k}{k-1} \right\rceil. \text{ Subtracting } (n-k+1) \text{ from each side gives}$$

$$\left\lceil \frac{n-1}{k-1} \right\rceil \leq 2 + \left\lceil \frac{n-k}{k-1} \right\rceil \quad (3.4)$$

Applying the division algorithm write  $n-k = \alpha(k-1) + r$  where  $0 \leq r \leq k-2$ , thus  $\alpha = \left\lfloor \frac{n-k}{k-1} \right\rfloor$ .

Hence  $n-1 = (n-k) + (k-1) = \alpha(k-1) + (k-1) + r = (\alpha+1)(k-1) + r$ . If  $r \geq 1$ , i.e.,  $(k-1)$

does not divide  $(n-1)$ , then  $\left\lceil \frac{n-1}{k-1} \right\rceil = \alpha + 2 = \left\lfloor \frac{n-k}{k-1} \right\rfloor + 2$ . If

$r = 0$ , i.e.,  $(k-1)$  divides  $(n-1)$ , then  $\left\lceil \frac{n-1}{k-1} \right\rceil = \alpha + 1 =$

$$\left\lfloor \frac{n-k}{k-1} \right\rfloor + 1.$$

**Theorem 5.2.** Let  $G = W_n$  be wheel on  $n$ -nodes then

$$\lambda_c^{(k)}(W_n) = \begin{cases} (n-k+1) + \left\lceil \frac{n-1}{k-1} \right\rceil & \text{if } (k-1) \text{ does't divide } (n-1) \quad (1) \\ (n-k+2) + \left\lceil \frac{n-1}{k-1} \right\rceil & \text{if } (k-1) \text{ does divide } (n-1) \quad (2) \end{cases}$$

#### IV. CONCLUSION

Edge connectivity failure model provides opportunities that if new model component subnetworks that are separated by the removal of some links, the resulting subnetworks can still in operate if every subnetwork has node of order greater than  $k-1$ . This provides advantages over conventional forms of edge connectivity failure model, which does not give an opportunity to operate subnetwork if overall network is not connected. Although such communication networks are disconnected with only one node that is not connected while the other  $n-1$  subnetwork that has a numbered node, it can still communicate well with each other.

From the description of the amount of investment cost of link construction, if the purpose of the construction of a communications network is intended for the construction of a fiber optic network that spans the width of the country, the total investment cost of the construction of the link must be considered to determine the economic network model, given the cost is expensive enough. But it also needs to consider choosing a network model that has a low level of vulnerability

to the threat of dissolution all personal communication network. So the level of vulnerability to edge connectivity new models discussed above can be considered to select the appropriate network. For the number of  $n = 30$  and by taking a value  $k = 5, 10, 15$ , both of large investment costs and the level of development link vulnerability are compared. Star and Path networks need the same investment cost, 29 units cost, but Star network is less vulnerable than Path network. Cycle network needs 30 units cost of investment, with degree of vulnerability less than Path but higher than Star networks. Complete and Wheel networks need investment cost of 435 and 58 units cost, respectively, with Complete less vulnerable than Wheel. However, Complete network has never been implemented in the real communication network. Wheel network is the most expensive but has less vulnerability compared with others. The highest vulnerability is the Path network.

#### REFERENCES

- [1] Chartrand, G. "A Graph-Theoretic Approach to a Communications Problem", SIAM J. Appl. Math. 14, 1966, pp. 778-781D.
- [2] Boesch, F., Gross, D., Kazmierczak, L., Suhartomo, A., and Suffel, C.: "Component Order Edge Connectivity – An Introduction", Congressus Numerantium 178 (2006), pp. 7-14
- [3] Suhartomo, A., "Component Order Edge Connectivity: A Vulnerability Parameter for Communication Networks". Doctoral Thesis, Stevens Institute of Technology, Hoboken NJ, May 2007.
- [4] F. Boesch, D. Gross, L. Kazmierczak, J. T. Saccoman, C. Suffel, and A. Suhartomo, "A Generalization of an Edge-Connectivity Theorem of Chartrand", Networks—2009—DOI 10.1002/net.20297.
- [5] Suhartomo, A. "An Alternative Design Topology For Metropolitan Area Network", ITB Journal ICT, Vol. 6, No. 2, 2012, pp. 103-111.

# Circularly Polarized Array Pentagonal Microstrip Antenna for Mobile Satellite Applications

Muhammad Fauzan Edy Purnomo  
 Electrical Department, Faculty of Engineering  
 University of Brawijaya  
 Malang, Indonesia  
 mfauzanep@ub.ac.id

Edi Supriana  
 Physics Department, Faculty of Mathematics and Science  
 State University of Malang  
 Malang, Indonesia  
 edisupriana@yahoo.com

Vita Kusumasari  
 Mathematics Department, Faculty of Mathematics and Science  
 State University of Malang  
 Malang, Indonesia  
 vitakusumasari@yahoo.co.id

**Abstract**— At the firstly, single element of the singly fed pentagonal patch antenna using air gap is proposed. The results show that the bandwidth of impedance, axial ratio, and gain at the resonant frequency 2.4925 GHz are 15.67 %, 4.11 % and 52.16 %, respectively. Moreover, the value of S-parameter, axial ratio and gain at 2.4925 GHz are -15.03 dB, 0.06 dB and 8.74 dBic, respectively.

Furthermore in this research, it is also investigated circularly polarized array pentagonal microstrip antenna for mobile satellite communications especially to enhance the bandwidth axial ratio that are examined both of simulation and measurement. The results of array pentagonal patch antenna is similar with its single, especially the value of S-parameter, axial ratio and gain as the mentioned above.

The other results related the simulation show that the cutting of beam angle between of them is the same. In case of measurement results, owing to loss during measuring, the gain decreasing and affect the cutting of beam angle between gain and axial ratio that is not satisfied yet.

**Keywords**— *Single element, Circularly polarized, Array pentagonal antenna, Cutting of beam*

## I. INTRODUCTION

Multimedia communications through geostationary satellites will be an essential part of future information infrastructure since the satellite-based communication provides "simultaneous" and "flexible" information network without large facilities. The future satellite networks will be tightly integrated with the terrestrial networks as an integral part of our future global information infrastructure. Space-based network which has survivability against disasters and flexibility will complementally work with mobile and fixed ground-based system in order to realize a reliable and mobile "ubiquitous" information society.

As geostationary satellites are remotely located (about 36,000 km) from the earth, the incoming wave is very weak. Consequently, it is required that the antenna for mobile satellite communications has a high gain in the case

multimedia communications performing large-capacity data communication is aimed. Furthermore, when thinking of the integration to cars, from the point of view of the car design, it is recommended the overall system to be light and compact.

Inside a view of the car that the antenna located above it need a feeding. The singly fed circularly polarized (CP) antennas have inherent limitation in gain, impedance and axial ratio bandwidths. This is mainly owing to the resonant nature of the patch antenna which has a high unloaded Q-factor and the frequency-dependent excitation of two degenerative modes ( $TM_{01}$  and  $TM_{10}$ ) when using a single feed. In order to achieve enhanced gain, impedance and CP bandwidth, several single-feed single element patch antenna designs using an air-layer or foam substrate for minimizing the unloaded Q-factor [1],[2]. Another way to increase the bandwidth of antenna by using the stacked patches and electromagnetically coupled patch configurations have been presented [3],[4].

Here, it will be designed pentagonal antenna using thick substrate (with air gap) for enhancing bandwidth of antenna with a simple configuration (see Figure 1) and also for designed the array pentagonal antenna configuration both of simulation (by the method of moments using Ensemble version 8 software) and measurement to prove that the cutting of beam angle between gain and axial ratio is the same. The other shape of pentagonal like a kite has been proposed by Weinschel [5] which the characteristic of antenna parameter similarly with pentagonal antenna. The purpose of this research is to yield the enhanced bandwidth of antenna for mobile satellite and radar applications.

One of the most common techniques for calculating the unknown current is the Method of Moments. This discretizes the integral into a matrix equation which can then be solved. This discretization can be considered as dividing the antenna surface into a number of small elements. From the current distribution, the S-parameters, radiation pattern and any other parameters of interest can be obtained.

## II. CONFIGURATION OF ANTENNA

Figure 1 and Figure 2 show the configuration of antenna design, for single and array pentagonal antenna, respectively. Both of antennas are using a conventional substrate (relative permittivity 2.17 and loss tangent 0.0009) and fed by a coaxial probe to avoid the degradation of elliptic by unwanted radiation from the feed network.

Figure 1 show the single model designed of pentagonal antenna using air-gap whose angle  $\angle\theta$  is  $45^\circ$ . The shape of such a pentagonal can be prescribed completely by two parameters  $c/a$  and  $b/a$ . The pentagon becomes a rectangle when  $c/a = 0$ , an isosceles triangle when  $c/a = 1$ . It is considerable for enhanced the bandwidth, its position of  $c/a$  is  $0 < c/a < 1$  or in the others word the patch shape should combine two or more shapes in becoming one (pentagon = triangle + rectangle). In this case, only combining two shapes for getting wide bandwidth of antenna is not enough, for matching impedance  $50 \Omega$  and smoothly axial ratio and gain are added the dimensions of antenna, air gap and feed location which must be chosen correctly (see Figure 1). They are used to excite more than one mode where each of mode degenerates two frequencies closed, hence much of the magnitude currents paths around this area move to  $y$  direction and  $x$  direction which perpendicular with each others, hence increasing the bandwidth of axial ratio.

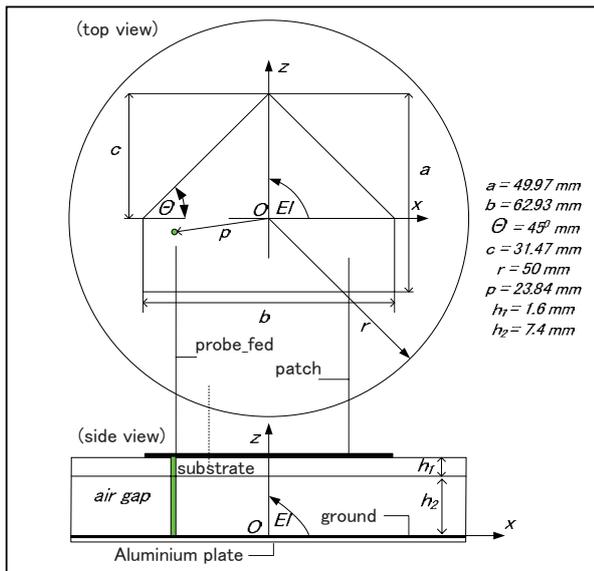


Figure 1. Configuration of single pentagonal antenna

For LHCP (Left Hand Circular Polarization), the feeding is located on the left side from null potential. This is happened 3 modes at the frequency operation 2.4925, 4.5 and 6.8 GHz, but only a good radiation characteristic is happened in the first mode at 2.4925 GHz. This is dominant modes ( $TM_{01}$  and  $TM_{10}$ ) owing to by the shape perturbation (pentagonal) using air-gap, the effective excited patch surface current path in the  $y$  direction is slightly shorter than that in the  $x$  direction, which gives the  $y$ -directed resonant mode a resonant frequency slightly larger than that of the  $x$ -directed resonant modes of

equal amplitudes and  $90^\circ$  phase difference at the left side of pentagonal for LHCP operation.

In this paper, the method of moment (Ensemble version 8 software) is employed to simulate the model with an infinite ground plane. Consideration of the efficient thickness of the antenna (see Figure 1) allowed either the substrate thickness for pentagonal patch to be defined with the single substrate or single layer using air-gap ( $h_1 = 1.6 \text{ mm}$  and  $h_2 = 7.4 \text{ mm}$ ).

Figure 2 depicts design of simulated array pentagonal antenna is composed of three pentagonal patch antennas which fed directly from the switching circuit on the beneath of the construction. Figure 3 shows geometry of array the fabricated antenna is made by microstrip material ( $\epsilon_r = 2.17$ , loss tangent 0.0009) which instead of three pentagonal patch antennas and the same fed with simulated antenna, but this antenna without used the parasitic elements. With this geometry the antenna becomes simple, compact and low loss, because no need a power divider to distribute power signal to the antenna element. The dimension of the construction is 190 mm and 7.2 mm in diameter and height, respectively.

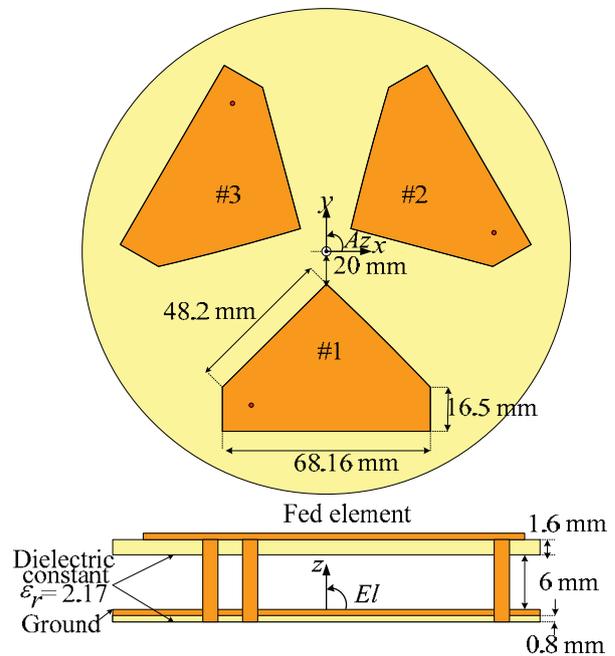


Figure 2. Design of simulated array pentagonal antenna

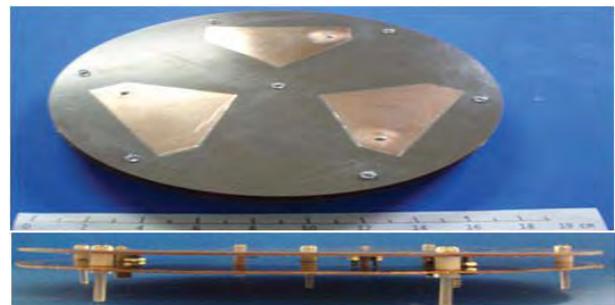


Figure 3. Geometry of array fabricated antenna

### III. DISCUSSION

Figure 4 to Figure 6 shows the result for simulation both single element and array pentagonal antenna, in the case of frequency characteristic,  $S$ -parameter, and input impedance. Figure 4 shows that the value of gain and axial ratio ( $Ar$ ) for simulated at the resonant frequency 2.4925 GHz i.e. about 8.74 dBic and 0.06 dB, respectively. In addition, the bandwidth of axial ratio antenna is about 4.11%.

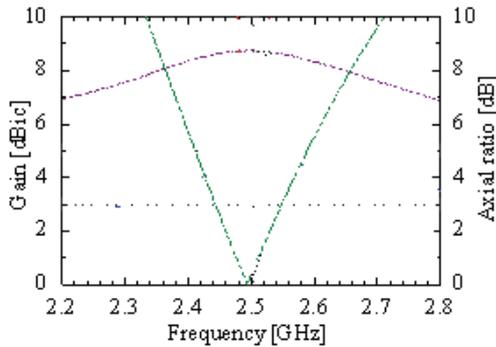


Figure 4. Gain and axial ratio vs frequency

Figure 5 shows the relationship between the reflection coefficient ( $S$ -parameter) and frequency for the simulation antenna. From this figure, it can be seen that the bandwidth of  $S$ -parameter enough width i.e. about 15.67%. It is caused by the new shape of perturbation antenna likely a pentagonal where the area square is large about 2154.3 mm<sup>2</sup>. In addition, it is also caused the effect of air-gap and location of feeding that matched with the configuration of antenna to yield the targets satisfied. Moreover, the value of  $S$ -parameter at the resonant frequency is good around -15.03 dB.

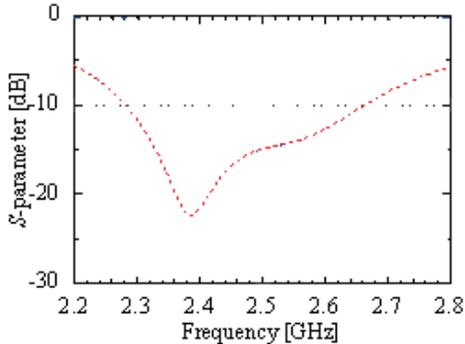


Figure 5.  $S$ -parameter

Figure 6 depicts the input impedance characteristic that the real and reactance part are satisfied where for real and reactance impedance by closed 50  $\Omega$  and by closed 0  $\Omega$ , respectively.

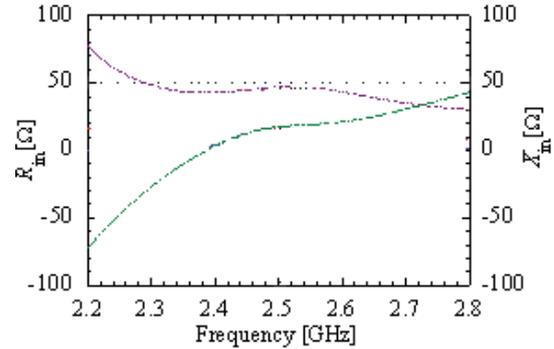


Figure 6. Input impedance

For coaxial-fed antennas, it can slightly effect toward the resonant frequency, axial ratio,  $S$ -parameter and input impedance which is dependent on the feed position. By choosing the feed position properly, an effective match between the antenna and the transmission line can be obtained.

Figure 7 shows the frequency characteristics for the simulation and measurement of array antenna results are difference between them, usually the measurement antenna shifted to higher frequency, but in this case shifted to lower frequency. This is probably owing to error during fabricated and measurement. The resonant frequency for simulation located at 2.48 GHz, but measurement is located at 2.43 GHz [8]. In this case, the phenomenon of antenna is still investigated for knowing the reason of this anomaly. Furthermore, to analyze radiation pattern, this antenna allocated at 2.5 GHz.

It is necessary to have a traveling wave current distribution which has constant amplitude and a linearly changing phase for a pentagonal antenna to radiate a circularly polarized wave. In the generally theoretically of antenna, a circularly polarized wave can be radiated by means of loading a reactance of an appropriate value. Instead of loading an appropriate reactance, a very simple method is to use air gap. By introducing such air gap with a certain size of pentagonal antenna and feeding the antenna with a coaxial probe, a traveling-wave current distribution could be excited, and as a result, a circular polarization can be achieved.

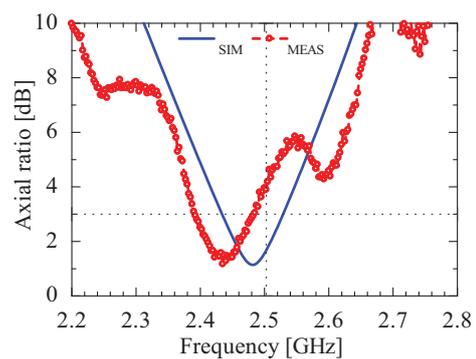


Figure 7. Frequency characteristics at  $El = 48^\circ$

Figure 8 describes the elevation cut-plane with performance of the antenna at the elevation angle  $El = 38^\circ$ .

58°. In this results, generally are the same between simulated and measured array antenna results, especially of gain, but axial ratio in measured is considerably effected by the shape of ground (considering that simulation used infinite ground and measurement used finite ground with a circle-shape) and also effected by conductivity ( $\sigma$ ) and permittivity ( $\epsilon_r$ ) of ground. Hence, the axial ratio at the elevation direction from 38° - 58° is not satisfied the targets yet. Moreover, it owing to error during fabricated, especially when soldering a feed on the ground is still not optimized.

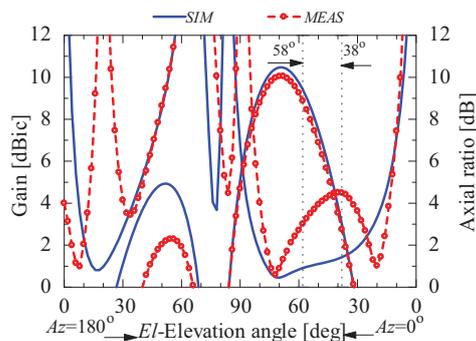


Figure 8. Elevation cut-plane at  $f = 2.5$  GHz

Figure 9 depicts conical cut plane for  $El=48^\circ$  at the frequency  $f = 2.5$  GHz for measurement. This is meant to evaluate the antenna system without circuit switching as far as how the good performances could be occurred with a new shape of antenna and also the effected of using a ground antenna [9].

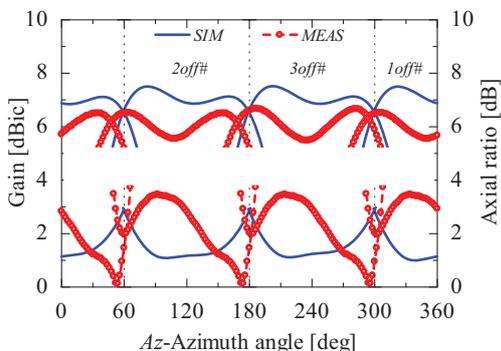


Figure 9. Conical cut-plane at  $f = 2.5$  GHz

In this figure, it is seen that the cutting of beam angle between the axial ratio and gain in simulated is the same. This happened probably owing to the phase of modes both of gain and axial ratio in simulation are the same. Contrary, in measurement that is not occurred yet in one beam angle for that case. This is owing to performed of ground is not optimized, especially its conductivity ( $\sigma$ ) and permittivity ( $\epsilon_r$ ) is not matched with the radiating antenna. The strongly effect of a ground could be seen in gain measurement, it decreases significantly compared with the gain simulation, so the cutting of beam angle in measurement is difference between axial ratio and gain [10]. The other reason is probably in fabricated

antenna, whereas a soldering between feed and ground also not good, hence the current distribution on the patch radiating of antenna could not flowed normally. In addition, owing the effected of power divider and semi-rigid is not optimized, especially a phase of semi-rigid circuit to connected two of three feed on beneath of the construction antenna is not same, hence the axial ratio could not obtained satisfy, because of the axial ratio is very sensitive with difference of phase.

#### IV. CONCLUSION

- A configuration of circularly polarized single and array pentagonal microstrip antenna for mobile satellite applications is proposed.
- A circular polarization can be simply obtained by properly adjusting the element parameters and using air gap.
- The results show that the bandwidth of impedance, axial ratio, and gain at the resonant frequency 2.4925 GHz are 15.67 %, 4.11 % and 52.16 %, respectively.
- Moreover, the value of S-parameter, axial ratio and gain at 2.4925 GHz are -15.03 dB, 0.06 dB and 8.74 dBic, respectively.
- The results of characteristic performance, especially bandwidth of axial ratio of the pentagonal antenna is good, caused by a new shape of pentagonal antenna using air-gap and good choosing of a feed position.
- The problem in cutting of beam angle between gain and axial ratio owing to phase of modes both of gain and axial ratio in simulation and measurement.

#### REFERENCES

- [1] F.S. Chang, K.L. Wong, and T.W. Chiou, "low-cost broadband circularly polarized patch antenna," *IEEE Transactions on Antennas and Propagation*, vol.51, no. 10 pp3006-3009, October 2003.
- [2] C. Wang and K. Chang, "single-layer wideband probe-fed circularly polarized microstrip antenna," in *Proc. IEEE Antennas Propagat. Soc. Int. Symp. Dig.*, Salt Lake City, UT, 2000, pp. 1000-1003.
- [3] Q.L. Richard and L. Kai-Fong, "experimental study of the two-layer electromagnetically coupled rectangular patch antenna," *IEEE Transactions on Antennas and Propagation*, vol.38, no. 8 pp1298-1302, August 1990.
- [4] N.C. Karmakar and M.E. Bialkowski, "circularly polarized aperture coupled circular microstrip patch antenna for L-band applications," in *IEEE Trans. Antennas Propagat.*, vol. 47, pp. 933-940, May 1999.
- [5] Weinschel, H.D., "a cylindrical array of circularly polarized microstrip antenna," *Int. Symp. Dig. Antennas Propagat. Soc.*, pp. 177-180, June 1975.
- [6] Ansoft Corporation, "ANSOFT Ensemble User Guide Manual (ver. 8)", 2001.
- [7] D. Wu and D. Chang, "A review of electromagnetic properties and the full-wave analysis of the guiding structures in MMIC", *Proceedings of the IEEE*, vol. 79, no. 10, pp. 1529-1537, Oct. 1991.
- [8] Iyer, S.M.V., and Karekar, R.N., "Edge effects for resonance frequency of covered rectangular microstrip patch antenna", *Electron Lett.*, 1991, 27, pp. 1509-1511.
- [9] Muhammad Fauzan Edy Purnomo, Basari, Kazuyuki Saito, Masaharu Takahashi, and Koichi Ito, "Developing Antenna for ETS-VIII Applications", *Proceedings of IJSS2008*, Chiba, Japan
- [10] Kawakami, H., Sato, G., and Wakabayashi, R., "Research on circularly polarized conical-beam antennas", *IEEE Antennas Propag. Mag.*, 1997, 39, (3), pp.27-39.

# Design Of Monitoring Status Dvor in Desk at the Airport Tower Halim Perdanakusuma using Sms (Short Message Service)

Bekti Yulianty  
 Electrical Department  
 Suryadarma University  
 Jakarta, Indonesia  
 simondewanto@gmail.com

Nur Wijayanti K.N  
 Electrical Department  
 Suryadarma University  
 Jakarta, Indonesia  
 simondewanto@gmail.com

**Abstract**— Halim Perdanakusuma an alternative airport for domestic flights and overseas, lack of human resources and the amount of electronic equipment at the airport does not allow technicians to always be on station transmitter 'DVOR' (VHF Doppler Omny Range). 'DVOR' is an air navigation system that emits electromagnetic waves all these directions and provide information bearing on the station as well as the data plane bearing, beacon transmitter also transmits data to the three-letter code identity or the identity of the sound to be received by the recipient on the plane. This resulted if DVOR 'off', the technician cannot know the condition early this highly disturbing aviation safety. We need a draft monitoring status on the desk DVOR tower. One is to use 'sms' DVOR order status can always be monitored.

This research was designed a system of observers. In the design of the system output RCSE DVOR will affect the output of the logic gate, if it is operating normally at the logic gate output = 0 so that the relay is not switched on, the green LED will be on the line desk Tower will produce a voltage of 3 Volts DC in addition to the microcontroller does not work. In DVOR, RJ11 stated, if the output on RJ 11 = 0 Volt DC and if DVOR 'off' at the transmitter is on one or both transmitter off the output at the logic gate = 5 Volt DC so that the relay will be active so that line the red LED on the desk tower will generate a voltage of 3 Volts DC and output on an RJ 11 = 0.5 Volts DC so that the modem will be activated and sends a message to the technician in charge DVOR.

**Keywords**— DVOR, re-engineering, wireless communication

## I. INTRODUCTION

DVOR (Doppler VHF Omny Range) is an air navigation system that emits electromagnetic waves all these directions and provide information bearing aircraft of the station DVOR equipment is working at a frequency of 108-118 MHz, in addition to bearing the data, beacon transmitter also transmits data to the identity of the three-letter code or the identity of the sound to be received by the recipient on the plane. By looking at the function of the equipment were very influential to aviation safety, the required equipment is always in a condition ready for use. However, there are many things that cause the equipment off, both internal factors such as the condition of older equipment and the condition of the components are not functioning properly, as well as external

factors such as lightning. Given such conditions, should be in charge of electronics technicians constantly monitor the status DVOR. However DVOR, the lack of adequate manpower, while the amount of equipment that is under the responsibility of electronics so much that it is not possible to always be on the equipment that is located very DVOR far as non workshops electronics technician. All this to determine whether or not an operating DVOR pilot to report through the ATC (Air Traffic Control). Thus, the flight safety can be compromised. In addition, the presence of complaints - complaints that often occurs can lead to decrease in the company's image as the manager of airport services in the eyes of the domestic flights, and airport image in the eyes of the international flight. From the description above, one solution to determine if it is operating normally DVOR or not, is to create a design DVOR status monitoring.

## II. BASIC THEORY

### A. DVOR (Doppler VHF Omnidirectional Range)

DVOR is an air navigation aid that can provide directional information to aircraft on the airport to provide information bearing aircraft of the marionette DVOR. This equipment works at a frequency of 108- 118 MHz, in addition to bearing the data, beacon transmitter also transmits data to the identity of the three-letter code or voice identification that will be accepted by the recipient on the plane. Besides, it is a function of DVOR Indicates the position of the aircraft station transmitter so as to know the area in its path, and shows the radial direction so as to Run Way. Run Way towards specified. Reference signal is 30 Hz AM signal emitted by the instantaneous phase uniformly in all directions resulting from the RF carrier signal ( $f_c$ ) are modulated AM signal with 30 Hz. The resulting signal is then emitted by the antenna carrier see figure 1(a).

The variable signal is a signal generated from the modulation frequency from the simulation of movement or rotation of non directional RF signal source ( $f_c \pm 9960$  Hz) around the circle with a speed of 1800 rpm which cause modulation frequency of 30 Hz, this is done by connecting the electronic switching sequentially at each sideband antenna located on the antenna around the carrier signal variable pattern formation is shown in figure 1(b).

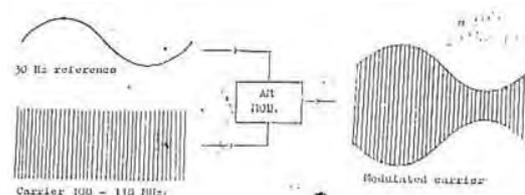
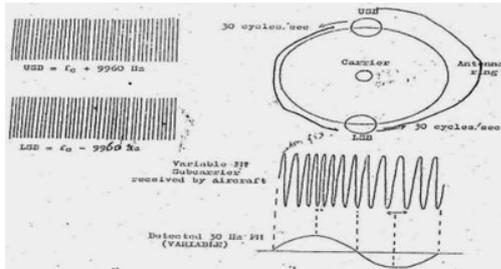


Figure 1 (a) AM Modulation between reference 30 Hz and carrier signal



(b) Pattern formation variable signal

Mixing between the reference signal and the variable signal occurs in the air, a combination of variable reference signal and the signal power radiated into the air will produce a carrier frequency modulated by a 9960 Hz AM (Subcarrier). Further 9960 Hz subcarrier FM modulated with 30 Hz, because of the Doppler effect see Figure 2. Reference signal and the signal is generally used as a pattern variable instantaneous phase, the phase difference between the signal and reference signal to the variable direction see figure 3.

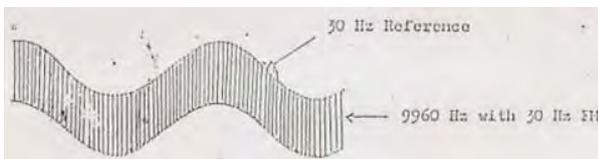


Figure 2. Signals emitted from DVOR

DVOR transmits all directions antenna DVOR have 1 piece of antenna carrier and subcarrier antenna 48 pieces. DVOR antenna signals emitted a high frequency, so any solid objects can reflect signals. Ground bounce signal power radiated by the antenna DVOR. Therefore the receiver aircraft to obtain two signals emitted signals (direct) and the signal beam reflectance (reflected). Both have the same frequency but have different emission lines. The lines transmit the reflected signal is longer than the direct signal transmission lines.

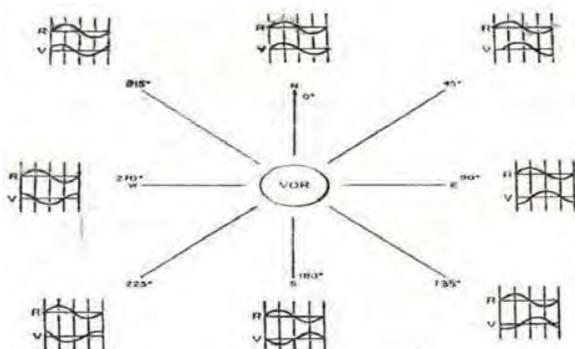


Figure 4. Variable phase difference between the signal and reference signal

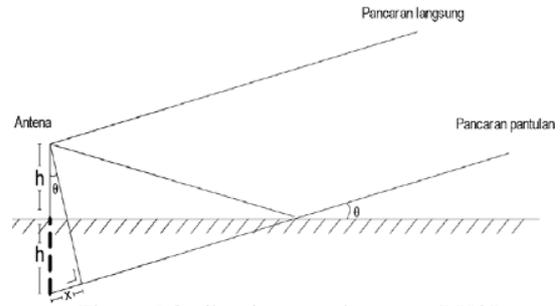


Figure 5 Outline the transmit antenna DVOR

Figure 5. seen that reflected signal transmission line is longer than the direct beam transmission lines are marked by the addition of whole X. Antenna DVOR in principle is to emit 30 Hz variable signal is FM modulated and the reference signal 30 Hz modulated AM. Two signals having the same frequency emitted together but separated from each other. The results of the combination of the two signals emitted form the carrier frequency of 30 Hz. This frequency is obtained from the playback DVOR antenna 30 times rev / sec. In one pair of antennas such as antenna 1 to antenna 25 has a frequency USB (upper sideband) and LSB (lower sideband). Antenna 1 is USB while the antenna 25 is LSB.

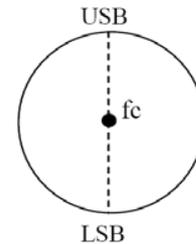


Figure 6. LSB dan USB pada antenna DVOR

The resulting radiation pattern DVOR the radiation pattern that has 3 main lobe to the center in  $8^{\circ}$ ,  $28^{\circ}$  and  $50^{\circ}$ . Figure 7 shows there is a considerable distance between the lobe with one another, leading to the absence of radiation (due to the removal of the direct signal and the reflected signal.) To overcome this it will be installed Counterpoise DVOR additional antenna mounted just below the act as an additional reflective area. If the antenna is mounted above  $\frac{1}{2} \lambda$ . Counterpoise it will result in major energy lobe wide and centered at  $30^{\circ}$ . The combination of radiation signals coming from the ground and from the reflection of the overall radiation produced Counterpoise DVOR which will result in wider coverage at an angle of between  $0^{\circ}$  to  $60^{\circ}$ , while the area

just above DVOR (angle of more than  $60^{\circ}$ ) there is no radiation and is called the area Cone of Silence as shown in figure 9.

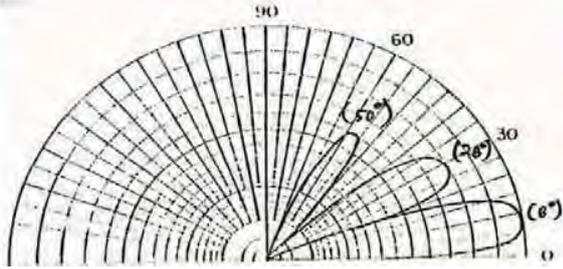


Figure 7. Three major lobe centered

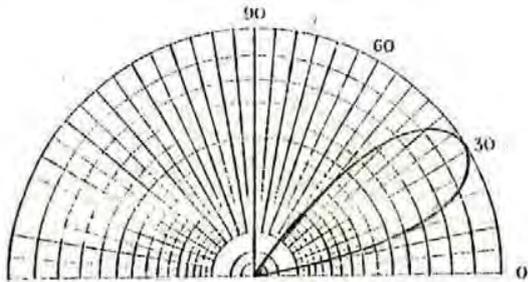


Figure 8. Major lobe centered using the counterpoise

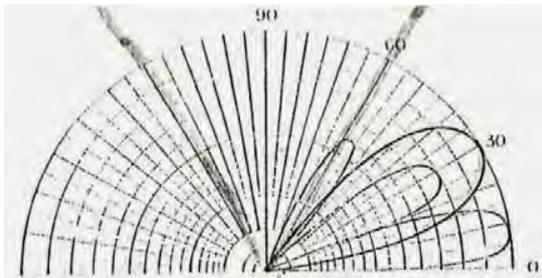


Figure 9 The area of the emission cone of silence

Size of Counterpoise effect on the radiation pattern that will act as a reflector or reflector above a certain angle. While the point of the reflector is ground level. This angle is called the critical angle. Therefore, the low-angle coverage resulting from surface reflection while for high angle coverage resulting from the reflection counterpoise.

### B. Remote Control and Status Equipment

In control DVOR there is a unit that can control the RCSE DVOR (Remote Control Status Equipment) is a module that can control DVOR, while the information that can be provided by the RCSE are as follows: Status transmitter is used, help the transmitter is used, select or move the transmitter is used, select equipment that will be on the controls of (DVOR or DME). RCSE can also be connected via the PC to see DVOR and DME equipment parameters, as well as full control equipment via a data output on a block SIB (Serial Interface Board).

## III. SYSTEM DESIGN

### A. Hardware Design

Overall block diagram design DVOR Status Monitoring. At the Desk Tower at Halim Perdanakusuma Airport Using SMS as a block below

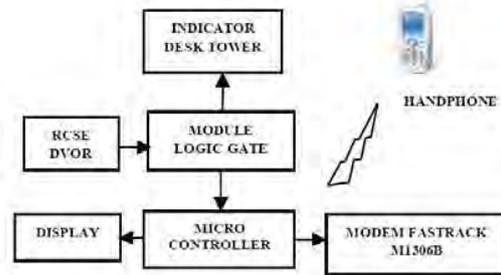


Figure 10. Block System Design

The workings blocks are designed, at RCSE DVOR is off then at that time on the logic gate output LED will turn red on the desk next to that tower will enable the microcontroller, the microcontroller will activate Fastrack M1306B modem and transmit data in the form of SMS to the person in charge DVOR and microcontroller will display the same phone number charge. If when RCSE DVOR under normal conditions the output of the logic gate module only turn green LED on the desk and does not activate the microcontroller.

### B. Logic Gate Module

Logic Gate serves as a monitoring status ON or OFF for the case of the condition of the equipment DVOR transmitter 1 and transmitter 2, then you want only two conditions, namely 1 and 0 only. To get the output and the desired condition then use NAND logic gate. So the output of DVOR can be converted into a truth table NAND gate. The circuit for this design is as follows

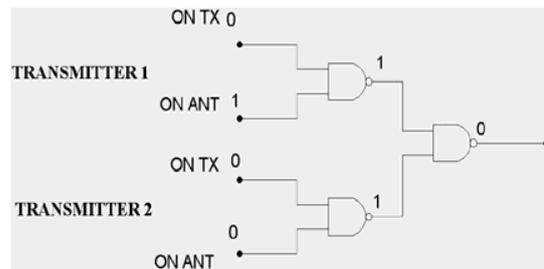


Figure 11. DVOR Transmitter 1 Normal operating conditions and Transmitter 2 Standby

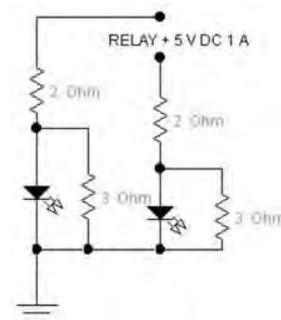


Figure 12. Lowering circuit Voltage and current on Indicator LED Desk Tower

C. Indicator Desk Tower

In the design of the Desk Tower taken from Vcc at 5 Volt DC and 1 A, which is connected to the first switch omron relay, but voltage and current to turn on the LED is too large, while the LED operates at 3 VDC 100 mA. So the decline in the use of voltage and current in the LED, see Figure 12.

D. Microcontroller ATmega 16

In this design ATmega microcontroller used is 16 to control the system, for monitoring system, used in the form of an LCD display and MODEM Fastrack M1306B, transmit information to the condition RSCE DVOR phone number officers, for all the design system see figure 13.

IV. SYSTEM UNDER TEST AND ANALYSIS

A. Desk Tower Data Analysis

The test data on the desk tower begins at 5 Volt DC OMRON relay the switch will be connected so that the voltage on the line green LED will light up with a value of 3 Volt DC voltage on the red LED will otherwise die, otherwise at the time of death DVOR the relay will die so relay switches back to the open position and the switch is connected to the red LED will light up with a 3 Volt DC voltage, see Table 1.

B. Data Microcontroller Test and Analysis

Testing microcontroller begins when the voltage of DVOR logic 0 so that the relay is not working so the relay will switch back to normally open so that at the same time the red LED will light up and the pins 0 and 1 on port B is connected so that it will enable the IC ATMEGA 16 and will work according with

Figure 13. Picture All module in the System

Table 1. LED Indicator on Desk Tower

DVOR	DESK TOWER	
	GREEN LED	RED LED
ON	ON	OFF
OFF	OFF	ON

Table 2. Output Microcontroller

Microcontroller Input	RJ 11
pin 0 and 1 Short	0,5 Volt
pin 0 and 1 Open	0 Volt

instructions that have been uploaded into the microcontroller ATMEGA 16 and RJ 11 produced in the form of a voltage of 0.5 volts per message delivery takes place, which is then sent to the modem to be broadcast in addition it will produce output on Port C are connected to the LCD display 16 x 2 to display the number of short messages sent purposes.

C. Modem FASTRACK M1306B

Modem FASTRACK M1306 modem B is working on a dual frequency on the 900/1800 Mhz and has an input voltage of 5, 5 Volt minimum voltage, current modem power supply given the time it will turn the whole modem component, after the modem is active, will be in a condition standby waiting for input from the microcontroller, if the microcontroller to provide input on the modem, the modem will send data and destination address in the format that has been in ATMEGA 16 and then radiated through the modem to the phone DVOR charge. see Table 3.

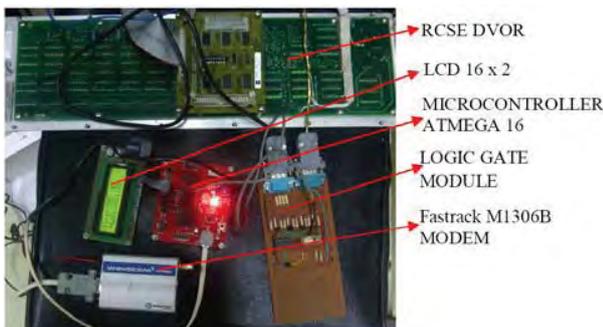


Table 3. Data form testing for all system

INPUT TX 1 AND TX2		OUTPUT LOGIC GATE	OUTPUT MICROCONTROLLER RJ 11	DESK TOWER INDICATOR	
TX	ANT			GREEN	RED
1	1	0	0	ON	OFF
0	1	1	0,5 V	OFF	ON
0	0	1	0,5 V	OFF	ON

Testing and analysis of the overall data began in DVOR ie when it is in normal condition and then output to the TX ANT ON, on Transmitter 1 and Transmitter 2 will control the input to the fourth transistor, and the transistor will produce a combination of input NAND gate, the output of NAND gate will be logic 1 or 0, if logic 1 it will activate the transistor and which serves as a direct current switching because of the NAND gate is not able to activate the relay coil. Green LED will light tower on the desk, if NAND gate transistor logic 0 then it does not work that ultimately will make the relay is not working so the Red LED Desk Tower will be blamed, at the same time switch relay to be short so that the two inputs on port B pin 0 and 1 on ATMEGA 16 microcontroller will be connected so that the microcontroller will work according to the instructions that have been uploaded, then the microcontroller ATMEGA 16 will result in the RJ 11 which will then input data on Fastrack M1306B modem which then sends the data in the form of a short message that "DVOR OFF" to 5 numbers DVOR is responsible, "085255525308, 081389597256, 081380211201, 081522572110, 085649599334" who had been in the previous program in microcontroller ATmega16 see Table 4.

Table 4. Data Test in the form of SMS

Modem Input	Destination Number and Location				
	085255525308 Makassar	081389597256 Depok	081380211201 Bogor	081522572110 Halim Perdanakusuma	085649599334 Halim perdanakusuma
0,5 Volt	DVOR OFF	DVOR OFF	DVOR OFF	DVOR OFF	DVOR OFF
0 Volt	-	-	-	-	-

Table 5. Data Test in system design

INPUT TX 1 AND TX2		OUTPUT LOGIC GATE	OUTPUT MICROCONTROLLER RJ 11	DESK TOWER INDICATOR	
TX	ANT			GREEN	RED
1	1	0	0	ON	OFF
0	1	1	0,5 V	OFF	ON
0	0	1	0,5 V	OFF	ON

1. If the normal operating status DVOR the logic gate output module = 0 Volt and DVOR in OFF condition when the output of the logic gate = 5 Volt so that control the relay input on the microcontroller and LED Desk Tower will be Active.
2. If DVOR status is in normal condition, the green LED will be on the line desk Tower will produce a voltage of 3 volts DC, when DVOR dead at the transmitter is on one or both transmitter off the line the red LED on the desk tower will produce a voltage of 3 volts DC.
3. If the transmitter 1 and transmitter operate normally DVOR 2 standby or vice versa, then the microcontroller does not work, so that the output on an RJ 11 = 0 volts so that the modem does not work and if the transmitter 1 and 2 on the transmitter is off, it will activate the modem to send data in the form of SMS to 5 numbers that have been programmed in the microcontroller.

#### REFERENCES

- [1]. Alcatel, RCSE 443, stuttgart, "Alcatel Air Navigation System", GmbH, 1999
- [2]. Alcatel, Technical Manual DVOR 432, Stuttgart "Alcatel Air navigation System" GmbH, 1999
- [3]. Texas instruments Incorporated, "The TTL data Book For Engineers", Second Edition, Texas, 1976
- [4]. Daryanto, "Keterampilan Kejuruan Teknik Elektronika", cetakan pertama, Bandung, 2010
- [5]. Budi Eko Purwanto, "Teori dan Aplikasi Sistem Digital", Edisi Pertama, Graha Ilmu, Bandung, 2011
- [6]. H William, Hayrt Jr, Kemmerly, M Steven, Durbin, "Rangkaian Elektronika", Edisi Ke Enam, Erlangga, 2005
- [7]. Budiharto Budi, Firmansyah Sigit, Elektronika Digital Dan Mikroprosesor, CV Andi Offset, Yogyakarta, 2010
- [8]. <http://www.interscan.com.au>, tanggal 15 Jjuli 2011
- [9]. <http://www.datasheetcatalog.com> tanggal 15 Juli 2011
- [10]. [http://www.nxp.com/documents/data\\_sheet/74\\_F00.pdf](http://www.nxp.com/documents/data_sheet/74_F00.pdf) Tanggal 1 Agustus 2011
- [11]. [www.atmel.com/atmel/acrobat/doc2466.pdf](http://www.atmel.com/atmel/acrobat/doc2466.pdf) Tanggal 3 Agustus 2011
- [12]. [http://en.wikipedia.org/wiki/7400\\_series](http://en.wikipedia.org/wiki/7400_series) Tanggal 5 Agustus 2011

#### V. CONCLUSION

# Development and Measurement Analysis of Transceiver and TNC for IiNUSAT Nanosatellite Payload Communication

Muhamad Asvial,  
 Electrical Engineering Department,  
 Universitas Indonesia  
 Kampus UI Depok, 16424, Indonesia  
 E-mail: asvial@ee.ui.ac.id

Galih Dewandaru  
 Electrical Engineering Department,  
 Universitas Indonesia  
 Kampus UI Depok, 16424, Indonesia  
 galih\_elkom2008@yahoo.com

**Abstract** –In this paper, some development and testing for payload communication board using Transceiver ADF7021, temperature sensor and integration with TNC are proposed. Transceiver ADF7021 is developed for 145.95MHz uplink frequency and 436.915MHz downlink frequency and to be applied for IiNUSAT Nanosatellite payload communication. The payload communication board is developed to be able for 2FSK demodulation and 1200bps data rate for receiver, and 2FSK modulation with 9600bps data rate for transmitter. In addition, the payload communication board is also support for data encapsulation using ADI protocol, and data delivery and must match for uplink frequency. TNC is designed to be able to fulfill the utility as data processing storage FX.25 data protocol, and temperature sensor at TNC board. Temperature monitoring is developed using LM35DZ and is designed for temperature range from 0-100°C. The testing results showed that payload communication board is work at the center frequency of 436.915MHz with -29.2dbm gain and -28.8dbm gain at a frequency of 436.91MHz. TNC is work and can be communicate the data to nanosatellite OBDH system. In addition, programming LM35 temperature sensor has been successfully implemented with the normal conditions of 33°C.

**Keywords** — Payload Communication board, ADF7021, TTC, TNC, Nanosatellite.

## I. INTRODUCTION

IiNUSAT (Indonesian Inter-University Satellite) is a nanosatellite which proposed by researcher from five state university and LAPAN. IiNUSAT Nanosatellite is designed for emergency calls and from the planning, the satellite is to be launched in 2013. The focus of our research related to this research project is to develop payload communication board including data communication interface between payload communication board to OBDH nanosatellite and also to design temperature sensor for payload communication board.

Payload communication is one of the subsystem which consist of Transmitter, Receiver, and TNC [1], [2], [3] [4]. Nanosatellite payload communication must be able to process data delivery, data encapsulation using protocol, and also to manage data delivery to the ground station. There are two kinds of RF which can be used, there are analog RF and IC RF. RF which used IC Transceiver has some benefits, they are easier to set register at processor chip and

the components of transceiver are stronger and reliable for space condition [5]. NC is the storage board of decode data which proposed to receive and communicate the to OBDH satellite system board.

In this paper, some development and testing of payload communication board using Transceiver ADF7021 and integration to TNC board and temperature sensor are proposed. Payload communication board is desinged for 145.95MHz uplink frequency and 436.915MHz downlink frequency and to be applied for IiNUSAT Nanosatellite payload communication. some tests for the parts of TTC payload IiNUSAT nanosatellite. The payload communication board is developed to be able for 2FSK demodulation and 1200bps data rate for receiver, and 2FSK modulation with 9600bps data rate for transmitter. In addition, the payload communication board is also support for data encapsulation using ADI protocol, and data delivery and must match for uplink frequency. TNC is designed using ATMEGA1280 microcontroller and to be able to fulfill the utility as data processing storage FX.25 data protocol, and temperature sensor at TNC board. Temperature monitoring is developed using LM35DZ and is designed for temperature range from 0-100°C. Register settings and simulation for ADF7021 can be performed by using ADIsim software, TNC hardware design using ALTIUM, and temperature monitoring process simulated using ISIS proteus.

The testing results showed that payload communication board is work at the center frequency of 436.915MHz with -29.2dbm gain and -28.8dbm gain at a frequency of 436.91MHz. TNC is work and can be communicate the data to nanosatellite OBDH system. In addition, programming LM35 temperature sensor has been successfully implemented with the normal conditions of 33°C.

## II. IINUSAT COMMUNICATION PAYLOAD

### A. Communication Payload Specification

Payload Communication specification consists of transmitter, receiver, TNC, and antenna and components specification are selected and adjusted for space proven condition. The specification of IiNUSAT payload communication system is shown in Table 1.

TABLE 1. IiNUSAT Payload Communication Specification

Communication Payload Specification	
Parameter	Provision
System	Full Duplex
Delivery Method	Real Time & Store and forward
Protocol	FX-25
Center Frequency	Downlink = 436.915 MHz (bandwidth 30 KHz) Uplink = 145.95 MHz (bandwidth 10 KHz)
Data type	TTC Uplink = Command dan update OBDH Downlink = Telemetry dan house keeping Data = Character Packet (500 character)
Bit rate	Downlink = 9600 Bps (FSK) Uplink = 1200 Bps (FSK)
Minimum BER	$10^{-5}$
Payload Type	Regenerative
Antenna Type	Receiver = Monopole Transmitter = Monopole

**B. IC Transceiver**

IC transceiver ADF7021 for nanosatellite is used and developed for IiNUSAT nanosatellite because this transceiver has fully support for all function of payload communication system that is to be used for payload communication satellite system. The IC Transceiver ADF7021 is much easier to developed circuit to get frequency both uplink and downlink of satellite system. ability to set the frequency much easier, suitable modulation and demodulation. Also, the value of power amplifier can be adjusted that are already include for power amplifier and LNA function. The block diagram of the transceiver ADF7021 is shown in Figure 1 [5].

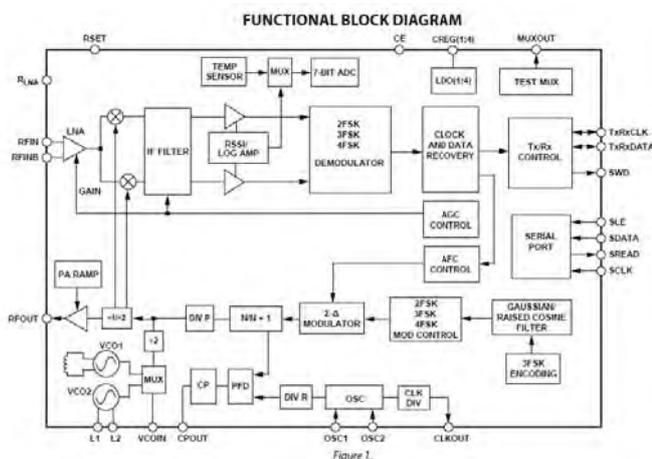


Figure 1. Functional Block Diagram of ADF7021

Transmitter is designed and should be works at 436.915MHz of center frequency, and the receiver should be works at 145.95MHz of center frequency. The type of ADF board that is used for transceiver nanosatellite is ADF7021DBZ3 for transmitter and ADF7021DBZ5 for receiver. The board is developed with with some additional components that is used to fix of both frequency, uplink and downlink frequency of IiNUSAT nanosatellite. To calculate and simulate the board for these frequency, the ADIsimSRD design studio software is used.. The circuit design and the additional component for ADF7021DBZ5 receiver board is shown in Figure 2 as below.

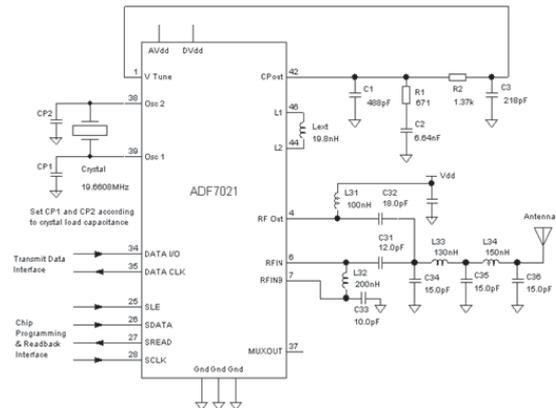


Figure 2. DBZ5 for 145.95MHz center frequency

**C. TNC Microcontroller**

Microkontroller ATMEGA1280 is used for TNC. We used this microcontroller because the this microcontroller has the availability of four-chip UART interface to be able to communicate (send and receive data) with transmitter, receiver, and OBDH system, and also the data delivery overhead which no moe than 10%.. TNC Board needs to be designed to meet the required functions, such as functions of FX.25 protocol storage, interconnection function UART with transmitter, receiver and OBDH system , and also with temperature sensor board.

The TNC board is designed for two layer PCB that be united, where the top layer is a layer of chip mounting ATMEGA1280 and the bottom layer is a layer of interconnections and other utilities as shown in Figure 3 and 4.

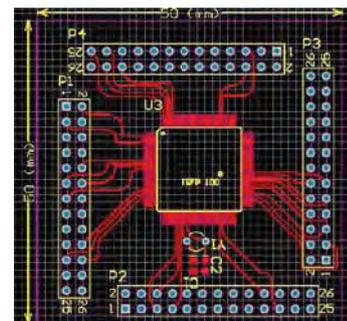


Figure 3. Top layer PCB

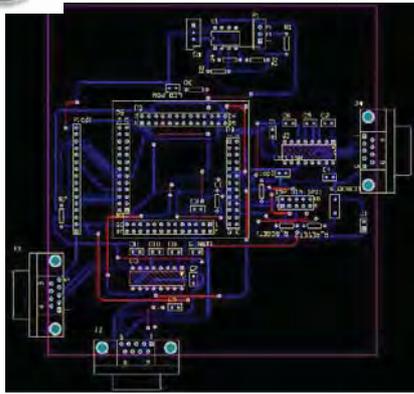


Figure 4. Bottom Layer PCB

### III. SIMULATION, TESTING RESULTS, AND ANALYSIS

The results of testing conducted to measure the validity of the actual device performance and can be analyzed to find the solution of some problems.

#### A. Simulation, testing results ,and analysis of Transmitter

Simulation of the transmitter by using the ADF7021 transceiver IC has been done using ADIsimSRD software design studio. The simulation results obtained of frequency and bandwidth, phase noise, and power transient.

From simulation results showed that the spectrum has 436.915MHz of frequency center. The spectrum peaks occur at  $\pm 5$  kHz from frequency center. But this frequency (436.915MHz) is still be able to work well for IiNUSAT nano satellite specification. From simulation , the phase noise obtained different results at 1kHz, 10kHz, 100kHz, 1MHz, and 10MHz. Transmitter spectrum simulation is shown in Figure 5. Transmitter Phase Noise performance is shown in Figure 6 and we can see that for higher frequency, the phase noise is to be smaller.

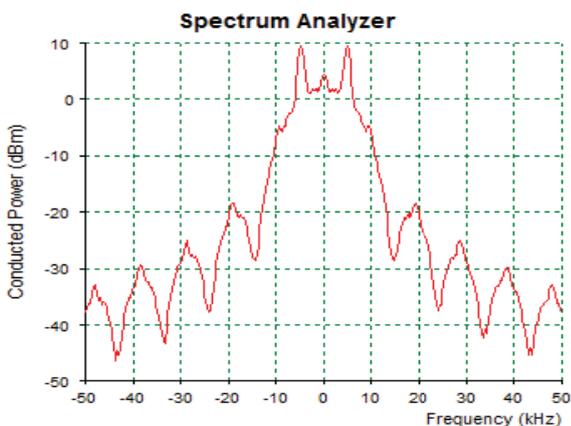


Figure 5. Transmitter Spectrum Simulation

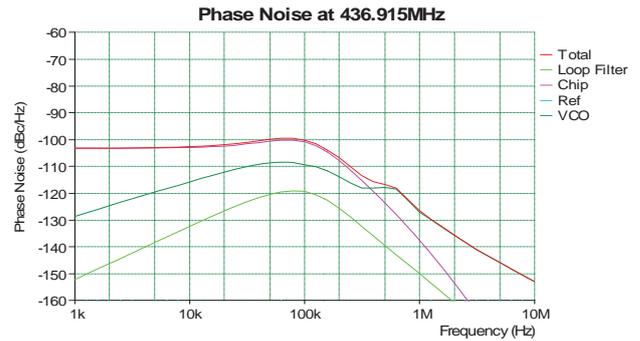


Figure 6. Transmitter Phase noise



Figure 7. Transmitter Power Transient

Figure 7 shows the performance of transmitter power transient. Overshoot is performed at 440 MHz of frequency and saturation is appeared after 20 us.

Measurements and testing results for frequency measurement and transmitter clocking are shown in Figure 8 and Figure 9. Frequency of testing was conducted on the transmitter that indicates for the frequency of 436.915MHz, -29.2dbm of gain is obtained. -28.8dbm of gain can be achieved at a peak of 436.91MHz of frequency. Besides that, 9600bps of clocking data are conducted.

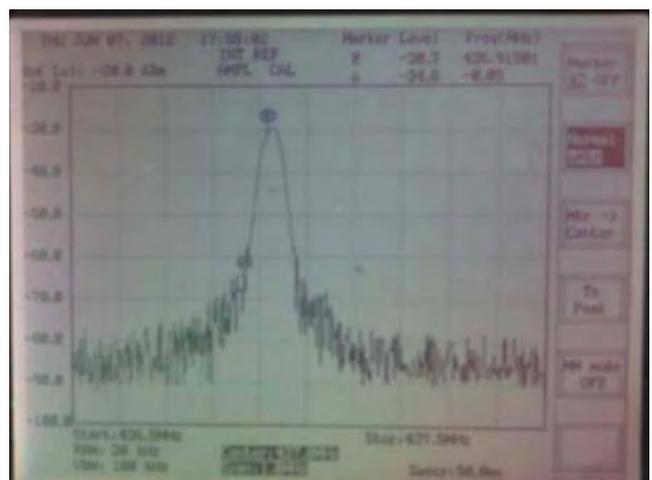


Figure 8. Frequency Center Measurement



From the temperature testing, we can see that the temperature around 33° C for the microcontroller board is achieved and still in normal condition for space characterization.

### III. CONCLUSION

The results of measurements on the transmitter indicates that the ADF7021 has an appropriate working frequency, which is able to work at 436.915MHz of frequency center, with a gain-29.2dbm and-28.8dbm (peak) at 436.91MHz of frequency. For the receiver, based on the results of the simulation, the system is able to work at 145.95MHz of frequency and 64.6km of the distance. TNC interface utility is designed to meet the criteria for Tx, Rx and OBDH. In addition, programming LM35 temperature sensor has been successfully implemented with the normal conditions of 33°C.

### REFERENCE

- [1] Ippolito Jr, Louis J. *Satellite Communication System Engineering*. USA : John Wiley & Sons Ltd. 1st edition. 2008.
- [2] *Miniaturized Satellite*. <http://centaur.sstl.co.uk/SSHP/sshpclassify.html>.
- [3] *Preliminary Design Review*. Indonesian Nano Satellite Platform Initiative for Research and Education (Inspire). 2010 : 47-55
- [4] Gunawan, Hendra. *Satellite Ground Segment/ Earth Station Overview*. 2010.
- [5] *ADF7021.pdf*. <http://www.analog.com/en/index.html>. 2007.
- [6] *ADIismLink\_V2\_AirInterfaceProtocol.pdf*. <http://www.analog.com/en/index.html>. 2007.
- [7] *Satellite Communication System.pdf*. Telkom. 2010.
- [8] Pozar, David M. *Microwave Engineering*. USA : John Wiley & Sons, Inc. 3<sup>rd</sup> edition. 1998.
- [9] Adi, Rhyando Anggoro (2011). *Rancang Banun Low Noise Amplifier dan Bandpass Filter pada Sistem Receiver Payload Komunikasi IiNUSAT*. Departemen Teknik Elektro, Universitas Indonesia.
- [10] [Http://www.mikron123.com/index.php/Aplikasi-Pengukuran/Pengukur-Suhu-Berbasis-Mikrokontroler.html](http://www.mikron123.com/index.php/Aplikasi-Pengukuran/Pengukur-Suhu-Berbasis-Mikrokontroler.html)

# Call Processing Simulation in GSM Network

Yus Natali, Renny Chaerunnisa /Akademi Telkom Jakarta  
Telecommunication Programme,  
Akademi Teknik Telekomunikasi Sandhy Putra,  
Jakarta, Indonesia  
[yus@akademitelkom.ac.id](mailto:yus@akademitelkom.ac.id), [Renny\\_chaerunnisa@yahoo.com](mailto:Renny_chaerunnisa@yahoo.com)

**Abstract**—GSM is a 2nd generation of cellular which mostly used around the world until now, even though it can only bring voice and text data. Through circuit switching based, data process from one mobile station to the other.

This research was about Call processing simulation in GSM network, which aimed to give an overview, assist, facilitate the learning process of call processing in GSM networks and the simulation was intended to increase knowledge about it's own natural cellular telephone network that is now progressing. In addition, the simulation was also designed to calculate cluster, Carried to Interference (C / I) and the general traffic in the GSM network.

Sample data was taken from one of operator GSM in Indonesia. According to call attempt on a BTS ABKS named at BSC JAT 1, the simulation counted that GoS as 0.0147, so the success call was 725,18 erlang, with 4 cell in one cluster. Besides that, the simulation shows the number of C/I as 144 or 21.5836 dB within frequency/cell was 6.25 Mhz/cell

**Keywords**—GSM (Global System For Mobile Communication); MS (Mobile Station); BSS (Base Station Subsystem); Cluster; traffic carried.

## I. INTRODUCTION

Global System for Mobile is one of the second generations of cellular technology. In addition to higher demands of communication, users want to be able to communicate with others – anywhere, anytime. Around the early 1990s, the ITU-R (International Telecommunication Union-Radio) formed a group named Global Special for Mobile to begin setting the standard for digital cellular phones under the coordination of the European Conference of Postal and Telecommunications Administrations (CEPT). Next, further preparation has been carried out by ETSI standards since 1992 through the 'Technical Specification' (TS). At the early times, this technology was tested in the first phase; the name of GSM became popular. However, the name stands for (Global Special for Mobile) was no longer relevant to the applied technology so that the name was changed to Global System for Mobile Communications [1].

The system of GSM consists of 3 parts, namely: Base Station Subsystem (BSS), Network and Switching Subsystem (NSS), and Operation and Maintenance Subsystem (OMS). BSS is a provider and controller of cellular radio transmission system. NSS is a control switch for mobile communication services. OMC is an operational support for each subsystem. Call processing becomes a fundamental requirement for users, that is, a GSM technology which is based on the circuit switching.

This research discussed a call processing that occurs in the GSM technology in the form of simulation which illustrates the architecture of GSM and its system as well. Through this simulation system, it was expected that the study of GSM system can be easier to understand

### A. Research Objective

The objective of this research was to design a simulation of GSM network call processing between a user and other users using software Matlab 7.6.0 R2008a.

Due to the amount of discussion about the calls system of GSM cellular, this research only discusses: GSM cellular networks in a single operator. Simulation using matlab software that simply describes the communication between two users on a GSM network. Mobile phone used by the user of the simulation is Nokia. Parameter used in simulation of calculation is only the cluster, carrier to interference, and traffic. The simulation does not show handover simulation.

### B. Research Methodology

In the implementation of this research, the authors conducted several research methods, namely Literature and Design of Software. The activities the authors conducted aim at designing on how the software displays as well as how to link the software with data. The making of Software was carried out by using the programming language MATLAB 7.6 or version 2008 after the process of program design. Software Testing and Revision Activities – in order to obtain maximum results, the software which has been made is tested. Analysis – doing a research and analysis about what to discuss.

## II. GLOBAL SYSTEM FOR MOBILE COMMUNICATION

This part are consist of two information about GSM.

### A. GSM Network Architecture

GSM system architecture consists of three subsystems which are interconnected each other, so are to the users through a network interface. These subsystems are: a BSS, NSS, and OMS. The cell phone (mobile station) is also a subsystem; however, it is supposed as a part of BSS in the terms of architecture. [2]

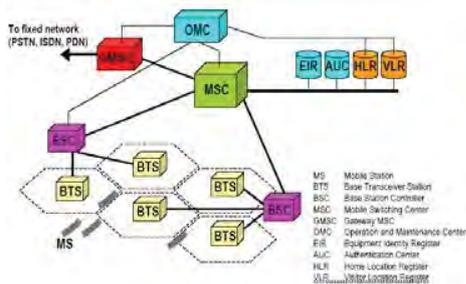


Fig. 1. GSM Network Architecture

BSS is known as the radio subsystem which provides and controls radio transmission path between the mobile phone and MSC. BSS also controls the radio interface between mobile phone and any other GSM subsystem. Each BSS consists of many BTS controllers called Base Station Controller (BSC) which connects the phone to NSS via the MSC. NSS controls the functions of switching to the system and allows the MSC to communicate with other networks such as Public Switch Telephone Network (PSTN) and Integrated Switch Digital Network (ISDN).

In addition to addressing the switching of communication between GSM system and other external networks, NSS also handles BSC in radio subsystem as well as to be responsible in organizing and providing access to exit for some customer data base. MSC is a central part or the center in the NSS which controls traffic among all BSC. There are three different kinds of database in this NSS namely; Home Location Register (HLR), Visitor Location Register (VLR), and the authentication center (AUC). [2]

Each OSS handles one or several operation maintenance center which is used to monitor and maintain the performance of every Mobile Station (MS), BSC, and MSC in the GSM system. This OMC has three functions, namely:

- Handling work / maintaining telecommunications hardware and network operations.
- Setting all telecommunication cost calculation procedures (billing system).

- Setting all the mobile phones that are in the system.

### B. The Structure of GSM Channels

In the GSM networks, there are some components known as channels which are especially used on the radio to transmit information or messages. Those channels are Logic channel and Physical channel.

On the Radio Sub System (RSS), there are two categories of channels which support the logic channels, namely Traffic Channel which carry information such as voice or data; and Control Channel, which carry signaling information or data synchronization.

Traffic channels (TCH) carry information such as voice or data. There are two channels of traffic carried by the speed of information, namely Full (speed) Rate Traffic Channel and Half (speed) Rate Traffic Channel.

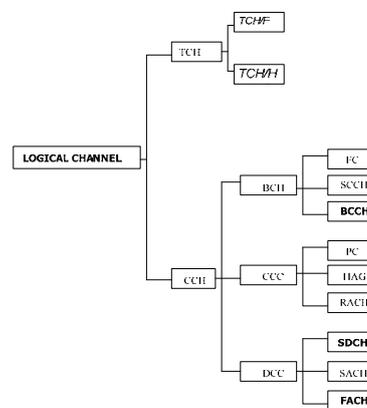


Fig. 2. GSM Logical Channel Structure

Control channel (CCH) is used to carry signal or data synchronization. This channel falls into three categories:

#### 1) Broadcasting Channel or BCH

This logical channel sends a message from the network to the mobile station that causes it gets information about the network configuration on a particular area of the procedure to access the network. This channel consists of:

##### a) Frequency Correction Channel or FCCH.

This channel carries the information to correct the frequency generated by the mobile station so that the mobile station is able to synchronize to get a frequency that is finally able to be used for communication.

##### b) Synchronization Channel or SCH

This channel carries information for frame synchronization from the mobile station to identify a BTS used for operations on the Radio Sub System.

##### c) Broadcast Control Channel or BCCH

This Channel carries general information about concerned BTS cell service. The channel is also used to define the channel configuration of a cell which is part of the information sent.

2) *Common Control Channel or CCCH*

This channel sends information either from the network to the MS or from MS to the network in the form of procedures to access the network which consists of:

a) *Channel Call (Paging Channel or PCH)*

This channel is used by network to call the mobile station during the incoming call that contains the identity of IMSI and TMSI.

b) *Random Access Channel or RACH*

This channel is used by the mobile station to request a signaling channel allocation in the process of establishing a network connection (call set-up).

c) *Hold Channel Access (Access Grant Channel or AGCH)*

This channel is allocated by network to the mobile station to provide the signaling channel.

3) *Specified Control Channel (DCCH Dedicated Control Channel or DCCH)*

This channel serves to transmit important information in the process of establishing a call signaling, authentication, location update, and messaging (Short Message Service or SMS). This channel consists of:

a) *Stand Alone Dedicated Control Channel or SDCCH*

This Channel is used in the signaling procedure to get the traffic channel allocation which is very important to establish the call, authentication, and location updating.

b) *Fast Associated Control Channel or FACCH*

This channel is used by the mobile station at the time of handover so that the capacity of the canal traffic could be replaced by this channel for a moment when the mobile station moves from one cell to another.

c) *Slow Associated Control Channel or SACCH*

During the call, the mobile station always measures the level of acceptance, transmission quality, and distance of the mobile station to the network. Due to information above, the network uses the control channel to transmit information periodically.

Physical channel is defined as a series of radio channel frequencies represented as the physical content of a timeslot, and it is illustrated in terms of bursts. Those bursts are contained in the timeslot which are divided into 156, 25 bytes per period. There are several types of bursts which are used as physical of a logical channel for tasks such as;

4) *Normal Burst (NB)*

Normal Burst (NB) is a type of physical channels that serve data transmission either signaling or speech that carries almost all logic channels, namely; Traffic Channel (TCH), Frequency Correction Channel (FCCH), Synchronization Channel (SCH), Broadcast Control Channel (BCCH), Paging

Channel (PCH), Stand Alone Dedicated Channel (SDCCH), Access Grant Channel (AGCH), Fast Associated Control Channel (FACCH), and Slow Associated Control Channel (SACCH).

5) *Frequency Correction Burst (FB)*

Frequency Correction Burst (FB) functions to transmit Frequency Correction Channel (FCCH). With this channel, the mobile station is able to check the transmitter and its receiver. It is also able to compensate for irregularities that may occur.

a) *Synchronization Burst (SB)*

Synchronization Burst (SB) functions to transmit Synchronization Channel (SCH) which contains the number TDMA and identity of a base station or BSIC.

b) *Access Burst (AB)*

This channel transmits Random Access Channel (RACH) which is used when the MS moves at the first time to ask for access to the network to perform its services. The network will measure the distance from the mobile station to the BTS used to determine the time delay.

c) *Dummy Burst (DB)*

This Physical channel does not transmit any logical channels; however, these channels are extra bytes that do not contain any information. This channel ensures whether the transmitter or receiver is running well. [2]

### III. THE DESIGN OF SIMULATION

The simulation consist of two part, which are stages of design and simulation results.

#### A. Stages of Design

The first step in the development of this simulation is to define the problem. This problem identification has a major influence to the next phases, that is, design. The less accurate of problem identification will affect the design of unfavorable results; therefore, some requirements that should be met to identify the problems are:

- The purpose of software development. This goal setting aims at directions to development which can be determined to the next steps to achieve goal.
- Target of users. In this simulation, the target of users must be recognized in order to meet their needs. The targets of users are either the students learning about wireless communication – particularly GSM, or anyone who wants to know about wireless communication.
- The use of resources. The resources used in making these simulations have certain elements which are certainly designed by using matlab version 7.6.0 or R2008a.
- Flow diagram of simulation



which decide the traffic call for MS. If both MS get call attempt from each BTS so the call processing can be done. Not to mention the parameters which affect in MS or mobile equipment.

The third call processing occurs in different BSC. The process in this case is influent with two BSC condition, two BTS traffic and the MS' parameters. One of the parameters which affect the call processing is the bandwidth, cluster, and bandwidth allocation in one cell. Others parameters is not include in this simulation. This third process calculation is showed on Figure 9 as below here.



Fig. 9. Call Processing Calculation Between Different BTS in Different BSC

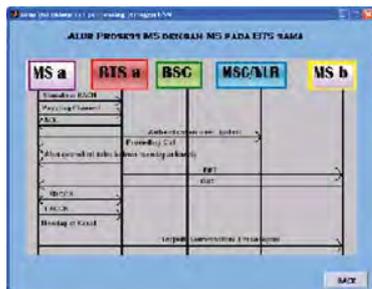


Fig. 10. Call Processing in One BTS

Figure 10 and 11 are part of simulation which can be choosed from Main Menu in Figure 6. In Figure 10, it shows the channels which occur while the call process between MS a and MS b in one BTS.

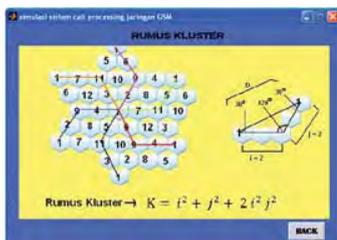


Fig. 11. Help Menu

Figure 11 shows the mechanism of cluster in GSM network. Cluster is a group of cells with different frequency.

The numbers of cell in a cluster will influence the bandwidth allocation in one cluster. The more cell in one cluster will affect the less bandwidth allocation for one cell.

#### IV. ANALYSIS OF DESIGN RESULT

This call processing simulation is from MS to MS (with the same BTS). MS caller is known as Originating Call while MS receiver is known as Terminating Call. Both of them are controlled by the same base station. In this simulation, there are parameters that must be input by the user to make calls and also as a requirement of MS to do a calling. Based on this simulation trial to make a call within the BTS, it can be concluded that:

- Phone credit must be greater than 1000 rupiahs
- There is a caller or the destination (number)
- MS, which is used to call, requires a correct dial to destination.
- MS battery is also must be greater than 40%
- In addition, the signal quality of MS must be at least 3dB.

In extended example, MS with the number 085692294237 is the caller or the originating call. In order to make calls, one must meet the following requirements: having credit at least Rp.1000, dialing a correct destination, having battery/power, and having good quality signal. Importantly, MS with the number 085714809346 is a receiver or terminating call that is in the absence of a call or busy.

Upon MS is eligible, one can make calls then. MS also considers calculating the accessibility of channel, such as MS traffic parameters on the BTS that serves to calculate the amount of traffic that accesses to channel. Traffic channel is a circuit in which an individual communication may pass. The trial presented in this journal is call processing in a single BTS. The conditions of call when it reached BTS will be affected by the BTS traffic condition. Such Traffics can be distinguished into three parts, namely:

- Offered traffic (Ao), is a traffic which is offered or about to access to network.
- Traffic Carried (Ac), is a traffic that gets loaded or channeled.
- Lost Traffic (Ar) is a traffic which is lost or gets no channel.

Call processing simulation MS to MS on the same BTS.

One of the data obtained from the operator about the number of calls that occurs in one BTS is as follows:

To examine this simulation, traffic data in BTS is taken from real condition in one GSM network . The data consist of call attempt, call seizure and call success with 92.4 erlang for traffic design.

TABLE I. SAMPLE DATA SIMULATION FROM OPERATOR

B S C	S i t e	Call Attempt	Call Seizure	Call Success	Fail	Traffic Carried
K 5 T	K A A	1182	1181	917	264	7.4
K 5 T	K G C	2034	2030	1423	607	12.7
K 5 T	G A A	1763	1759	1161	598	8.8
K 5 T	I A A	1428	1426	881	545	4.4
K 5 T	D Y A	1907	1908	1115	793	11.4
K 5 T	G K A	1315	1312	922	390	7.1
K 5 T	A N B	4172	4167	3060	1107	26.3
K 5 T	G R A	198	196	143	53	1.4
K 5 T	R P B	537	539	351	188	2.3

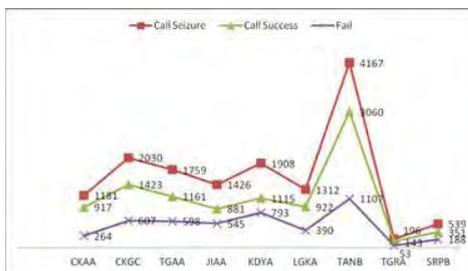


Fig. 12. Sample Traffic in JK5T BSC in GSM Network

To be able to make a call, the BTS traffic conditions (ABKS) should not be so full that MS gets the channel and BTS condition which is dialed. At BSC JK5T, both call seizure and the lowest call success is found in the BTS TGRA. The highest call seizure or call success is found in BTS TANB. This simulation discusses only to the traffic conditions at the BTS in one of the operators in Indonesia.

A. CONCLUSION

This simulation mainly discusses a call processing communication. It consists of theory with three basic views on the GSM network namely: Simulation MS to MS at the same BTS, different BTS with the same BSC, and different BTS for different BSC.

The success of call processing is initiated by the MS eligibility to make a proper call. This simulation facilitates the understanding of call processing in GSM, and helps operators count the traffic conditions at the BTS. The success of call processing in the simulation is determined not only from a connectivity building process from a caller to the receiver and the web structure, but also from a traffic condition in the originating BTS and the terminating BTS.

ACKNOWLEDGMENT

Thank you for Akatel Jakarta lecturers who encouraged to publish this research. Special thanks for the company which has shared its' data to examine in this simulation.

REFERENCES

- [1] <http://www.etsi.org/WebSite/Technologies/Cellularhistory.aspx>
- [2] Gunnar Heine, "GSM Networks: Protocols, Terminology, and Implementation," Artech House, 1998, Ch. 7, pp 93-98.
- [3] Reshma Begum Shaik, T.Krishna Chaitanya, "Simulation of GSM Mobile Networks Planning Using ATOLL Planning Tool," International Journal of Engineering and Innovative Technology (IJEIT), vol. 2, no. 1, pp. 341-344, July 2012.
- [4] M. Dachyar, Yudavedito, "Portfolio Simulation in GSM Cellular Telecommunication Industry for Company's Decision and Policies Making," World Academy of Science, Engineering and Technology, vol. 57, pp. 364-367, 2011.
- [5] Nikhil Deshpande, "Matlab implementation of GSM traffic channel," Thesis, University of South Florida, October 2003.
- [6] Sunomo, "Pengantar Sistem Komunikasi Nirkabel," PT Grasindo, Jakarta, 2004
- [7] Siegmund M. Redl, Matthias K. Weber, Malcolm W, "GSM & Personal Communication System," Artech House, 1998, Ch. 6-7.
- [8] Gunaidi Abdia Away, "The Shortcut of Matlab Programing," Informatika, Bandung, 2006
- [9] Vijay K.Garg dan Joseph E.Wilkes., "Wireless and Personal Communication System.," Prentice Hall PTR, 2005

## The Generation of Synthetic Sequences of Monthly Rainfall Using Stochastic-Autoregressive Model

Maimun Rizalihadi<sup>a</sup>, Alfiansyah, J.Bc<sup>b</sup>

<sup>a</sup> Dept. of Civil Engineering, Faculty of Engineering  
The University of Syiah Kuala, Darussalam-Banda Aceh 23111  
Tel./Fax : (0651) 7552222  
email: dilamalia@hotmail.com

<sup>b</sup> Dept. of Civil Engineering, Faculty of Engineering  
The University of Syiah Kuala, Darussalam-Banda Aceh 23111  
Tel./Fax : (0651) 7552222  
email: fian\_7anur@yahoo.com

### ABSTRACT

The generation of synthetic rainfall is useful for the planning, design, and operation of water resource systems due to lack of data. Most rainfall series are periodically stationary; namely; their mean and covariance functions are periodic with respect to time. The objective of this paper is to generate the sequences of monthly rainfall using Stochastic-Autoregressive Model (SAM). Monthly rainfall is provided from Blang Bintang Rainfall Station for ten year records. The monthly rainfall time series is developed by an additive model with trend, periodic and stochastic as their components. Each component is identified and, if found, removed from the original series. The turning point test is applied for detecting the trend, variance analysis is applied to identify the number of significant harmonics. The series is then tested for stationarity and dependent part of the stochastic components. The results found that the series is free trend series, is well expressed using six harmonics coefficient for periodic components, and third order autoregressive for stochastic components. The adequacy of fit is judged by the insignificant correlation and normal distribution of the obtained residuals. So, The SAM might be well used for representing the rainfall time series in Blang Bintang Rainfall Station.

### Keywords :

Time series, Trend, Periodic, Stochastic, Autoregressive.

### 1. INTRODUCTION

The generation of synthetic rainfall data being able to reproduce the essential statistical features of historical rainfall is useful for the planning, design, and operation of water resource systems. To provide long sequence records of data is very difficult, so it is necessary to extend them by generating the historical record. Various methods have been used by engineer to provide this information. Most of the existing methods are either deterministic or probabilistic in nature, not considering the random effects of various input parameters. With the ever increasing demand for accuracy of analyzing rainfall data, these methods are no longer sufficient.

At present, many publications that study the stochastic modelling have been published, such as: analysis of time series of streamflow, waves, evapotranspiration and irrigation requirement as in [2][3] and [6]. The stochastic model approach also have been used for generating the rainfall data. The Rainfall is one of the significant parameters in many hydrological models. They are stochastic in nature because they are affected by climatological parameters, namely, stochastic climate variations are transferred to become stochastic component of rainfalls. These series are a complex atmospheric process and periodically stationary in which their mean and covariance functions are periodic with respect to time as in [4][7] and [11]. Considering all other factors known or assumed the rainfall is a function of the stochastic variation of the climate. Hence stochastic analysis of rainfall time series should be computed using a mathematical model that account both for the deterministic and stochastic parts of the process, as stated in [7]. However, most rainfall data is not continue or discrete, so this method fits only for generating annually or monthly data. For example, reference [10] used autoregressive model (AR) to generate the annual rainfall, using the autoregressive moving-average models (ARMA) [8] and stochastic modelling of monthly rainfall [9]. But the former study has been done on the synthetic generation of rainfall using stochastic structure of the time series without combining both periodical and stochastic component.

The aim of research is to generate the sequences of monthly rainfall using stochastic autoregressive model (SAM) by combining the periodical and stochastic component in the developed model.

The scope of research consist of testing the monthly rainfall time series for stochasticity, identifying and removing trend and periodic components, studying the structure of dependent stochastic component, and diagnostically checking for the independent stochastic component.

## 2. MATERIALS AND METHODS

### 2.1 Data

The point rainfall data is collected from Blang Bintang rainfall station, Aceh, The data provided was on the basis of daily record during 10 years (1987-1996). The data, then, was analyzed to be a monthly base in accordance with the purpose of study. Generally, in Aceh the climate is divided into two season, that are; rainy season and dry season. Rainy season start from September to December, which is maximum rainfall in December, while in June to August are dry with a little rain. Whereas the rest in between January up to May, as the second mayor peak of monthly rainfall. The monthly distribution pattern in Aceh can be seen in the Figure 1. The amount of yearly rainfall is in between 1200 up to 1900 mm. The characteristic of rainfall in Blang Bintang was described more detail in section result and discussion.

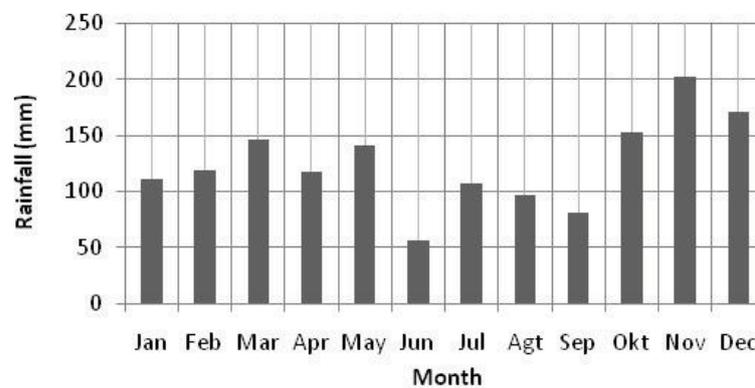


Figure 1. The Pattern of Monthly Rainfall Distribution

### 2.2 Model Structure Methods

Generally a time series can be constructed by deterministic component consisted of trend and periodic factor, which could be formulated in manner that allowed exact prediction of its value. And a stochastic component, which is always present in the data and can not strictly be accounted due to random effects in [4][6] and [9]. The time series,  $X_t$ , was represented by a decomposition model of the additive type, as follows:

$$X_t = T_t + P_t + S_t \tag{1}$$

where  $T_t$  = the trend component at time,  $t$ , for  $t = 1, 2, \dots, N$ ,  $P_t$  = the periodic component,  $S_t$  = the stochastic component having dependent and independent parts, and  $N$  = the number of data points. Eq. 1 was systematically identified and its components removed.

#### 2.2.1 Trend Component

The component of trend  $T_t$  was identified using the seasonal values ( $Z_i, i = 1, 2, 3 \dots n, n =$  number of seasons) obtained by the algebraic sum of monthly data of each season [6]. For detecting trend, a hypotheses of no-trend was made using Turning Point Test to test the hypotheses [6]. The procedure is to determine the number of times,  $p$ , occurs at time  $i$  if  $Z_i$  is either greater than  $Z_{i-1}$  and  $Z_{i+1}$  or lesser than the two adjacent values. The expected number of  $p$  in a random series is

$$V = \frac{2(n-2)}{3} \tag{2}$$

where variance ( $V$ ) can be computed as

$$\text{var}(V) = \frac{(16n-29)}{90} \tag{3}$$

and standard measure ( $m'$ ) can be expressed as

$$m' = \frac{(p - V)}{\sqrt{[\text{var}(V)]}} \quad (4)$$

which is treated approximately as a standard normal variate. The value of  $m'$  was compared with its table value at 5 % level of significance [5]. If the calculated value of  $m'$  is within the limits, the hypotheses of no-trend is not rejected or accepted.

### 2.2.2 Periodic Component

The component of periodic ( $X_t$ ) can be expressed in Fourier form as described in [4] and [7], as follows :

$$X_t = A_o + \sum_{k=1}^{\infty} \left[ A_k \text{Cos}\left(\frac{2\pi kt}{P}\right) + B_k \text{Sin}\left(\frac{2\pi kt}{P}\right) \right] \quad (5)$$

In which P is time span of periodicity; k is number of harmonics,  $1 < k < P/2$ ; M is number of significant harmonics,  $1 < M < P/2$ ; and N is number of data points, and  $A_k$  and  $B_k$  are Fourier coefficients, expressed as;

$$A_k = \frac{2}{N} \sum_{t=1}^N \left[ X_t \text{Cos}\left(\frac{2\pi kt}{P}\right) \right] \quad (6)$$

$$B_k = \frac{2}{N} \sum_{t=1}^N \left[ X_t \text{Sin}\left(\frac{2\pi kt}{P}\right) \right] \quad (7)$$

and

$$A_o = \frac{1}{N} \sum_{t=1}^N [X_t] \quad (8)$$

Where, K = number of significant harmonics, p = base period, N = number of observation points and  $A_k$  and  $B_k$  = Fourier coefficients. These coefficients were obtained by a least square fit of the data to the  $K^{\text{th}}$  harmonic components, then a least squares approximation could be given by the finite series.

$$P_t = A_o + \sum_{k=1}^M \left[ A_k \text{Cos}\left(\frac{2\pi kt}{P}\right) + B_k \text{Sin}\left(\frac{2\pi kt}{P}\right) \right] \quad (9)$$

Where, M is the number of significant harmonics (maximum, P/2). In Eq. (5) if  $M \rightarrow \infty$ ,  $P_t \rightarrow X_t$ , then  $X_t$  could be represented satisfactorily by Eq. (9) only. However it may not be practical or desirable to allow the condition,  $M \rightarrow \infty$ . Thus the appropriate approach would be the selection of a value of M which contains only those harmonics which are significantly contributing towards  $X_t$ . With this as the objective two tests namely test of analysis of variance and Fourier decomposition of mean square were conducted. In this test, the null hypothesis was that the variance explained by harmonic k, which was  $(N/2)(A^2 + B^2)$ , is zero. Computations were made to test the  $A_k$  and  $B_k$  values for  $k = 6, 5 \dots 1$  in order to obtain the F-ratio, which was then compared with its table value of F distribution at 0.01 level of significance,  $F_{(a,v1,v2)}$  [5]. If  $F_{\text{cal}} > F_{(a,v1,v2)}$ , the harmonic coefficient is significant and can be put into the equation 5 to obtain the periodic component.

### 2.2.3 Stochastic Component

The component of stochastic ( $S_t$ ) was assumed that the value of  $S_t$  at time t is the combined effect of the weighted sum of the past values so that the dependent part of  $S_t$  as in [4][7] and [11], may be represented by the following equation :

$$S_t = \left[ \sum_{k=1}^{\infty} \Phi_{p,k} S_{t-k} + a_t \right] \quad (10)$$

$a_t$  = the independent normally distributed error variable. Because of the diminishing effect of past values of the present, the upper limit of Eq. 10 may be made finite, say p, resulting in a finite order Markov model equation as follows:

$$S_t = \Phi_{p,1} S_{t-1} + \Phi_{p,2} S_{t-2} + \dots + \Phi_{p,p} S_{t-p} + a_t \quad (11)$$

The model in Eq. (11) is known as the autoregressive model of order p, AR (p). The fitting procedure of this model involves two stages, namely, selection of the model order, p, and estimation of autoregressive coefficients,  $F_{p,k}$ . For selection of order p, the residual variance method is used where residual variance,  $S^2_z(p)$  was computed using the following equations :

$$S^2_z(p) = \frac{1}{N - 2p - 1} S(\mu, q_1, q_2, \dots, q_p) \quad (12)$$

in which

$$S(\mu, q_1, q_2 - q_p) = (N - p)(C_0 - A_1 C_1 - A_2 C_2 \dots A_p C_p) \quad (13)$$

$A_1, A_2 \dots A_p =$  AR-parameters and  $C_0, C_1 \dots C_p =$  autocovariance function at lag p,  $p = 0, 1, 2 \dots k$ . The value of  $C_p$  for any p is computed as,

$$C_p = E [(S_t - \mu) (S_{t+p} - \mu)] \quad (14)$$

where

$$\mu = E (S_t) \quad (15)$$

or can be described as

$$C_p = \sum_{i=1}^{N-k} (x_i - \bar{x})(x_{i+p} - \bar{x}) \quad (16)$$

In the present analysis,  $C_p$  was computed for  $p = 0, 1, 2$  and  $3$ . The minimum value of  $S^2_z(p)$  computed by Eq. (12), gave the appropriate order of the model, p, for representing the dependence structure of time series. The autocorrelation coefficients,  $r_p$  were determined as :

$$r_p = \frac{\sum_{i=1}^{N-k} (x_i - \bar{x})(x_{i+p} - \bar{x})}{\sum_{i=1}^{N-k} (x_i - \bar{x})^2} \quad (17)$$

The autoregression coefficients  $F_{p,k}$ , were expressed as a function of  $r_p$  and are computed by using the following recursive formula as in [4] and [7] :

$$\Phi_{p,p} = \frac{r_p - \sum_{k=1}^{p-1} \Phi_{(p-1,k)} r_{p-k}}{1 - \sum_{k=1}^{p-1} \Phi_{(p-1,k)} r_k} \quad (18)$$

and

$$\Phi_{p,p} = [\Phi_{(p-1,k)} - \Phi_{(p,p)} (\Phi_{(p-1,p-k)})] \quad (19)$$

in which  $k = 1, 2 \dots p$ . The first three linear autoregressive models (i.e.,  $p = 1, p = 2$  and  $p = 3$  of Eq. (19)) usually are good approximations for representing a time series, and hence were tried for analyzing the  $S_t$  of the rainfall time series. The dependent part of  $S_t$  was obtained by Eq. (11) and then was removed, leaving the independent part as follows :

$$a_t = S_t - \sum_{k=1}^p \Phi_{(p,k)} S_t \quad (20)$$

#### 2.2.4 Diagnostic Checking

Diagnostic checking means statistically verifying the adquacy of the formulated model. For this checking, the residual series was examined for any lack of randomness. Autocorrelation coefficients of residual series for lag 1 ( $l = 30$ ) were computed and were drawn against 1 with 95 % tolerance limits. If the correlogram thus obtained is well within the limits, then it can be

derived that residuals are normally distributed with zero mean and var (1/I). Various other tests, details of which are not given here due to lack of space, were also done to confirm the randomness of the residuals, which is the condition for accepting the formulated autoregressive model.

### 3. RESULTS AND DISCUSSIONS

#### 3.1 The Characteristic of Rainfall

The above mathematical method of analysis was used in investigating the structure of the time series of rainfall in Blang Bintang, Banda Aceh. The monthly rainfall values were obtained by computing the daily rainfall record during the 10 years (1987-1996) from Blang Bintang Station. Figure 2 shows the mean values of the monthly rainfall over the 10 periods under analysis. Based on analysis, mean monthly rainfall ranges from 56.47 to 202.38 and the deviation standard in between 33.87 to 141.30, while the coefficient of variation ranges from 0.37 to 1.19, which signifies the importance of time variability of monthly rainfall values. Again the values of SCC are also significantly different from zero ranging in between -0,30 to 0.35, which shows that the rainfall is mutually dependent.

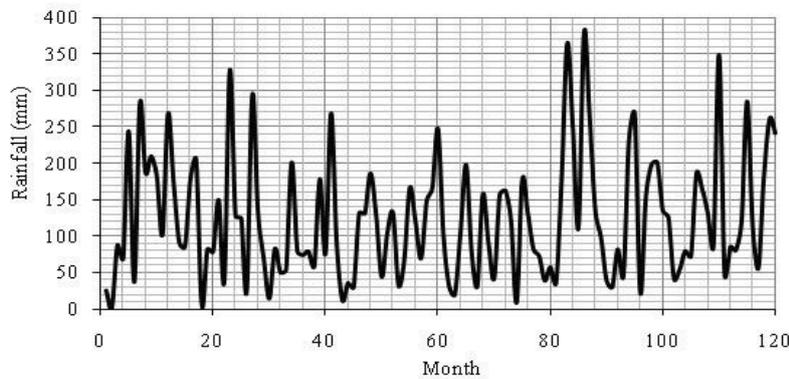


Figure 2. Monthly Rainfall during 1987-1996

This confirms that the rainfall process is time-variant and not independent, so the rainfall time series can be modeled on stochastic theory.

#### 3.2 Trend Component.

The seasonal values,  $Z_t$ , for 10 years is drawn in the Figure 3. Based on the figure is found 5 turning points, namely; in 1989, 1991, 1992, 1994 and 1995. The computed  $m'$ , for the Turning Point test is  $-0.276$ , which are within the limits of  $\pm 1.960$  at 5 % level of significance [5]. It reveals the absence of  $T_t$  in the rainfall time series, hence the  $X_t$  in the equation (1) may be treated as the trend-free series, or, the SAM was developed by periodic ( $P_t$ ) and stochastic ( $S_t$ ) component only, as follows,

$$X_t = P_t + S_t \tag{21}$$

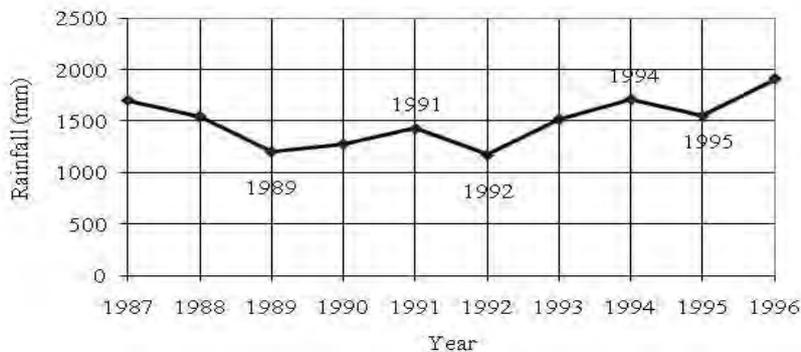


Figure 3. Turning Points in Yearly Values of Rainfall

#### 3.3 Periodic Component.

For representing the periodic component of the rainfall series the numbers of significant harmonics were determined by analyzing by cumulative periodogram. Using Equations (6), (7) and (8) the Fourier coefficients  $A_k$  and  $B_k$  were estimated. The value of  $A_k$  and  $B_k$  were found as shown in the Tabel 1. The table show that no one single of harmonic is more than 95 % of the total variance, so it is recommended that the use of the six harmonics in estimating the periodic component is necessary in order to find 95% of the total variance. Presence of  $P_t$  in the rainfall series was confirmed by the oscillating shape of the displayed figure. Using Eq. (22),  $P_t$  was computed for  $k=1,2,3,4,5$  and 6 and the result as shown in Fig. 4 below. The figure showed that the line was depicted closely between measured and generated rainfall. This confirm that the selection of the six harmonics ( $k = 6$ ) was significant for representing the  $P_t$  of rainfall time series.

Table 1: Harmonic Analysis of Monthly Rainfall Series

Harmonic (K)	Fourier Coefficients		Variance K-Harmonic (%)	Total Variance (%)
	$A_k$	$B_k$		
1	33.41	4.242	35.41	35.41
2	6.282	-26.085	22.48	57.89
3	9.568	-20.332	15.77	73.66
4	-11.350	-10.101	7.21	80.87
5	14.474	7.657	8.37	89.24
6	-12.463	0	4.85	93.09

$$\begin{aligned}
 P_t = & 125.2167 + 33.41 \cos\left(\frac{\pi}{6}\right) + 4.242 \sin\left(\frac{\pi}{6}\right) + 6.282 \cos\left(\frac{\pi}{3}\right) - 26.085 \sin\left(\frac{\pi}{3}\right) \\
 & + 9.568 \cos\left(\frac{\pi}{2}\right) - 20.332 \sin\left(\frac{\pi}{2}\right) - 11.350 \cos\left(\frac{2\pi}{3}\right) - 10.101 \sin\left(\frac{2\pi}{3}\right) \\
 & + 14.474 \cos\left(\frac{5\pi}{6}\right) + 7.657 \sin\left(\frac{5\pi}{6}\right) - 12.463 \cos(\pi)
 \end{aligned}
 \tag{22}$$

After estimating the periodic component it was removed from by subtracting the periodic component from historical time series. This process obtained a new stationery series,  $S_t$ , resulting from stochastic non-deterministic process as a new stationary series  $S_t$ .

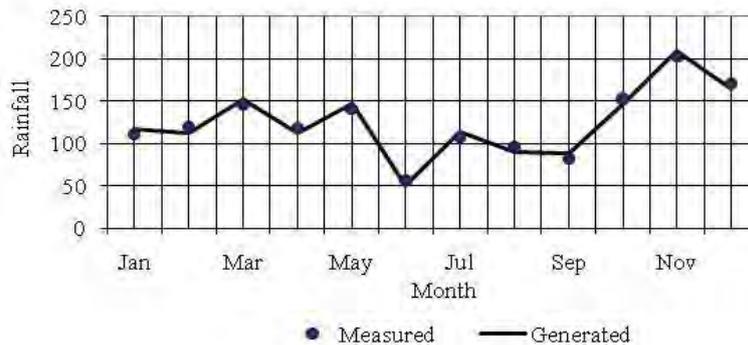


Figure 3. Monthly Measured and Generated Rainfall.

### 3.4 Stochastic Component.

$S_t$  was analyzed by fitting the autoregressive or Markov schemes to the series, as outlined in Eq. (11). The order of the model was determined by the procedure explained in the previous section.  $S_z^2(p)$  was computed using Eq. 12 for  $p = 1, 2,$  and 3. The results were given in Table 2. It shows that  $S_z^2(p)$ , 0.9900 is minimum at  $p = 3$  or third order; hence  $S_t$  can be suitably approximated by the third order Markov model, as shown in the equation (23).

$$S_t = 0.139168S_{t-1} - 0.02861S_{t-2} - 0.023586S_{t-3} + a_t \quad (23)$$

Table 2. Residual Variance for Different Orders of Markov Model

Order (P)	Model AR(p)	Autocorrelation coefficient, $r_p$ at lag p	Residual variance $S^2_z(p)$
1	AR(1,1)	0.135519	0.9908
2	AR(2,1) AR(2,2)	0.139843 -0.031908	0.9903
3	AR(3,1) AR(3,2) AR(3,3)	0.139168 -0.028610 -0.023586	0.9900

The autoregression coefficient (p,k where p = 3 and k = 1, 2, and 3) was computed using Eqs. (18) and (19). As the rainfall time series,  $X_t$ , is a trend-free series, the developed model describes the periodic-stochastic behavior of the original series. It is a superposition of a harmonic-deterministic process and third order Markov model. The developed model, so called SAM, can be denoted as follows :

$$\begin{aligned}
 X_t = & 125.2167 + 33.41 \cos\left(\frac{\pi t}{6}\right) + 4.242 \sin\left(\frac{\pi t}{6}\right) + 6.282 \cos\left(\frac{\pi t}{3}\right) - 26.085 \sin\left(\frac{\pi t}{3}\right) \\
 & + 9.568 \cos\left(\frac{\pi t}{2}\right) - 20.332 \sin\left(\frac{\pi t}{2}\right) - 11.350 \cos\left(\frac{2\pi t}{3}\right) - 10.101 \sin\left(\frac{2\pi t}{3}\right) \\
 & + 14.474 \cos\left(\frac{5\pi t}{6}\right) + 7.657 \sin\left(\frac{5\pi t}{6}\right) - 12.463 \cos(\pi t) + 0.139 S_{t-1} - 0.02861 S_{t-2} - 0.023586 S_{t-3} + a_t
 \end{aligned} \quad (24)$$

In which the first to twelfth terms in the formulated model represented by Eq. (24) constitute the deterministic part of the rainfall time series. The first term is a constant, indicating the arithmetic mean of the rainfall. The second are the harmonic portions of the deterministic part, and are functions of time. The thirteenth to fifteenth terms represent the dependent stochastic part of the model. The current value,  $S_t$ , depends on the weighted sum of its preceding three values. The last term,  $a_t$ , is the random independent part of the stochastic component with a zero mean. The formulated model was subjected to various checks to test its adequacy for representing the time dependent structure of the rainfall. The autocorrelation coefficients of the residuals for lags (1 = 30) were computed. They are displayed in Figure 4 in the form of a correlogram with 95 % tolerance limits.

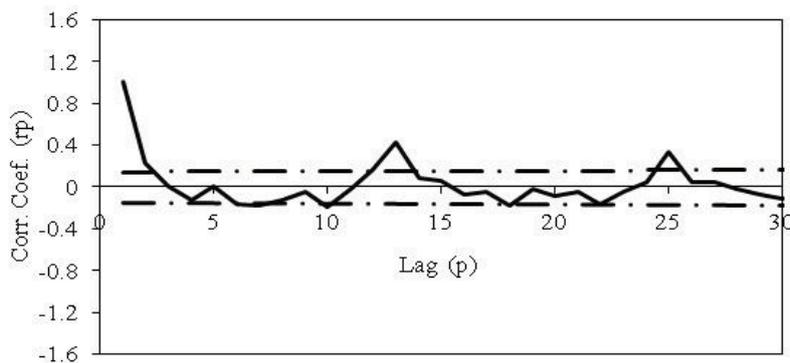


Figure 4. Correlogram of Residual Series with 95 % Tolerance Limits

The correlogram shows that almost all the coefficients are very small under tolerance limits, therefore the correlation coefficient can be treated as non-significant. The residuals are normally distributed with a mean value of closing to zero (0.0008), and variance of 0.0188 less than  $(1/l=1/30 = 0.033)$ . This leads to the conclusion that the residuals are independent

normally distributed. The rainfall, generated by the formulated model, are plotted with the corresponding observed and generated values as displayed in Figure 5.

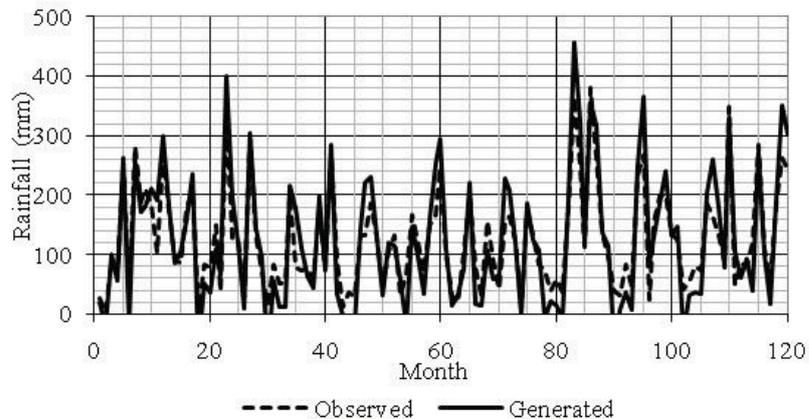


Figure 5. Comparison of Observed and Generated Data of Monthly rainfall

The plot indicates closeness of both observed and generated values, and thereby reflects the appropriateness of the formulated rainfall model. Therefore, the Stochastic-Autoregressive Model (SAM) is one of alternative synthetic model which might be employed to generate monthly rainfall at Blang Bintang Rainfall Station for use in planning hydrologic studies or water resources systems.

#### 4. CONCLUSIONS

The SAM rainfall in Blang Bintang was developed under free trend series, six harmonics as periodic component, and the third order autoregressive as stochastic component.

The models developed in this study seem promising in the analysis of rainfall in Aceh for planning hydrologic studies or water resources systems. A rigorous data collection scheme is need to get reliable data for such analysis.

The models need some improvements and comparison with other hydrologic model to see how fit the results. The authors are considering these issues in their future studies.

#### ACKNOWLEDGEMENT

The first writer is grateful to the Dean of Engineering Faculty of Syiah Kuala University for financial support in attending the international conference research, and the Committee Teams of 13th QIR FTUI and Reviewer Teams for giving permission to publish this paper.

#### REFERENCES

- [1] M. Rizalihadi, "The generation of synthetic sequences of monthly rainfall using autoregressive model", *Jurnal Teknik Sipil* volume 1, No. 2, Universitas Syiah Kuala, 2002.
- [2] M. Rizalihadi & M. Jamil, "Stochastic Modelling of Wave Height in KR. Raya Port", *SST Proc., HEDS-JICA*, Batam, 2000.
- [3] M. Rizalihadi & M. Jamil, "Stochastic Modelling of Discharge of Krueg Aceh River", *SST Proc., HEDS-JICA*, Lampung, 1998.
- [4] N. T. Kottegoda, "Stochastic Water Resources Technology", The Macmillan Press Ltd., London, 1980.
- [5] R.E. Walpole and R.H. Myers, "Probability an Statistics for Engineers and Scientists, 2<sup>nd</sup> edition, New York, Macillan Publishing Co. Inc., 1978.
- [6] R. K. Gupta, "Stochastic Modeling of Irrigation Requirements", *Journal of Irrigation and Drainage Engineering.*, Vol. 112, 1986.
- [7] R.T. Clark, "Mathematical Models in Hydrology", Food Agriculture Organization, FAO-19, Rome, 1973.
- [8] S.K.K. Babu, K. Karthikeyan, M. V. Ramanaihah and D. Ramanah, "Prediction of Rain-fall flow Time Series using Auto-Regressive Models. *Advances in Applied Science Research*, 2 (2): 128-133, 2011.
- [9] S. R. Bhakar, R.V. Singh, N.C. and A.K. Bansal, "Stochastic Modeling of Monthly Rainfall at Kota Region, *ARPN Journal of Engineering and Applied Sciences*, Volume 1, No.3, 2006.
- [10] S. Tantane, S. Patamatammakul, T. Oki, V. Sriboonlue and T. Prempee, "Coupled Wavelet-Autoregressive Model for Annual Rainfall Prediction", *Journal of Environmental Hydrology* Vol.13, 2005.
- [11] V. Yevjevich, 'Stochastic processes in hydrology, *Water Resources Publications*, Colorado, 1972.

# Genesis of Saline/Brackish Groundwater in Parangtritis and Surrounding Area, Yogyakarta Province

T. Listyani R.A.

Geological Engineering Department, STTNAS, Yogyakarta 55281  
 E-mail: [listyani\\_theo@yahoo.co.id](mailto:listyani_theo@yahoo.co.id)

## ABSTRACT

The saline/brackish groundwater phenomena was found at Paris and its surrounding area, Bantul District, Yogyakarta Special Province. At this area, saline water found at dug well and hot spring of Parangwedang. Whereas, fresh to brackish water can be found at several dug wells along Parangtritis Coastal Plain. Hydrogeological survey has been carried out completed with hydrochemical analysis to know genesis of saline/brackish water.

Saline water of Parangwedang area usually has chloride or natrium chloride type, included in saline class (Cl content are 6.528 - 7.498 ppm). Whereas, groundwater at Parangtritis Coastal Plain found as fresh water class, indicated by 20 – 23,9 ppm, but sometimes it ever changes to be brackish. This brackish water of coastal plain may be originated from mixing of fresh and saline (sea) water by flushing process. This brackish water flows in Merapi sand sediments aquifers directed from sand dunes behind coastal plain. The saline water of Parangwedang area predicted originated from deeper aquifers, involve breccia of Nglanggran Formation, or the older rocks, rose up to the surface after taken several hydrochemical processes like chemical evolution, cation exchange, seawater intrusion, and may be influenced by magmatic activity for long time.

## Keywords

Groundwater, hydrogeology, saline, brackish, hydrochemical.

## 1. INTRODUCTION

At the southern end of Yogyakarta Special Province (Fig. 1), on the physiography of Yogya - Bantul Plain [10] there is saline and brackish groundwater phenomena. Saline groundwater in the area can be found at Parangwedang as the hot springs (Fig. 2) and in dug well near from the hot springs. Meanwhile, brackish groundwater can be found in the dug wells at Parangtritis Beach (Fig. 3).

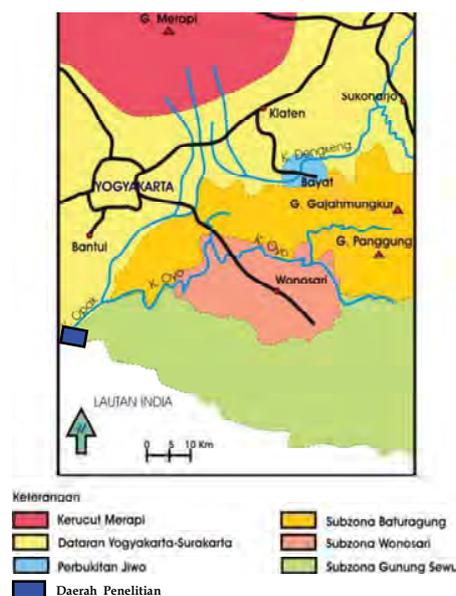


Figure 1. The research area in geomorphological map of Yogyakarta [2].

In the field, some wells showed the brackish water in taste. There is also fresh water from wells in coastal plain, but at longer time it will tasted salty in the mouth. Both saline and brackish water in the research area make interest to study about its genesis. This genesis of salinity can be studied by approaching of hydrochemical and hydrogeology.

The study of groundwater salinity is very interesting to determine the origin and the processes that occur during the water flowing beneath the surface. This study can be done by looking at the chemical constituents of groundwater.



Figure 2. Photograph of hot spring at Parangwedang.



Figure 3. Example of dug well with fresh – brackish groundwater at Parangtritis Beach.

## 2. BASIC THEORY

Groundwater in nature can be found in fresh to saline. Salinity level is varied, and can be determined based on the element of chloride (Cl) or the total dissolved solid (TDS) of water (Table1).

Table 1. The salinity level of groundwater (PAHIAA, 1986, in [3]; Carroll, 1962, in [9]).

Water characteristic	TDS (mg/l) [3]	TDS (mg/l) [9]	EC (µmhos/cm) [3]	Cl (mg/l) [3]
Fresh	≤ 1,000	0 – 1,000	≤ 1,500	≤ 500
Almost brackish	> 1,000 - ≤ 3,000		> 1,500 - ≤ 5,000	> 500 - ≤ 2,000
Brackish	> 3,000 - ≤ 10,000	1,000 – 10,000	> 5,000 - ≤ 15,000	> 2,000 - ≤ 5,000
Saline	> 10,000 - ≤ 35,000	10,000 – 100,000	> 15,000 - ≤ 50,000	> 5,000 - ≤ 19,000
Brine	> 35,000	> 100,000	> 50,000	> 19,000

As long as the water flows below ground level, the different hydrochemical processes can occur. The hydrochemical processes that occur in groundwater systems include dissolution - hydrolysis - precipitation, adsorption, ion exchange, reduction -

oxidation, mixing, membrane filtration and metabolism microbiology [9]. The chemical composition of groundwater depends on the chemical composition of water in the recharge and many reactions that occur in the flow system [5]. Genesis of saline water is also determined by a variety of hydrochemical processes which occur along the path flow.

Mixing occurring in the groundwater at coastal areas could be seawater intrusion or flushing. There are different types of brackish water chemistry caused by the intrusion of seawater or flushing process (Fig.4). Seawater intrusion generally change the type of water from NaCl into  $\text{CaCl}_2$  type. The reverse process occurs when fresh water from the brine aquifer goes leaching (flushing), where brackish water will generally has the  $\text{NaHCO}_3$  type. When seawater intrudes in a coastal fresh water aquifer, an exchange of cations takes place. Sodium is taken up by the exchanger, and  $\text{Ca}^{2+}$  is released. The water quality thus changes from NaCl to  $\text{CaCl}_2$  type water. The reverse process takes place with refreshing, i.e. when fresh water flushes a salt water aquifer, where  $\text{Ca}^{2+}$  is taken up from water, in return for  $\text{Na}^+$ , with a  $\text{NaHCO}_3$  type as result [4].

In addition to the mixing, the chemical evolution is often a major cause of groundwater salinity. Evolution of groundwater is generally followed by regional changes of anion dominance as indicated by the Chebotarev sequence (1955, in [4]) as follows:



To the right sequence is characterized by an increasingly distant flow path of groundwater accompanied by increasing age.

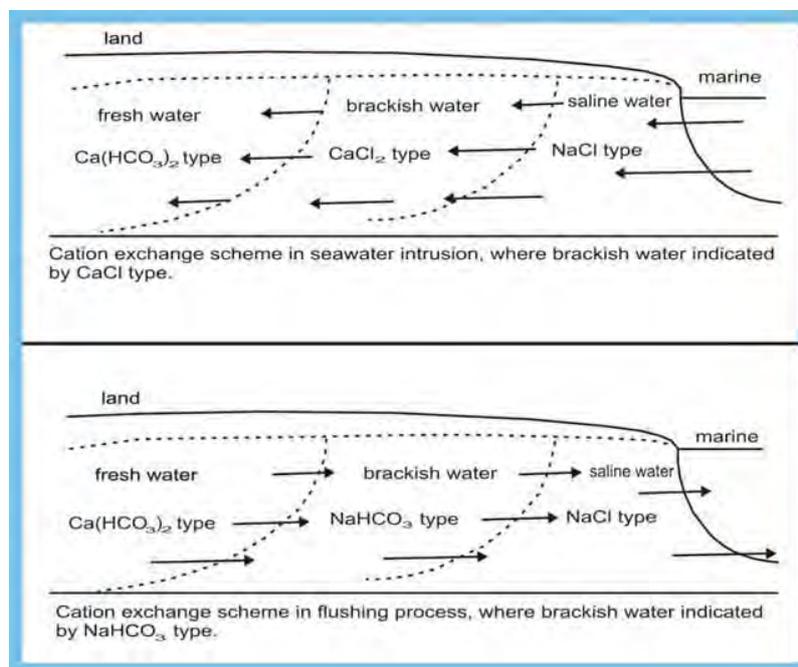


Figure 4. The groundwater chemical type caused by hydrochemical processes in the aquifer [3].

### 3. METHODOLOGY

To answer the problem of the genesis of saline groundwater at Parangtritis, geological field survey has been conducted with an emphasis of hydrogeology. This hydrogeological field survey aims to find the data and the physical properties of groundwater aquifers. The field work was carried out by measurements of groundwater table, completed with groundwater sampling. Mapping of groundwater table is useful to know the general direction of groundwater flow. Then, the groundwater samples should be tested in the chemical laboratory. Furthermore, an hydrochemical and hydrogeological analysis used to answer about the genesis of saline/brackish water in the study area.

### 4. RESULT AND ANALYSIS

#### 4.1. Hydrogeological Analysis

To understand the potential intrusion of seawater we must do shallow groundwater table mapping. By looking at the level of the groundwater table in the Parangtritis area, it has been known that generally groundwater flows direct to southward to the sea, it means that the possibility of seawater intrusion is almost imposible. On the other hand, there may be caused by flushing of saline/seawater by fresh water from the mainland.

The groundwater at Parangtritis Beach flows in the alluvial aquifer, especially in the beach sand deposits that form the plain sand and sand dunes morphology, which are loose, porous and permeable [6]. Groundwater comes from meteoric water, generally has young age (the present groundwater). Under the alluvial deposits, there are Nglanggran Formation breccia and other older aquifers zones. Groundwater is emerging as wells and hot springs in Parangwedang usually flows in this aquifer. The appearance of springs in the area is controlled by the inter-grain and joint/fracture rocks porosity. Groundwater should be mixing of meteoric water, volcanic water and past seawater intrusion. The presence of seawater intrusion is not supported by the present pattern of groundwater flow direction.

#### 4.2. Hydrochemical Analysis

Some groundwater chemistry data related to this paper are summarized in Table 2 below. Sample 1 is the data from the hot springs Parangwedang (T =35oC), the second sample was taken from the wells which is located ± 20 m to the east from spring, with hot temperature (T =45° C). Samples 3 & 4 were taken from dug wells at Parangtritis Beach.

Table 2. The chemical data of groundwater at Parangtritis and vicinity [7,8].

Parameter	Sample			
	1	2	3	4
Cl	6,528.6	7,498	20	23.9
TDS	-	17,500	-	-
Type	Chloride	CaNaCl <sub>2</sub>	NaMg –HCO <sub>3</sub>	CaMg – HCO <sub>3</sub>
Salinity level	Saline	Saline	Fresh (sometimes changes to be brackish)	

The four groundwater samples showed varying levels of salinity. Samples 3 and 4 which were taken from dug wells in Parangtritis indicate fresh water, but sometimes it can be brackish. According to information from the local citizens, water is sometimes saline especially when the tide. Beside the two wells sampled, some dug wells in the study area identified contain brackish water.

The test results showed that the water chemistry of groundwater in Parangwedang is chloride type, characterizing the intrusion of seawater or groundwater chemical evolution in advanced stages. This chemical type of water is usually indicate an old groundwater or groundwater has undergone a long journey and a long time. However, mixing with young meteoric water or the Tertiary volcanic/magmatic water may also occur. Volcanic activity usually enriches the element of chloride in groundwater. Meanwhile, mixing with meteoric water less intensive, characterized by a little bicarbonate ions.

Based on the chemical type, the groundwater in Parangtritis interpreted as the result of freshwater flushing (see mixing models in Figure 4). Seawater intrusion is unlikely in this area because it is not supported by the groundwater flow pattern. Fluctuating of salinity levels caused by the infiltration of seawater below the surface at high tide. It is strongly supported by rocks aquifer consists by loose, fine - medium sand deposits. In summary, the hydrogeological cross-sectional illustration of study area is shown in Figure 5.

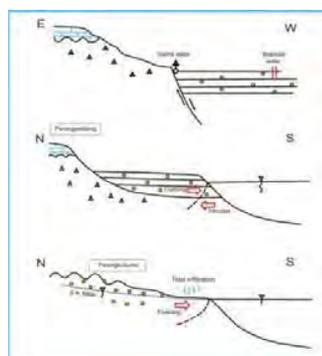


Figure 5. Illustration of aquifer and hydrochemical processes at Parangtritis and its vicinity.

## 5. SUMMARY

The saline/brackish groundwater at Parangtritis and surrounding area found in Parangwedang and Parangtritis Beach. Genesis of saltwater /brackish is different, and can be summarized briefly as follows.

1. Saline water at Parangwedang is originated from mixing of meteoric water and old groundwater, influenced by magmatic activity and the intrusion of seawater through the aquifers.
2. The salinity of groundwater at Parangtritis caused by infiltration of tidal seawater and controlled by the flushing of seawater by fresh water.

## ACKNOWLEDGMENT

This paper is done by compilation of many data, especially based on research which has been funded by Kopertis Region V Yogyakarta in 2008 and 2009, so the author want to give thanks to goverment through Kopertis Region V.

## REFERENCES

- [1] Appelo, C.A.J. & Postma, D., 1996, *Geochemistry, Groundwater and Pollution*, A.A. Balkema, Rotterdam.
- [2] Bronto, S., dan Hartono, H.G, 2001, *Panduan Ekskursi Geologi Kuliah Lapangan 2*, STTNAS, Yogyakarta, unpublished.
- [3] Disbang DKI Jakarta - Sapta Daya Karyatama, 1997, *Observasi Intrusi Air Asin/Laut di Wilayah DKI Jakarta*, Final Report, unpublished.
- [4] Freeze, R.A. dan Cherry, J.A., 1979, *Groundwater*, Prentice-Hall Inc., Englewood Cliffs, New Jersey.
- [5] Matthes, G., 1982, *The Properties of Groundwater*, John Wiley & Sons, Inc.
- [6] Soladopo, F.V., 2007, *Geologi Daerah Kretek dan Sekitarnya serta Kajian Dampak Kerusakan Akibat Gempa di Kecamatan Kretek Kabupaten Bantul, Propinsi Daerah Istimewa Yogyakarta*, Thesis Type I, Geological Dept. STTNAS, Yogyakarta, unpublished.
- [7] Listyani, T., 2008, *Pengaruh Litologi Batuan Samping terhadap Hidrokimia Mataair Panas Parangwedang, Kabupaten Bantul, Daerah Istimewa Yogyakarta*, Final Report, Kopertis Region V, Yogyakarta, unpublished.
- [8] Listyani, T., 2009, *Identifikasi Intrusi Air Laut di Wilayah Gumuk Pasir Parangtritis*, Final Report, Kopertis Region V, Yogyakarta, unpublished.
- [9] Todd, D.K., 1980, *Groundwater Hydrology*, 2<sup>nd</sup> Ed., John Willey & Sons Inc., New York.
- [10] Van Bemmelen, R. W., 1949, *The Geology of Indonesia*, Vol 1A, Martinus Nijhoff, The Hague, Netherland.

## Influence of *Pseudomonas aeruginosa* presence in The Biodegradability Study of Solvent-based and Water-based Dispersant in Oil Spill Handling

<sup>a</sup>S.S.Moersidik, <sup>b</sup>Z.R. Pratiwi, <sup>c</sup>Zulkifliani

<sup>a</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
Tel : (021) 7270029. Fax : (021) 7270028  
E-mail : [ssarwanto@eng.ui.ac.id](mailto:ssarwanto@eng.ui.ac.id)

<sup>b</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
Tel : (021) 7270029. Fax : (021) 7270028  
E-mail : [rpzoraya@gmail.com](mailto:rpzoraya@gmail.com)

<sup>c</sup> Research and Development Centre for Oil and Gas Technology LEMIGAS Cipulir, Jakarta 12230  
Tel:(021) 7228614. Fax : (021) 7246150  
E-mail : [zulkifliani@lemigas.esdm.go.id](mailto:zulkifliani@lemigas.esdm.go.id)

### ABSTRACT

Dispersant reduces interfacial tensions of oil and water turning oil spill into droplets that makes crude oil easier to be degraded by hydrocarbonoclastic bacteria such as *Pseudomonas aeruginosa*. Objective of study is to assess the effect of dispersant utilization (solvent-based and water-based) related its performance efficiency in the presence of *Pseudomonas aeruginosa*. The research was carried out in lab-scale varying the Oil Spill Dispersant (OSD)-oil ratio in 3 levels (1:8, 1:20, 1:25) and carbon source adaptation into 3 levels (0%, 1%, 2%). The total number of samples prepared was 84 consist of 21 samples without *Pseudomonas aeruginosa* addition and 63 samples with *Pseudomonas aeruginosa* addition. Total petroleum hydrocarbon (TPH) measured using gravimetric method to determine the biodegradation of crude oil. Also measured pH samples with *Pseudomonas aeruginosa* addition and COD of samples with dispersant. Data were analysis using ANOVA. The result shows *Pseudomonas aeruginosa* has the ability to degrades crude oil despite the presence of dispersant, whereas the use of water-based dispersant showed better biodegradation ability than solvent-based dispersant usage. Dispersant effectiveness of solvent-based and water-based is 33% and biodegradation by *Pseudomonas aeruginosa* achieved 25% in 72 hours periode.

### Keywords:

Solvent-based Dispersant, Oil-based Dispersant, Contaminated Seawater Remediation, Biodegradability, *Pseudomonas aeruginosa*

**This paper is published in International Journal of Technology (IJTech)**

## Biodegradation of Azo Dye Remazol Black 5 by Mono Culture Bacteria with Tempe Industrial Wastewater as Co-substrate

Puti Sri Komala<sup>a</sup>, Yommi Dewilda<sup>b</sup>, Zilvia Wulandari<sup>c</sup>

<sup>a</sup> Department of Environmental Engineering Andalas University, Padang 25163  
E-mail : putisrikomala@ft.unand.ac.id

<sup>b</sup> Department Environmental Engineering Andalas University, Padang 25163  
E-mail : yommi\_tl@ft.unand.ac.id

<sup>c</sup> Environmental Engineering Andalas University, Padang 25163  
E-mail : laan6190@yahoo.co..id

### ABSTRACT

Azo dye is one of the synthetic organic dye groups most widely used in the textile industry. The release of this component into the environment can be harmful to the living organisms and the ecosystems. Therefore, it is necessary to treat wastewater that contains dye before it is discharged into the water bodies. The decolorization using mono or mixed culture has been developed since decades because environmental friendly and completely mineralization. 16 species of pure culture bacteria derived from aerobic-anoxic membrane bioreactor were used for biodegradation of azo dye Remazol Black 5 using tempe industrial wastewater as co-substrate. The optimum co-substrate concentration for biomass growth under shaking condition was 40% v/v or 2,560-2,720 mg COD/L, while dye decolorization was not significant. The azo dye biodegradation in anaerobic condition showed that dye was decolorized best by Isolate A1A, *Exiguobacterium* sp. A2, and *Bacillus* sp. A4 with efficiency of 43.82%, 29.94% and 35.91% respectively. The highest color degrading bacteria were also the highest organics removing bacteria. It was confirmed that dye decolorization process required carbon source addition.

### Keywords

Azo dye remazol black 5, biodegradation, mono culture, tempe industrial wastewater

**This paper is published in International Journal of Technology (IJTech)**

## Urban Water Management Challenges: Case Study PDAM 'Tirtawening' Bandung

Setyo Sarwanto Moersidik<sup>a</sup>, Djoko M. Hartono<sup>b</sup>, Yusuf Latief MT<sup>c</sup>,  
Rahayu S. Arifin<sup>d</sup>

Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel : (021) 7270011 ext 51. Fax : (021) 7270077  
E-mail :

<sup>a</sup>: smoersidik@yahoo.com ; <sup>b</sup>: djokomh@eng.ui.ac.id, <sup>c</sup>: latief73@eng.ui.ac.id; <sup>d</sup>: rahayu.s.arifin@gmail.com

### ABSTRACT

*The growth of urban public service infrastructure never keep up with their population growth in developing countries. Residential water use (RWU) over half of total municipal water consumption in most urban within developed countries. RWU requires higher quality and reliability, which in turn leads to higher costs. Historically, RWU is directly linked with the health of the general public and is crucial to the well being of a society. RWU shows a strong positive correlation with living standards and is one of the important proxies for economic development. Many factors affect residential water demand. such as water tariff; education level; income; water storage media; water metering; temperature and precipitation; household size, people numbers at a house, house age, number of families in a house, the rise in employment and the number of labor force in urban areas. These attributes and their interrelationship have dynamics characteristic.*

*PDAM Bandung for example, in this last 5 years, the average of the urban water coverage services growth 0.65%, and Bandung municipal population growth is 1.42% per year. Total RWU is 72% from PDAM total water allocation. It serves 1.6 milion (66%) from the total registered population.*

*The water supply capacity is 2706 liter/ second. The water sources are from surface water (86.51%), ground water and springs (13.49%). The production and distribution capacity usage is 84.7%. The non revenue water is decreased, from 50.6% in year 2006 into 38% in year 2010; However, that number is still higher than PDAM target (20%). In financial management point of view, the tariff adjustment is done twice within 10 years and the billing lifecycle always late around 42 days. PDAM Bandung never have profit at all. In human resource performance, an employee serve 5.5 customers in average.*

*The above information is based on previous research. The primary data is obtained thru series of interview with PDAM management. Medium long term and long term plan (RJPM and RJPP) of Bandung municipal and PDAM are treated as the secondary data. PDAM and Bandung Municipal RJPM, RSJPP data are treated as the secondary data.*

*If Bandung population historical data is extrapolated until year 2020, with the current PDAM Bandung performance, Bandung will experience water scarcity in year 2016. and impossible for PDAM Bandung to expanding the coverage services until it reaches 80%.*

*This research is to figure out the current condition of PDAM Bandung, the challenges faced by them and the recommendation to overcome the challenges. This research is part of the overall research which will figure out the dynamics behavior of urban water coverage services expansion programme and to determine the most optimal program to enlarge PDAM coverage services .*

### Keywords

*Bandung Municipal RJPM & RSJPP, Residential Water usage, household, PDAM Bandung, Non Revenue Water.*

## 1. INTRODUCTION

In many part of the Globe, population growth and urbanization are increasingly becoming challenge to governments. According to the information from the International Year of Freshwater (2003), by the year 2020, around 60% of the global population will live in urban areas[26]. Currently, more than 80 countries, with 40% of the global population suffer from severe water shortages. In Asia developing countries, within the last 20 years, the progress of urban water supply program are slow, the comparison between the service coverage with the demand tend to be lower, the average

of non Revenue Water (NRW) is around 35% of production. Water Supplies in Asia will be of greater challenge to government agencies, local administrations and planners in the coming years. Condition in Indonesian cities is growing worse compared to other Asian countries because of tremendous population growth in urban.

Based on BPPSPAM data[3], from 335 total PDAM throughout Indonesia, 144 is categorized as healthy company, 105 less healthy, and sick 86 PDAM. Only 12 PDAM which have service coverage above 80% of population. Total direct connection customers are 7,574,154. The lowest service coverage in regency Seruyan Sulawesi that is 3.8% only. In average, the coverage services of PDAM West Java only 33.25%. By using year 2000 until year 2010 data[3],[25], the coverage services of PDAM Bandung municipality only ranged in 61.1%. The low access to drinking water will cause serious problems not only for individuals, but also for the city and the state. Effort to raise the level of health and economics of the individual and society, and raise the level of education for children and women, will be hampered by the lack of access to drinking water. Conflict between population and economics's losses are happened due to the low access to drinking water. [32],[20] .

The need for water is very dependent on the characteristic of the households of customers, such as number of people in the house, house's age, house's distance to reservoir, number of families in a house, education and income level, water tariff. ([9],[10],[21],[22],[29],[30]). Socio-economic factors including regional economic development, income growth in real estate industry, level of health services, increasement of job opportunities and growth rate of workers in urban areas, use of energy also contribute to the determination of the water needs volume.[5],[7],[24],[27]

The low coverage of drinking water service is influenced by the PDAM's performance, politics, energy, reliability of infrastructure, willingness to pay, water quality, billing system, PDAM operation, human resource's effectiveness, PDAM's financial condition, new distribution investment, and level of customer satisfaction. ([1], [10], [11],[13],[18]). A lot of RWU studies for developed countries are done and produce the research that the water tariff is the main driver to improve demand management. [6]. In developing countries where the economic growth in urban runs rapidly, and not in line with the infrastructure development growth, the main attribute that causes water consumption pattern is not in price factor, but the water sources accessibility.[5]. With a difference of attributes and the interaction among attributes in each study conducted in different cities, drinking water management system can not be generalized for all urban areas.

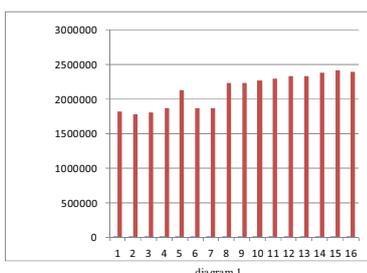
This research reveals the condition of Bandung municipal and its projection as well as the challenges faced by PDAM Bandung to be able to provide drinking water for its residents. This research is the first step of further research: Dynamics Behaviour of PDAM Coverage Services Program.

### 1.1. Bandung Profile.

Population growth is more prevalent in urban areas, as it provides better economic opportunities. Better of education, employment and health facilities in cities, always encourage people to migrate from rural into urban areas, and this has become a major social, environmental and political issue in Indonesia. an example Bandung Municipal.

Bandung city is located in region of West Java and constitute Capital city of Province of west Java. The area of Bandung city divided by a). 26 districts, b). Villages, c). 1498 community associations and d). 9215 neighborhood associations. Population density per km<sup>2</sup> maximum is 38,686 population per km<sup>2</sup>; The population density grow over year with the average growth rate is 0.92%. The population density of Bandung regency region:11.471, Sumedang:1025 and Cimahi: 24,067 population/km<sup>2</sup>. Bandung municipal population is 2,394,873 (58.43%), Cimahi 1091,323 (26.63%) and Sumedang 612,168. (14.94%). [4]

The areas around Bandung being a hinterland. The total population of West Bandung regency, Cimahi and Sumedang reach more than 6 million. With a role as a center for orientation, then the movement of population between the center and the hinterland be intermingled. The reality of the population activities in Bandung municipal are likely to exceed the number of registered residents.



The diagram 1 is a figure of Bandung registered population. The population grow 2.08% annually and the GDP grow 18.84% annually. They make Bandung over crowded. Urban land has become extremely scarce. When viewed from the age structure of Bandung population, the prominent segment is the early working age (25 – 34 years) and the age of higher education (20-24 years). A spike at those ages indicate the migration occurred in Bandung city; i.e. students who continue their studies in Bandung, simultaneously places looking for work as beginners in workforce. he economic structure of Bandung municipal is dominated by the services and process industries sector. Their growth rate is relatively high compared to the national and west java cities. The unemployment rate is around 15%. [4]

The average temperatur of Bandung municipal is 23 C; However, An average of maximum air temperatur in the city rise 2C within last 20 years. This is a significant increase based on world of meteorology assessment. Bandung air quality has exceeded a threshold, especially seen from the levels of dust, HC and Pb. The all locations have HC level that has surpassed the quality threshold. This condition might be as an impact of the vehicle growth which is 12% per year. Currently, Bandung transportation are facing serious problems and is increasingly become a major threat in the future, if there is no significant inroads. Moreover, some irregular business development locations and so much garbage from domestic which is not be able to transported spread on streets.

By so complex condition and the high pace of growth, Bandung municipal public services become bogged down, city management is often ineffectual, human misery has increased beyond imagination. The urban infrastructure has become outdated. The similar challenges faced by PDAM Bandung as well.[4]

## 1.2. Perusahaan Daerah Air Minum (PDAM) Bandung

### 1.2.1. Water Supply

Water Supply	Production capacity (l/s)	Production actual (l/s)	idle
<b>Surface water</b>			
IPA Badak singa	1800	1783.98	16.02
IPA Dago Pakar	600	595.25	4.75
MP Dago Pakar	40	42.78	-
MP Cibeureum	40	34.75	5.25
MP Cipanjalu	15	15.49	
MP Cirateun	0	0	
<b>Ground water</b>	221	111.63	109.37
<b>Springs</b>	216	123	93
<b>Total</b>	<b>2937</b>	<b>2706.88</b>	<b>230.12</b>

diagram 2

The supply of water for drinking in Bandung municipal are filled by domestic drilling and partly served by PDAM. PDAM water sources are obtained from the surface water and ground water. PDAM use the 10 water springs and 19 wells to pump out the ground water. They flow into the reservoir.[17]. Water shall meet a certain conditions in order to be eligible for consumption and can be used to meet daily needs.. The conditions that must be met in the services of PDAM are: quality, quantity and continuity. Water quality standard comprise of physical, chemical and biology quality standard that are regulated by ministry of health: No. 417/MENKES/PER/IX/2002. PDAM use the chemistry material to penetrate the water quality and . its impacted to the PDAM operational cost (OPEX).

### 1.2.2. Water Treatment and Distribution

PDAM has 2 water treatment instalation units. They serve 4 regions, i.e. western, northern, central and eastern of Bandung area. PDAM use the gravitation system to intake the surface water, and pump system to obtain the ground water. To accomodate the water processed, PDAM has 6 reservoirs with total capacity 42,600 m3. Although the IPA operate 24 hours, the distribution operation only lasted 15 hours a day. This is because the water supply is not stable, very low supply especially during the dry season. This limited water supply insist PDAM require a waiver to its new customers not to insist on PDAM, if PDAM service is not optimal. An affidavit must be signed off by the prospective new customer as a condition when they apply a new connection. [17],[25]

### 1.2.3. Idle Capacity, Non Revenue Water (NRW), Customer and employees

Description	Volume (m3)
<b>production capacit (liter/ second)</b>	
installed production capacity	92,621,232.00
Actual production capacity	75,166,458.00
Idle capacity (*1)	17,454,774.00
<b>Distribution Volume</b>	
Actual Production volume	75,166,458.00
Production loss	(11,880,456.00)
total distribution volume	63,286,002.00
Billable volume	33,202,155.00
Non Billable water	30,083,847.00
<b>Non Revenue Water (NRW)</b>	
NRW to distribution volume	15.81%
NRW to distribution volume	47.54%
NRW water to actual production volume	55.83%

diagram 3: source from PDAM Tirtawening Kota Bandung, 2009

The idle capacity (\*1) is happened because the lack of potential customers in several branches of the unit or there is no distribution network installed around the water sources. In year 2009, the percentage of leakage in PDAM Bandung's water distribution system reach 56% from its total production capacity. This is too high as based on BPPSPAM rule, the tolerable level of leakage on a water distribution system is approximately 18%-20%. This NRW rate can be calculated from the difference between the amount of water that is distributed by PDAM with the amount of water that is paid by the customer. The leakage level consist of the physical and non physical. The physical leakage is caused by the leakage of pipes and or its equipment, while the non physical leakage is caused by water's theft, the unregistered and unregulated connection, meter's accuracy is low or error in reading water meter as well as error in billing system. Many cases of RWU such as, about 30,000 direct conection (DC) with 0 m3 and about 60,000 DC RWU volume that are less than as usual. Its

predicted the number of non physical leakage exceed from physical leakage.

The total customer of PDAM Bandung in year 2011 is 150,236 DC, comprise of active subscribers 150,236 DC, 126, 442 DC, Social 2109 DC, Commercial 18,786 DC, industries 473 DC and government agencies 2427 DC. Total employee of PDAM is 824 people, consist of national servants 15, PDAM permanent employee, honorary employee 3, contracted employee are 4. [17]

### 1.2.4. PDAM Revenue and Cost

Based on Data from Perpamsi year 2011, operational cost of PDAM Bandung before depreciation and interest rate is 153,791,909,156 IDR. OPEX after depreciation and interest rate is 160,176,796,912 IDR and the revenue of PDAM is 159,416,126,802 IDR. It means PDAM Tirtawening does not have profit at all.[14],[17],[25]

## 2. METHODOLOGY

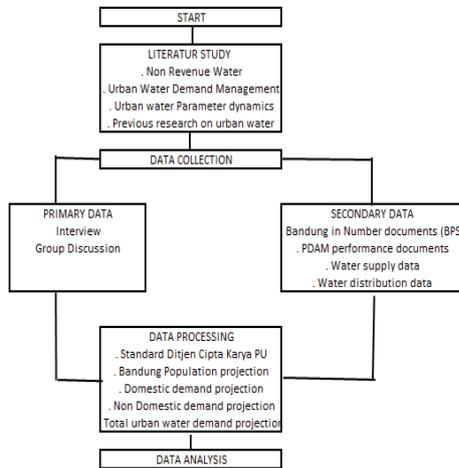


diagram 4. Methodology

Literature study was done by collecting all journals relating to the urban water management system, its challenges faced by developed countries as well as developing countries and Asian cities. The attributes that influence demand and supply of Residential Water Usage (RWU) are identified. The attributes behaviour resulted from the previous researches are assessed. The interrelationship among researches results are identified. The attributes that are not covered in the previous urban water and residential water usage researches are defined. The journals that pertain to water leakage problem in order to overcome the leakage issue on are gathered as well. Primary data is obtained by conducting interview and discussions with the water system experts from ITB, UI, BPPSPAM, and Public Work key players as well as PDAM Bandung key players and their top management. Informal discussion also held with Bapeda, Pusat Air Bandung. Secondary data were obtained from historical data of PDAM as well as from BPS Bandung. BPS data more concentrate on figure of Bandung's temperature, GDP, population, employment level, non domestic figures. while PDAM data contain performance of PDAM since year 1996 until year 2011. Diagram 4 figure out the research methodology

## 3. DATA PROCESSING, ANALYSIS AND DISCUSSIONS

### 3.1. Projection of Residential / Domestic Water Demand

Year	Arithmetic approach	Geometric approach	Population projection	Household Connection Demand	Public Hydrant	total domestic demand (liter/year)	total domestic demand (liter/second)
2011	13,043,048,494	13,010,793,673	13,026,921,083	91,783,507,725	7,867,157,805	99,650,665,530	3160
2012	13,394,047,521	13,155,633,001	13,274,840,261	93,475,089,390	8,012,150,519	101,487,239,910	3218
2013	13,920,546,061	13,302,084,715	13,611,315,388	95,186,525,664	8,158,845,057	103,345,370,721	3277
2014	14,622,544,116	13,450,166,765	14,036,355,440	96,918,229,522	8,307,276,816	105,225,506,338	3337
2015	15,500,041,683	13,599,897,301	14,549,969,492	98,670,622,530	8,457,481,931	107,128,104,461	3397
2016	16,553,038,764	13,751,294,674	15,152,166,719	100,444,135,022	8,609,497,288	109,053,632,310	3458
2017	17,781,535,359	13,904,377,439	15,842,956,399	102,239,206,284	8,763,360,539	111,002,566,823	3520
2018	19,185,531,467	14,059,164,359	16,622,347,913	104,056,284,738	8,919,110,120	112,975,394,858	3582
2019	20,765,027,089	14,215,674,405	17,490,350,747	105,895,828,134	9,076,785,269	114,972,613,402	3646
2020	22,520,022,224	14,373,926,758	18,446,974,491	107,758,303,741	9,236,426,035	116,994,729,776	3710
2021	24,450,516,873	14,533,940,816	19,492,228,844	109,644,188,552	9,398,073,304	119,042,261,856	3775
2022	26,556,511,035	14,695,736,189	20,626,123,612	111,553,969,476	9,561,768,812	121,115,738,288	3841
2023	28,838,004,711	14,859,332,707	21,848,668,709	113,488,143,553	9,727,555,162	123,215,698,714	3907
2024	31,294,997,900	15,024,750,422	23,159,874,161	115,447,218,160	9,895,475,842	125,342,694,003	3975
2025	33,927,490,603	15,192,009,607	24,559,750,105	117,431,711,229	10,065,575,248	127,497,286,478	4043

Tabel 1 : Domestic (household and public hydrant connections) demand with the 80% service level

domestic demand is figure out at tabel 1.

### 3.2. Non Domestic Segments

Year	Population	Worship places	Student at school	Student at univ	Big hospital	Small clinic	Hotel (bed)	Commerci- als places	Industry	Total Non Domestic Demand (l/year)	Total Non Domestic Demand (l/second)
2010	2,417,288	4006	468,669	84,888	32	237	11,184	778	147,606	12,867,548,980	408
2009	2,374,198	4004	260,534	135,494	32	237	11,184	717	104,781	11,899,807,533	377
2008	2,329,928	4002	142,935	135,494	10	248	10,635	657	163,633	10,903,136,459	346
2007	2,329,928	4001	350,450	160,870	0	276	10,635	596	171,427	12,069,239,031	383
2006	2,296,848	3999	447,556	180,565	0	428	10,635	535	179,222	12,677,624,889	402
2005	2,270,970	4110	445,985	214,643	30	580	7,870	474	123,747	11,901,002,058	377
2004	2,232,624	4106	475,423	212,707	29	604	13,410	414	125,601	13,905,296,124	441
2003	2,228,268	4131	460,354	171,993	33	409	11,965	353	223,254	12,732,057,869	404
2002	1,867,010	4116	450,253	165,483	27	409	11,965	292	285,137	12,437,173,719	394
2001	1,868,913	3994	454,496	86,536	29	378	11,965	231	304,915	11,602,435,297	368
2000	2,136,260	3994	482,595	53,606	22	352	11,983	110	152,056	11,112,553,845	352

tabel 2. non domestic places

Diagram 1 is a description of Bandung municipal population from year 1996 up to the year 2011. The growth rate can be derived from those data. The population projection can be obtained by Geometric, Exponential & arithmetic approaches. Based on Ditjen Cipta Karya PU standard, a city that has population above 1 million, has minimum 150 liters water consumption per persons per day. The comparison between household and public hydrant connections are 70:30 and the consumption of people who use public hydrant is 20 - 40 l/ person / day. (The hydrant supply 30 l/person/ day in the above calculation). the projection of

A city always has a commercial and industries as well as public places. They are established as an employment as well as the fulfillment of the daily needs of the population. tabel 2 figure out the BPS data of commercial and public places number from year 2000 - 2010. The water demand of non domestic segment can be calculated using Ditjen Cipta-karya PU standard.

### 3.3. Projection of Urban water demand

From the BPS data figure out at tabel 2 above, the water demand of each non domestic places can be calculated using Ditjen Cipatakarrya PU standard. The projection of the water demand for year 2011 – 2025 can be derived from the water demand figure, using the same approaches. The tabel 3 below is a projection of the total urban water demand figure for year 2011 – 2025. Based this the figure, and the water capacity figured out at diagram 2, at this current time, PDAM Bandung could not able to deliver the 80% service level. (80% is the PDAM Bandung target in order to fulfill the MDG standard).

Year	Gemotric approach	Population projection	total domestic demand (liter/ second)	total non domestic demand (l/second)	Total demand (100 service level)	80 % service level	72% service level
2011	13,010,793,673	13,026,921,083	3160	408	3568	2854	2569
2012	13,155,633,001	13,274,840,261	3218	413	3631	2905	2614
2013	13,302,084,715	13,611,315,388	3277	421	3698	2958	2663
2014	13,450,166,765	14,036,355,440	3337	432	3768	3015	2713
2015	13,599,897,301	14,549,969,492	3397	445	3842	3074	2766
2016	13,751,294,674	15,152,166,719	3458	461	3919	3136	2822
2017	13,904,377,439	15,842,956,399	3520	480	4000	3200	2880
2018	14,059,164,359	16,622,347,913	3582	502	4085	3268	2941
2019	14,215,674,405	17,490,350,747	3646	527	4173	3338	3004
2020	14,373,926,758	18,446,974,491	3710	555	4264	3412	3070
2021	14,533,940,816	19,492,228,844	3775	585	4360	3488	3139
2022	14,695,736,189	20,626,123,612	3841	618	4459	3567	3210
2023	14,859,332,707	21,848,668,709	3907	654	4561	3649	3284
2024	15,024,750,422	23,159,874,161	3975	693	4667	3734	3361
2025	15,192,009,607	24,559,750,105	4043	734	4777	3822	3440

tabel 3. Urban water demand

### 3.4. Non Revenue Water

Year	Distributed volume (m3)	Billed Volume (m3)	Billed in %	NRW in %
1,995	68,368,977	37,525,943	54.89%	45.11%
1,996	68,123,035	37,390,952	54.89%	45.11%
1,997	70,113,132	38,483,264	54.89%	45.11%
1,998	71,067,511	38,469,520	54.13%	45.87%
1,999	74,552,593	39,634,852	53.16%	46.84%
2,000	74,270,653	40,228,096	54.16%	45.84%
2,001	75,124,000	41,751,699	55.58%	44.42%
2,002	77,902,342	35,828,311	45.99%	54.01%
2,003	79,522,079	33,508,022	42.14%	57.86%
2,004	79,927,566	33,013,954	41.30%	58.70%
2,005	79,927,566	33,013,954	41.30%	58.70%
2,006	84,746,149	34,295,686	40.47%	59.53%
2,007	82,955,111	33,508,022	40.39%	59.61%
2,008	83,646,580	33,508,022	40.06%	59.94%
2,009	83,646,580	33,013,954	39.47%	60.53%
2,010	79,176,222	35888185	45.33%	54.67%
2,011	79,132,469	43,617,254	55.12%	44.88%

Non Revenue Water data is very difficult to be obtained. The NRW amount can be derived by subtracting the amount of distributed water to residential by the amount of water that is paid by residential. Tabel 5 describe the NRW profile.

From the results of an interview with PDAM management, the leakage in administration type is larger than the physical leakage. The administration leakage is a). The metter accuracy. b). Wild/ unregistered connection, c). Theft. d). Error in reading and data handling [2]. A follow up interview with the PDAM management has strong indications that the administration leakage case has greater than physical leakage. Currently, there are several accounts have zero water usage. Among that number, 51,522 account from business, such as hotels and restaurants. Beside that, there are about 21% from 140,000 PDAM customers who use water less than 10 m3 per year. These leakage cases give impact in lost revenue to PDAM until 82.200 milyar IDR.

## 4. CONCLUSIONS

The study reveals that water shortage is increasingly becoming a serious issue in Bandung municipal. Demand has been growing fast linear with the growth of population while the water availability is fast decreasing due to pollution, land use changes, shared water supply with Bandung hinterlands that are developing very rapidly aswell. Both surface and spring water in the city have been polluted. The Ground water supply considerably reduced due to the presence of the ground water are more deeper or dry.

Since at this present time, amount of water supply and the maintenance of the delivery system are quite inadequate. Suggestions for 1). Control properly the production system and 2). Control properly the non revenue water. To implement this suggestion, PDAM should do a technical audit to make sure the all equipment run well, especially to check the loss amount from water supply to production and water production to water distribution. This activity might cover the installation a monitor system in the input and output of production system, to make sure that the production

output volume match with the distribution input volume. Proper and timely maintenance of the public water system, Control of unauthorized use of public water, proper filtering of tanks, Reducing water loss in distribution system. Reward and penalty system to manage PDAM human resources especially to eliminate the administration water leakage. [8],[15],[16],[19],[23]

Since the the water supply is coming from the hinterland area which is outside of Bandung Municipal authority, the joint strategy and implementation with the hinterland's PDAM should be done effectively.

After all, there should be a strong government policy for urban water management, an appropriate adaptation strategy and a political will to implement the strategy.

## 5. RECOMMENDATION

This study of the PDAM challenge should be continued by the subsequent research so that the management model of PDAM to enlarge services to their customer can be achieved and can be applied in all PDAM, especially PDAM Bandung. It should be noted that the all attributes that affect the PDAM management such as, population, income, education, water supply, NRW, climate, number of city infrastructure are very dynamics. Model that is projecting the balance between demand and supply of drinking water should be developed with considering the dynamics of those attributes and the dynamics intensity of attribute interrelationship.[5],[8],[28]. The simple regression for attributes projection with ignoring the dynamics behaviour of attributes and their interconnection will produce a model of PDAM management that does not solve the PDAM challenges.

## REFERENCES

- [1] Abdelnaser OMRAN, FACTORS INFLUENCING WATER TREATMENT MANAGEMENT PERFORMANCE IN, ANNALS OF FACULTY ENGINEERING HUNEDOARA – International Journal Of Engineering, Romania, 2011
- [2] Alan S. Wyatt, Non-Revenue Water: tFinancial Model for Optimal Management in Developing Countries, RTI Press, 2010
- [3] Badan Pendukung Pengembangan Sistem Penyediaan Air Minum, Kinerja PDAM tahun 2008 – 2010, Kementerian Pekerjaan Umum.
- [4] Badan Pusat Statistik Kota Bandung, Bandung Dalam Angka 1999 – 2011
- [5] Cheng Qi, Ni-Bin Chang, 'System dynamics modeling for municipal water demand estimation in an urban region under uncertain economic impacts', Journal of Environmental Management 92 (2011)
- [6] Charles W. Howe, F. P. Linaweaver Jr, The impact of price on residential water demand and its relation to system design and price structure, Water Resources Research, Volume 3, Issue 1, pages 13–32, January 1967
- [7] Daniel Van Rooijen, Managing Water at the urban – rural interface: the key to climate change to resilient cities, ILRI campus Addis Ababa, 2010
- [8] Dale Whittington, John Briscoe, Xinming Mu, William Barron, Estimating the Willingness to Pay for Water Services in Developing Countries: A Case Study of the Use of Contingent Valuation Surveys in Southern Haiti, <http://www.jstor.org/stable/1154028>, 2012
- [9] David Hall, Emanuele Lobina and Robin de la Motte, Public resistance to privatisation in water and energy, Development in Practice, Volume 15, Numbers 3 & 4, June 2005
- [10] Dinusha Dharmaratna and Jaai Parasnis, Price Responsiveness of Residential, Industrial and Commercial Water Demand in Sri Lanka, Monash University, Business and Economics, 2010
- [11] E.G. Kolokytha, Y.A. Mylopoulos, A.K. Mentis, Evaluating demand management aspects of urban water policy—A field survey in the city of Thessaloniki, Greece, Urban Water 4 (2002) 391–400
- [12] Fernando Arbue's and Ramo'n Barbera'n, Price impact on urban residential water demand: A dynamic panel data approach, WATER RESOURCES RESEARCH, VOL. 40, W11402, doi:10.1029/2004WR003092, 2004
- [13] Francisco Gonzales-Gomez, Andres J. Picazo, Tadeo, Jorge Guardiola, Why Do Local Government Privatize the Provision of Water Services? empirical evidence from Spain, Public Administration, Volume 89, Issue 2, pages 471–492, June 2011
- [14] Hasan Lutfi , Tunggakan Pinjaman Perusahaan Daerah Air Minum Terhadap Pemerintah Pusat, Fakultas Hukum Magister Hukum, Hukum Keuangan Negara, Jakarta, Januari 2010
- [15] Henry H. Zhanga, David F. Brown, Understanding urban residential water use in, Beijing and Tianjin, China, Habitat International 29 (2005) 469–491, Elsevier
- [16] Jason Morrison, Mari Morikawa, Michael Murphy, Peter Schulte , Water Scarcity & Climate Change, Growing Risks for Businesses & Investors, the Pacific Institute, February 2000
- [17] Laporan Hasil Audit Kinerja Atas Perusahaan Daerah Air Minum (PDAM) Kota Bandung, Tahun Buku 1995 – 2010

- [18] Laurent Hardy, Alberto Garrido, Luis Juana, Evaluation of Spain's Water-Energy Nexus, *International Journal of Water Resources Development*, 30 Jan 2012
- [19] Malcolm Farley, Roland Liemberger, Malcolm Farley, *The Manager's Non-Revenue Water Handbook*, 2008, , Developing a Non-Revenue Water Reduction Strategy, Part 1: Investigating and Assessing Water Losses
- [20] Marion W. Jenkins, Jay R. Lund, and Richard E. Howitt, ECONOMIC LOSSES FOR URBAN WATER SCARCITY IN CALIFORNIA, University of California, Davis Davis, CA 95616
- [21] Mary E. Renwick and Sandra O. Archibald, Demand Side Management Policies for Residential Water Use: Who Bears the Conservation Burden?, *The Board of Regents of the University of Wisconsin System, Land Economics*, Vol. 74, No. 3 (Aug., 1998), pp. 343-359
- [22] MICHAEL L. NIESWIADOMY, Estimating Urban Residential Water Demand' Effects of Price Structure, Conservation, and Education, *WATER RESOURCES RESEARCH*, VOL. 28, NO. 3, PAGES 609--615, MARCH 1992
- [23] Michael Ward and Chris White, Managing residential water demand in the OECD, Australian National University (ANU), An Analysis of Eight California Water Agencies', *Water Resources Center University of Minnesota*, St. Paul, Minnesota 55108-6040, 1999
- [24] Mohammad Khaled Akhtar, A SYSTEM DYNAMICS BASED INTEGRATED ASSESSMENT MODELLING OF GLOBAL-REGIONAL CLIMATE CHANGE: A MODEL FOR ANALYZING THE BEHAVIOUR OF THE SOCIAL-ENERGY-ECONOMY-CLIMATE SYSTEM, The School of Graduate and Postdoctoral Studies, University of Western Ontario London, Ontario, Canada, 2011
- [25] Rencana Induk Air Minum PDAM Tirtawening Kota Bandung – Laporan akhir dari PT. Zonasi Konsultan. Tahun 2009.
- [26] Shadananan Nair, Challenges in urban water management in a changing environment – case study from a growing tropical city, Nansen Environmental Research Centre – India, Gopal Residency, Thottakkat, Road, Kochi-682011, Kerala, India (Email: [nair59@yahoo.com](mailto:nair59@yahoo.com))
- [27] R. Quentin Grafton, Michael B. Ward, Hang To, Tom Kompas, Determinants of Residential Water Consumption: Evidence and Analysis from a Ten-country Household Survey, *Water Resources Research*, 47, W08537, doi:10.1029/2010WR009685
- [28] Slobodan P. Simonovic, Assessment of Water Resources Through System Dynamics Simulation: From Global Issues to Regional Solutions, Department of Civil and Environmental Engineering, The University of Western Ontario, London, Canada
- [29] Sheila M. Cavanagh, W. Michael Hanemann, and Robert N. Stavins, Muffled Price Signals: Household Water Demand, Under Increasing-Block Prices, December 31, 2001
- [30] Steven Blake Thomas, Examining Impacts on Water Demand Resulting from Population and Employment Growth Using a Regional Adjustment Model, *University of Tennessee - Knoxville*, [sthoma57@utk.edu](mailto:sthoma57@utk.edu), May 2012
- [31] Tatiana Borisova, Colin Rawls, and Damian Adams, Balancing Urban Water Demand and Supply in Florida, Overview of Tools Available to Water Managers1, university of Florida, 2
- [32] Tiaji Salaam-Blyther, Global Access to Clean Drinking Water and Sanitation: U.S. and International Programs, September 10, 2012, Congressional Research Services

## Sedimentation and Water Pollution Control Systems Engineering To Prevent Upwelling in Cirata Reservoir West Java, Indonesia

<sup>a</sup>Kholil, <sup>b</sup>AniWidayati, <sup>c</sup>Linda Noviana

<sup>a</sup>Department of Environment University of Sahid Jakarta, Indonesia  
 kholil2005@yahoo.com

<sup>b</sup>Research Agency Ministry of Marine and Fisheries of the Republic of Indonesia  
 Linda.Noviana @ yahoo.com

<sup>c</sup>Department of Environment University of Sahid Jakarta, Indonesia  
 ani@yahoo.com

### ABSTRACT

Cirata reservoir which covers 6000 hectares is one of the 800 reservoirs in Indonesia which has 2 very strategic function, economic and ecological functions. The most dominant of economic function are (1) source of water for hydro electric power plant (HEP) to meet the electricity needs of Java and Bali. of total water volume 2,160,000,000 m<sup>3</sup> it is expected for producing 1008 megawatt (MW) power and (2) place of fish farming for the local community with the floating cage net system (Keramba Jaring Apung : KJA). While the most important of ecological function are (1) water balance system and micro-climate, and (2) water sources of irrigation. The biggest problems of Cirata reservoir today is the height of sedimentation and degradation of water quality due to pollution of water reservoirs caused by the growth of floating cage net (KJA) out of control, as a result is upwelling that makes massively the fish deaths and disorders of the turbine power plants.

This paper describes selection the best strategy of sedimentation and water pollution control in accordance with the objective conditions of local community using AHP method.

#### Keywords:

Floating cage net (KJA), sedimentation, water pollution, upwelling, AHP method.

### 1. BACKGROUND

Cirata Reservoir is one of the biggest reservoir in West Java which has a vital function for the Jakarta, Bekasi, Cianjur and Karawang, since the reservoir has a economic and ecological functions. According to documents released by BPWC (Cirata Reservoir Management Board) in 2010, Cirata Reservoir which established in 1988 has completely 6,200 hectares which derives from 28 villages and of 8 counties that includes 3 municipality : Cianjur, Purwakarta and Bandung. Water capacity is roughly about 2.160.000.000 m<sup>3</sup>, with a depth average of 34,9 m, maximum depth can reach 106m. Most ultimate economical function is working as Water Power Electrical Generator/hydro power to provide electric power for 1008 MW to supply Bali and Java electric power need (BPWC 2003).

In addition Cirata reservoir is also become breadwinner for 50.000 families through fish farming activities with a floating cage net system (Keramba Jaring Apung : KJA). At the time of the inauguration in 1988 the number of KJA 12.000 involving 4000 people. During 24 years periods (1988-2012) the number of KJA has reached about 53.000 (average increase of 14.32% per year), and the number of households who are directly involved about 50,000 people as both a guard labor of KJA, and other workers or porters.

KJA is a pool of fish farming which is made of nets and placed in the water, it is allowed an exchange of water from the KJA to the surrounding areas. One unit of KJA consists 4 pools and a guard house, the size of each pool is 7x7 m<sup>2</sup> or with a total area is 15.8x15.8m<sup>2</sup>. Fish farming with KJA is an intensive system, three times feeding a day some even more. Feed fish are given only about 30-50% are used and the rest went into the water as a sediment and pollutant source of water (Midlen and Redding: 2000). Accumulation of sediment and water pollution will cause upwelling, which causes mass of fish deaths.

Cirata reservoir is also become a tourism destination that attracts many tourists for touring the reservoir using speed boat whilst enjoying the panorama scene, whereas the first function of ecological side is as water balance, the source of raw water and water supply for farming and plantation irrigation for Cianjur, Purwakarta, Karawang, Bekasi and Jakarta.

Cirata reservoir issues faced at the moment is the height of sedimentation and degradation water quality due to pollution of water reservoirs caused by uncontrolled growth of KJA. Estimated the current number of KJA reached 53.000, beyond the amount allowed for around 12 -15 thousand of KJA. (Cirata Reservoir Management Board, 2012).

Sedimentation is occurred because of erosion, solid waste of industry and accumulated sediment remnants of fish feed due to the rising number of KJA. While water pollution was caused by increasing polluting agent particularly BOD (*Biological Oxygen Demand*), COD (*Chemical Oxygen Demand*), Amonia and Phosphate of industry waste and household garbage around the reservoir. Pollution of water has induced a corrosion to hydro power plant turbine and it would give an impact to electrical power resulted. In addition, it will also encourage an *upwelling*, the reversal of the toxic lower layers to the upper layers that caused a death of thousand tones of fish, so that fish farmers suffered huge losses. This was occurred in 2010 when death of the fish reach 150 tons with the lost of 2,25 billion rupiah (Cirata Reservoir Management Board; 2010).

The Most urgent problem that should be resolved is how to control the growth of KJA and managing existing KJA, so that sedimentation can be reduced and water quality is maintained. Therefore in order to control KJA growth and maintain water quality for avoiding upwelling, this research is required. The purpose of this research is to select the best strategy for controlling sedimentation and water quality of reservoir in accordance with objective condition of community around using AHP method.

## 2. Literature Review

### 2.1 Reservoir Function

Reservoir has a very strategic role in supporting human life as water resources, or water balance. There are 2 main functions; economics, and ecological functions. Water resource availability has a significant role in constructing a regional economy. Limited water resource in area which had an implication to this activity that will give an impact to people prosperity. The existency of reservoir has giving an economical benefit, especially for irrigation, water resource and electrical generator/hydro power plant. This is main function of economics. On the other side ecological function of the reservoir is micro-climate control, water balance for the surrounding areas. Besides two functions, reservoir also been attractive tourist destination. Some reservoirs that have become a tourist destination: Saguling, Kedung Ombo, Reservoir Dharma etc. In addition the existence of this reservoir has also become a fish farming place for local community through floating cage net (KJA) system. Reservoir can also be interesting tourism object from social aspect, while from ecological aspect this reservoir can give many function as water balance system, and flood controlling (Kartamiharja, 1998).

Act No.7 of 2004 on Water Resources explained that the management of the reservoir/lake has 3 main components, namely: (1) for conservation, (2) for the utilization of water resources, and (3) for flood control. Many related regulation or another law namely : Government Regulation No.51 of 1997, on the Environment; Regulation No.82 of 2001 on the Management of Water Quality and Water Pollution Control; Regulation No.32 of 1990 on Protected Areas; Presidential regulation No.123/2001 Coordination of Water Resources Management at the provincial level, the River Region, Municipality and City.

In the beginning of its establishment in 1998, KJA is only 21,000, nevertheless, according to Krismono (1999) KJA development in Cirata Reservoir will reach to 140% in short time (1988 – 1994). In 2012 KJA has reached number of 53,000 by estimation owner around 3500 people ( Cirata Reservoir Management Board, 2012). KJA development for 25 years (1987-2012) as the following table :

Table 1. KJA number and percentage which active and inactive (2012)

Region	Farmers	Floating Net Keramba ( KJA)				
	Number	Number	Active	Inactive	SPL (%)	NON SPL (%)
Bandung	1,198	21,766	21,314	45	9.0	91.0
Purwakata	492	10,104	8,643	1,461	7.6	92.4
Cianjur	821	21,161	18,634	2,527	12.7	87.3
TOTAL	2,511	53,031	48,591	4,033	10.4	89.6

Description : SPL (Site license /Location permit) ,

Non SPL : Non location permit

Source : Cirata Reservoir Management Board (2012)

Based on the table above, it appears that most of the cages are not licensed or illegal. There only 10.4 % had allocation permit and most of the rest (89.6 %) are do not have permission.

One of the factor caused the KJA increase rapidly and uncontrolled is weak of licencing system. Despite licence procedure has been made, nevertheless, since Cirata Reservoir is consist of 3 administrative region (Bandung, Cianjur and Purwakarta), this implementation is still low (Cirata Reservoir Management Board, 2011). In addition almost of people consider that Cirata Reservoir is belonged to them, so as anybody can use or exploit it (Widayati, D. Setyanto, D.G Bengendam Kholil, 2011).. According to Bromley (1991), Scott and Gordon (1988) and Hardin (1988) in S Hanna and Munasinghe (ed) (1995) claim that usage of natural resources without management and controlling in a long term tends to be "The tragedy of the commons" (Medow, 1977 and Kim, 1988) which had given an impact to environment damage. The best way to overcome the tragedy of the common is by constructing a regulation to manage and regulate natural resource usages (Medow, 1977 and Kim 1988).

## 2.2 Floating Cage Net (KJA) of fish farming system

Fish farming system by Floating Cage Net (KJA) is cultivation system which is technically and economically efficient. Since it don't take much cost and space but the results is multiplied. The fish placed in the water bounded by net to form the pool of 7 x 7 meters, so water circulation running smoothly and feeding is done 3 times a day. Fish farming system through KJA is frequently conducted at reservoir or lake. Hardjamulia (1991) claim that fish farming activities at reservoir is one of alternative way to use water resources of reservoir. KJA system has already begun in Indonesia since 1974 at Jatiluhur reservoir, then expanded to another reservoir such as Saguling Reservoir, Cirata Reservoir, Wonogiri Reservoir and Kedung Ombo Reservoir, because the results are doubled, then the growth of KJA is very high in all these reservoirs (Dahuri 1996).

KJA growth in Cirata reservoir already exceeded the amount allowed 12 000, during 25 years the number of KJA shown in figure below (Cirata Reservoir Management Board, 2012).

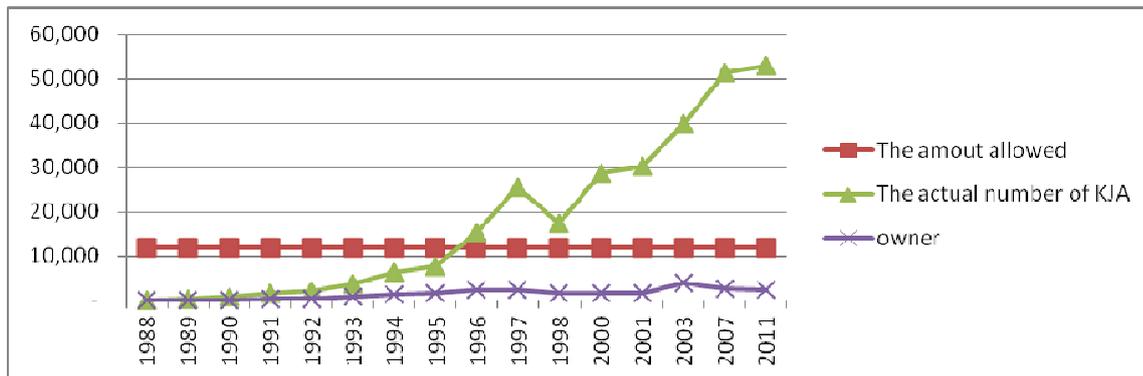


Figure 1. KJA

growth during 24 years (1988-2011), (Cirata Reservoir Management Board, 2012)

## 2.3 Reservoir Issue

Cirata Reservoir is a collection of 5 Citarum creek rivers: Cimeta, Citarum, Cisokan, Cikundul, and Cibalong flowing through settlements, agriculture, and industry. Suhata (2010) stated that increased sedimentation at Cirata reservoir has far exceeded planning design so the sedimentation in 2007 is reached to 146 million cubic meters, with an average rate of 3.9 millimeters sediment/year. The average rate is about three times faster than the average rate of just planning to reach 1.2 millimeters/year. Annual increased sediment in Cirata reservoir estimated 7.3 million cubic meters, over 2 million cubic meters of design made 5.30 million cubic meters. It will have an impact decreasing reservoir age of 20 years planned (Citarum Reservoir Management Board, 2010)

The feed given to the fish in the floating cage net (KJA) systems were used only 60-70%, the remaining of 40% into waters. Estimated the rest of feed into the water contain 10% of P and 65% N in the dissolved form, whereas 65% P and 10% N in the form of particles (Kartamiharja, 1998). Peace (2011) stated that increased sedimentation caused by blue algae has reduced the volume of water in the lake Kansas America. Kishiwai (2011) also stated that sedimentation has caused some reduction in the volume of water in the reservoir in Japan.

The impact of reservoir water pollution due to the residual contamination of feed and waste are the upwelling. It usually occurs regularly, especially at the beginning of the rainy season when the weather is overcast, with the sun very low

intensity. Upwelling can be divided into 3 types, namely (1) permanent upwelling, where it occur all over the year, such as in Ivory and Peru. (2) upwelling periodically, as in the northwest coast of Australia, and (3) successive upwelling (alternating type), Hardjamulia (1991) and Dahuri, (1996),

### 2.3. Metode AHP

AHP (Analytical Hierarchy Process) is an expert-based approach that can be used to select the best choice of many choices based on multiple criteria. The basic principle of this method is structuring a complex problem into simpler in the form of hierarchy, through pairwise comparisons by experts, so that it becomes easy to select the best. Saaty (1988) stated that through the structuring and pairwise comparisons, AHP method make us able to identify a hierarchy of options based on multiple criteria, and making it easy to determine the best option.

There are four main principles of AHP method, (1) Decomposition, dividing a whole problem into smaller elements, (2) Pairwise Comparison Judgment, making judgments about the relative importance of two elements in a certain level to the higher rating scale using a scoring system, which developed by Saaty (1986), as the following table

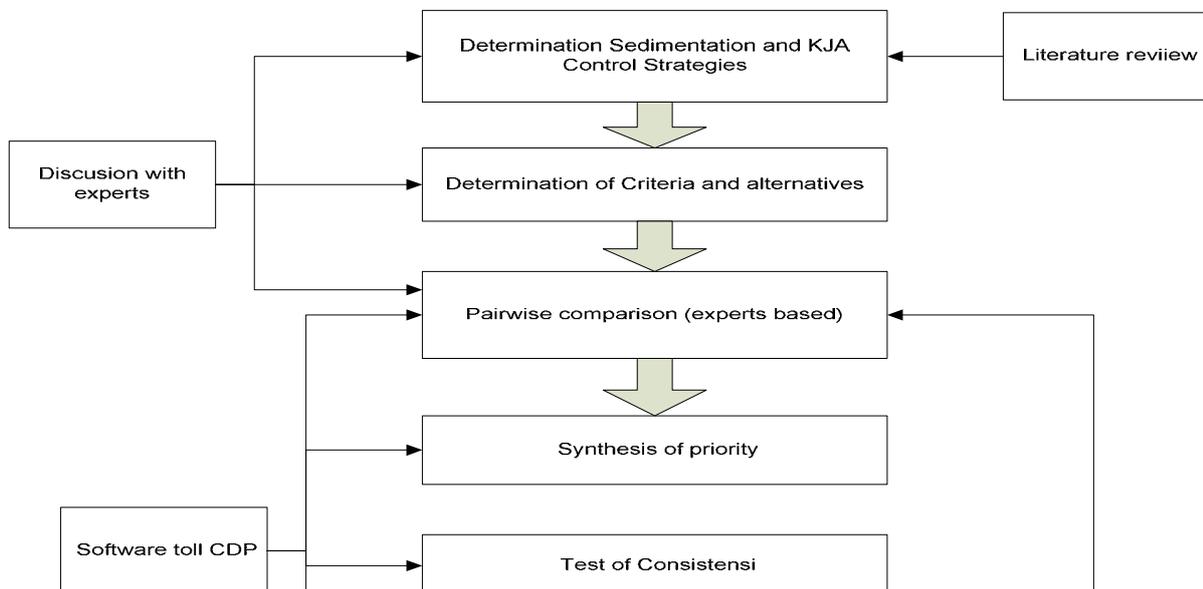
Tabel 2. Skala penilaian kepentingan relatif

Importance	Description
1	Equal important
2	Slightly important
3	Weakly more important
4	Weakly to moderately more important
5	Moderately more important
6	Moderately to strongly more important
7	Strongly more important
8	Greatly more important
9	Absolutely more important

(3) Synthesis of Priority, selection the best priorities based on the greatest of eigenvalue, and (4) Logical consistency, is to examine the consistency of each matrix weight pairs. Consistency assessment of pairs can be viewed from two aspects: (a) by looking at the multiplicative preferences, for example when A twice heavier than B and B two times heavier than C, then A should be four times heavier than C, and (b) by viewing preferences transitive, ie if A is less than B and B is less than C, then A must be smaller. Since AHP method was introduced by Saaty in 1977, it has been widely used to select the best alternatives in many research fields, such as economics, management, engineering, social and environmental.

### 3. METHODOLOGY

Determination of sedimentation and upwelling control strategies in Reservoir Cirata largely done through several stages as shown in figure 1. Analysis using software tools CDP (Cretirium Decession Plus) :



## Figure 2. Steps and method determination of priority strategies using AHP

Data input in the CDP is a single data, so for more than one expert to get a single data, the first step is making an average value using geometric mean.

### 4. RESULT AND DISCUSSION

Experts as resource persons in this study are 5 people, they are (1) Head of Cirata Reservoir Management Board, (2) Head of Planning and Program of Cianjur marine regional office (3) fish farming expert from Bogor Agriculture University (IPB), (4) Head of evaluation and program of PJB (Power Java-Bali) in Purwakarta, and (5) Fish farmer group leader of KJA. Results of expert discussions showed that to control sedimentation and floating cage net (KJA) in Cirata reservoir there are 7 criteria as a basis of determination the strategy, namely: (1) reservoir water quality, (2) reservoir water volume, (3) employment, (4) KJA business sustainability, (5) sustainability of tourist destination, (6) sustainability of hydropower and (7) sustainability of water source for irrigation. Based on the criteria, there are 5 possible alternatives: (1) standardization of KJA and fish farming system, (2) KJA zoning restrictions, (3) tightening of licensing, (4) fish farmer participation and (5) restriction on the number of KJA. Goal, criteria and alternative hierarchy based on the results of discussions with experts as shown below:

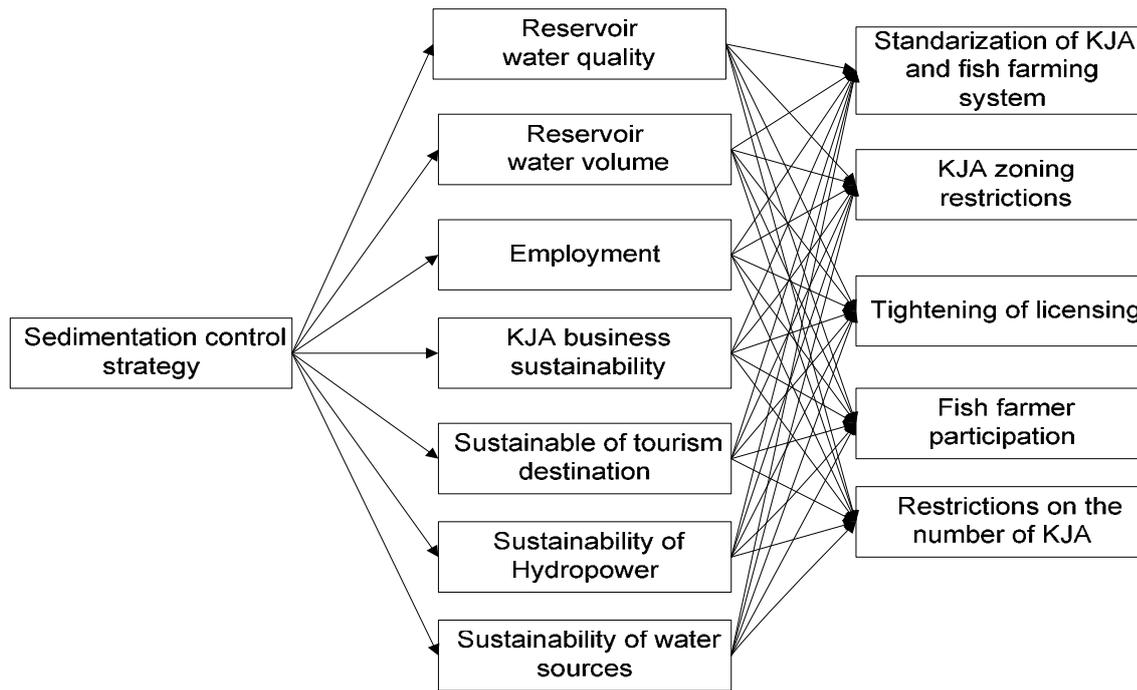


Figure 3. Hierarchy of goal, criteria and an alternatives sedimentation control in Cirata Reservoir KJA : Floating cage net (*KerambaJaringApung*)

The result an experts judgment to the criteria and refer to strategy as table 3 follow:

Table 3. Experts judgment to the criteria refer to strategy

	A	B	C	D	E	F	G
A	1	3	1	1	1	1/3	1
B	1/3	1	5	3	5	1	1
C	1	1/5	1	1	1	1	1/4
D	1	1/3	1	1	3	2	1
E	1	1/5	1	1/3	1	2	3
F	3	1	1	1/2	1/2	1	3
G	1	1	4	1	1/3	1/3	1

Descriptions :

- A : reservoir water quality
- B : reservoir water volume
- C : employment
- D : KJA business sustainability
- E : sustainability of tourist destination
- F : sustainability of hydropower
- G : sustainability of water source for irrigation

While an experts judgment to the alternatives refer to all criteria together, as shown below

Table 4 : Experts judgment to the strategy refer to criteria

	A	B	C	D	E
A	1	3	1/5	1/3	1/5
B	1/3	1	5	3	3
C	5	3	1	1/3	3
D	3	1/3	3	1	3
E	5	1/3	1/3	1/3	1

Descriptions :

- A :standarization of KJA and fish farming system,
- B :KJA zoning restrictions,
- C : tightening of licensing,
- D :fish farmer participation and
- E : restriction on the number of KJA

based on expert assessment above, the results of CDP output on criteria and alternatives over all as follows:

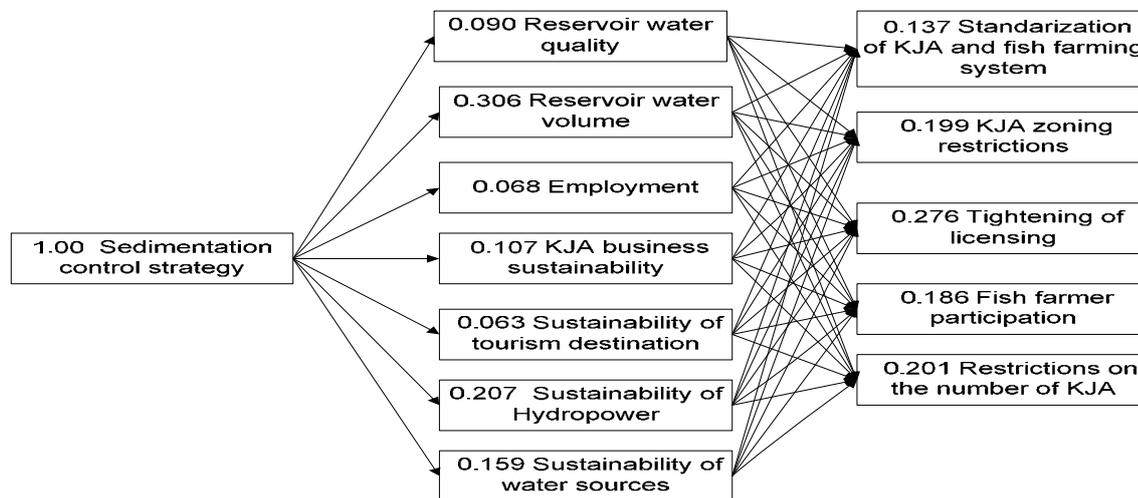


Figure 4. Out put of synthesis priority by CDP (based on experts judgment)

Based on the values obtained (figure 4) showed that the main criteria should be the basis in determining the sedimentation control strategy and control KJA is reservoir water volume as the highest value (0.306), followed by sustainability of hydro power (0.207). This criteria will support the preservation of the main functions of the reservoir or economic function, generating electricity for the Java and Bali. Based on selected criteria, the best alternative is the tightening of licensing strategy (0.276) followed by restriction on the number of KJA (0.201). Tightening of licensing strategy will facilitate the manager easier than the other strategies. When tightened of licensing the restrictions on number of KJA will be easily done, KJA placement on allowed or appropriate location can be set up easily. KJA structuring and control strategies in the field will be difficult, because it will receive challenge from KJA farmers.

Final result of priority strategy choices based on 7 criteria, more clearly as shown in Figure 5 below:

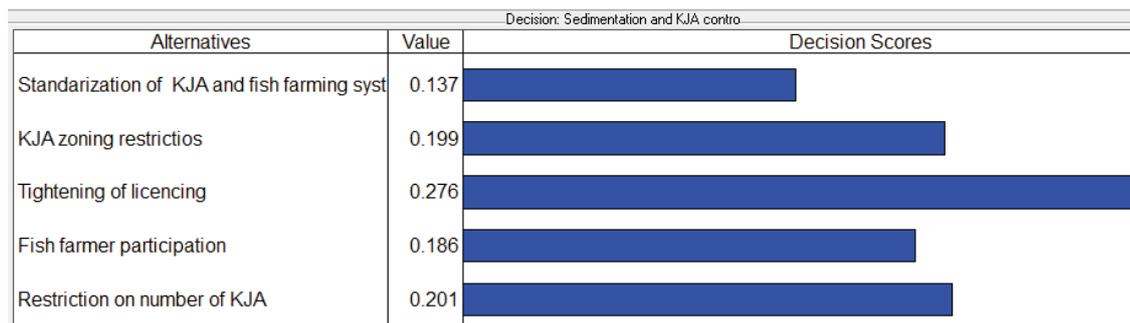


Figure 5. CDP out put for priority strategy based on expert assesment

Figure 5 showed that tightening of licencing is the highest of all, through tightening licencing system, existing floating cages net (KJA) that do not have a license must apply for a permit. Of 53,031 KJA current showed only about 10,40% (5,517), which has a permit and the remaining 89,60% (47,514) did not have a license. Most of KJA which do not have permission could be reduced with strict requirements. The results of research also showed that more than 65% of 2511 KJA owner are willing to complete the permit when any regulations oblige. This means that the government will have the opportunity to reduce and organize KJA through licencing. Reducing of KJA will affect to the reduction of sediment, finally upwelling can be reduced.

## 5. Acknowledgements

I would like to thank all those who have helped smooth the study, especially to the Ministry of Education for the research grants and BPWC who has given researchers the opportunity to conduct a study.

## 6. Conclusion

The best strategy for controlling sedimentation is by reducing the KJA through the tightening of licencing. KJA reduction will lower the level of water pollution, and reduce the risk of upwelling.

## Reference

- [1.] Atthirawong, Walailak; Bart McCarthy "An Application of the Analytical Hierarchy Process to International Location Decision-Making". In Gregory, Mike. *Proceedings of The 7th Annual Cambridge International Manufacturing Symposium: Restructuring Global Manufacturing*. Cambridge, England: University of Cambridge. September, 2002. pp. 1–18.
- Alphonse, C.B. "Application of the Analytic Hierarchy Process in Agriculture in Developing Countries". *Journal of Agricultural Systems*. 53, 1997, pp. 97-112.
- Bertolini, Bragiladan Carmignan. "Application of the AHP methodology in making a proposal for a public work contract" [International Journal of Project Management](#). Volume 24, Issue 5, , Pages 422–430. July 2006.
- Can Kara. "Application of GIS/AHP in siting sanitary landfill: a case study in Northern Cyprus. *Waste Manag Res*"; vol. 30, 9: pp. 966-980., September 2012
- Cirata Reservoir Management Board. "Annual report of water quality Cirata Reservoir", Bandung, 2012.
- Cirata Reservoir Management Board. "Annual report of KJA development of Cirata Reservoir", Bandung, 2011.
- Cirata Reservoir Management Board. "Monitoring of water quality Cirata Reservoir' 2008 – 2009. BPWC. Cianjur.
- Dahuri, R. "Ocean biodiversity, Indonesian sustainable development asset" Gramedia Pustaka Utama press, Jakarta, 2003.

- Dario, A., et al. (2011). [A new approach for dopant distribution and morphological stability in crystals grown by the axial heat processing \(AHP\) technique](#). *Journal of Crystal Growth*, Volume 337, Issue 1, pp. 65-71. 15 December 2011.
- Dewa, R. Pratista, Upwelling Potential Research in Perairan Selatan Pulau Jawa Jawa Tengah dan Selatan Pulau Sumbawa. <http://eprints.undip.ac.id> (diakses 6 Januari 2013)
- Harker, P.T. and Vargas, L.G., "The theory of ratio scale estimation: Saaty's Analytic Hierarchy Process". *Management Science*, 33 (11), 1383-1403. 1987.
- Kholil. "Selecting of region excellence commodities, Case study in West Aceh Regency". Ministry of Industry of the Republic of Indonesia, Usahid Press, Jakarta. 2010.
- Kim., E and R. Y. Cavana. "Systems thinking and modelling : Understanding change and complexity". Pearson Education, New Zealand, 2000, ch 4, pp. 75-95.
- Kartamihardja, H. "Budidaya ikan dalam KJA ramah lingkungan di perairan waduk dan auser baguna. Prosiding symposium erikanan Indonesia II, Ujung pandang 2-3 Desember 1977. JICA, Unhasanudin
- Midlen, A., Redding T.A., "Environmental Management for Aquaculture", Kluwer Academic Publisher, Dordrecht, 2000.
- Marimin. "Technique and application of multicriteria decision making. Grasindo Press. Jakarta, Indonesia, 2004, ch 3, pp. 40-53.
- Ministry of Marine and Fisheries of Republic of Indonesia. "Upwelling phenomena on fish farming using KJA system", 2011. Jakarta.
- Ministry of Marine and Fisheries of Republic of Indonesia. "upwelling", <http://www.kkp.go.id/index.php/mobile/arsip> downloaded 20 Mei 2012.
- Narasimhan, R., "An Analytical Approach to Applied selection. *Journal of Purchasing material management*", 19 (1), 72-32. 1983
- Saaty, Thomas L. "Relative Measurement and its Generalization in Decision Making: Why Pairwise Comparisons are Central in Mathematics for the Measurement of Intangible Factors - The Analytic Hierarchy/Network Process". *RACSAM (Review of the Royal Spanish Academy of Sciences, Series A, Mathematics)* **102** (2): 251-318. Retrieved 2008-12-22.
- Suardi, Y. 2009. "Upwelling". <http://ilmukelautan.com>. Downloaded 30 Des 2012.
- Widayati, D., Setyanto, D.G. Bengendam and Kholil. "Cirata Reservoir Management Model, to ensure Sustainability of economic, social and Ecological function", Dissertation of Doctoral Program in Bogor Agricultural University. IPB Press, 2011.

## Modeling of Domestic Wastewater Treatment Facultative Stabilization Ponds

Sunarsih<sup>a</sup>, Purwanto<sup>a,b</sup>, Wahyu Setia Budi<sup>c</sup>

<sup>a</sup> Doctor Program of Environmental Science, Diponegoro University, Semarang 50241  
Tel./Fax : (024) 8453635, 845363  
E-mail : narsih\_pdil@yahoo.com

<sup>a,b</sup> Chemical Engineering Departement Faculty of Engineering Diponegoro University, Semarang 50275  
Tel. (024) 7460058 Fax. (024) 76480675  
E-mail : purwanto@undip.ac.id

<sup>c</sup> Faculty of Science and Mathematics, Diponegoro University, Semarang 50275  
Tel./Fax : (024)74680822  
E-mail: wahyu.sb.undip.ac.id

### ABSTRACT

Wastewater Treatment Plant (WWTP) Sewon Bantul with capacity planning 15,500 m<sup>3</sup>/day, but data quality control for wastewater debit is 106 97.53 m<sup>3</sup>/day to serve 23,000 homes connection with used capacity on average 9700 m<sup>3</sup>/day. Biological treatment process intended to reduce the organic matter content by using microorganisms. Problems often occur in treatment process is WWTP only planned for treating domestic wastewater, but in fact the WWTP often accept non-domestic wastewater particularly taken by a fleet of feces. Modeling on 13 simultaneous systems of nonlinear differential equations, solved by the Runge-Kutta-Fehlberg (RKF45). Data validation is measured by facultative pond at a distance of 0 m, 25 m, 50 m and 75 m, the inlet and outlet of the pond to the concentration of bacteria, algae, zooplankton, organic matter, detritus, organic nitrogen, NH<sub>3</sub>, organic phosphor, dissolved phosphorus, Dissolved Oxygen (DO), total coliform, faecal coliform and Biochemical Oxygen Demand (BOD). Research results show that the time correlation toward observation and count data there are 11 concentration have a relative error <20% and 2 concentrations > 20% namely Chemical Oxygen Demand (COD) and faecal coliform. Wastewater quality is predicted with angle charts 45° and tolerance ± 20% for BOD (76.8%), COD (57.7%) and DO (81.9%). The model as the tool of performance evaluation of WWTP is appropriate with water quality standard Class II.

**Keywords :** Domestic wastewater, environmental modelling, facultative stabilization ponds

### 1. INTRODUCTION

Characteristics of urban wastewater that stands out is the high content of organic matter, the processing is done biologically which is aimed to reduce the organic matter content by using microorganism. Facultative stabilization pond used to improve the quality of wastewater. By relying on natural processes for wastewater treatment namely using the presence of bacteria, algae, and zooplankton to reduce organic pollutants contained in wastewater ([1], [2], [3], [4]).

Waste stabilization ponds is very suitable to be applied in developing countries (especially the tropics where the climate is warm), for the operation of the pond does not require investment and high operating costs, as well as requires no special operator personnel to operate it ([3], [4] [5], [6]).

The basic principle of stabilization ponds is to balance and maintain the organic load fluctuations and hydraulic load of waste water, precipitate solid particles from wastewater in the first pond, taking advantage of the photosynthesis process by algae as a major source of oxygen, the process of biological decomposition of organic matter by microorganisms (both aerobic and anaerobic), and reduction of pathogenic organisms through multiple interactive processes [7].

Common problems and much bother in the process of wastewater treatment is WWTP planned just to treat domestic wastewater or wastewater from households. But in reality WWTP Sewon often receive non-domestic wastewater especially carried by the feces vacuum fleet that sucks wastewater from small industries or home industry that actually their wastewater before being discharged to the WWTP should be processed first. This will bother the wastewater treatment process at the WWTP. Processing system is made two rows parallel, each are 2 facultative ponds and 1 maturation pond presented in Figure 1.

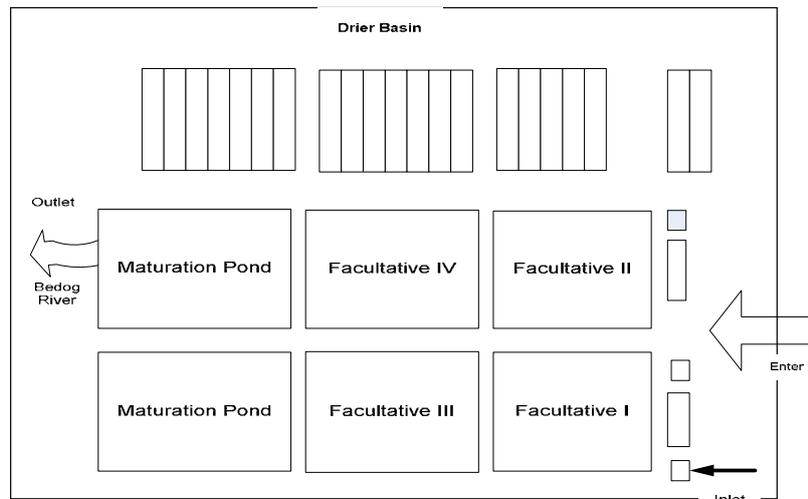


Figure 1. Layout Stabilization Pond WWTP Sewon

The purpose of this research is (a) to develop kinetic model process of the reform organic materials based on the rate of change of the concentration from biochemical models at facultative stabilization ponds, (b) validation and model simulations using the model parameters in (a).

## 2. MODELING

Forms of mass balance equations for each component of the biochemical model that is built in 13 (thirteen) equation which consists of 11 (eleven) nonlinear differential equations and 3 (three) order kinetics equation-1. With the 13 (thirteen) developed equation which is applied from Monod equation to the time correction as a maximum growth ([8], [9], [10], [11]):

### 1. Bacterial biomass (B) mass balance

$$\frac{dB}{dt} = \left( \frac{B_i}{\theta} - \frac{B_e}{\theta} \right) + Y_B \mu_B \frac{OM}{K_{BOM} + OM} \frac{DO}{K_{BDO} + DO} \frac{NH_3}{K_{BNH_3} + NH_3} \frac{SP}{K_{BSP} + SP} \left( 1 - \frac{B}{\eta_B} \right) B - (K_{BR} + K_{Bd})B \quad (1)$$

### 2. Algae (A) mass balance

$$\frac{dA}{dt} = \left( \frac{A_i}{\theta} - \frac{A_e}{\theta} \right) + \mu_A f(T) f(pH) f(L) \frac{NH_3}{K_{ANH_3} + NH_3} \frac{SP}{K_{ASP} + SP} \left( 1 - \frac{A}{\eta_A} \right) A - (K_{AR} + K_{Ad} + S_A)A \quad (2)$$

### 3. Zooplankton (Z) mass balance

$$\frac{dZ}{dt} = \left( \frac{Z_i}{\theta} - \frac{Z_e}{\theta} \right) + \mu_Z f(T) f(pH) \frac{NH_3}{K_{ZNH_3} + NH_3} \frac{SP}{K_{ZSP} + SP} \frac{DO}{K_{ZDO} + DO} \left( 1 - \frac{Z}{\eta_Z} \right) Z - (K_{ZR} + K_{Zd})Z \quad (3)$$

### 4. Organic Matter (OM) mass balance

$$\frac{dOM}{dt} = \left( \frac{OM_i}{\theta} - \frac{OM_e}{\theta} \right) - \mu_B \frac{OM}{K_{BOM} + OM} \frac{DO}{K_{BDO} + DO} \frac{NH_3}{K_{BNH_3} + NH_3} \frac{SP}{K_{BSP} + SP} \left( 1 - \frac{B}{\eta_B} \right) B \quad (4)$$

### 5. Detritus (D) mass balance

$$\frac{dD}{dt} = \frac{1}{d} (S_B B + S_A A) + U_r D \quad (5)$$

### 6. Organic Nitrogen (ON) mass balance

$$\frac{dON}{dt} = \left( \frac{ON_i}{\theta} - \frac{ON_e}{\theta} \right) - \alpha_{ON} ON + T_B BK_{Bd} - T_A A (S_A - K_{Ad}) + T_Z ZK_{Zd} \quad (6)$$

7. Ammonia Nitrogen (NH<sub>3</sub>) mass balance

$$\begin{aligned} \frac{dNH_3}{dt} = & \left( \frac{NH_{3i}}{\theta} - \frac{NH_{3e}}{\theta} \right) - T_B B \left\{ Y_B \mu_B \frac{OM}{K_{BOM} + OM} \frac{DO}{K_{BDO} + DO} \frac{NH_3}{K_{BNH_3} + NH_3} \frac{SP}{K_{BSP} + SP} \left( 1 - \frac{B}{\eta_B} \right) - K_{BR} - K_{Bd} \right\} \\ & - T_A A \left\{ \mu_A f(T) f(pH) f(L) \frac{NH_3}{K_{ANH_3} + NH_3} \frac{SP}{K_{ASP} + SP} \left( 1 - \frac{A}{\eta_A} \right) - K_{AR} - K_{Ad} \right\} \\ & - T_Z Z \left\{ \mu_Z f(T) f(pH) \frac{NH_3}{K_{ZNH_3} + NH_3} \frac{SP}{K_{ZSP} + SP} \frac{DO}{K_{ZDO} + DO} \left( 1 - \frac{Z}{\eta_Z} \right) - K_{ZR} - K_{Zd} \right\} + \alpha_{OP} ON + \frac{U_r D}{d} T_A \end{aligned} \quad (7)$$

8. Organic phosphor (OP) mass balance

$$\frac{dOP}{dt} = \left( \frac{OP_i}{\theta} - \frac{OP_e}{\theta} \right) - \alpha_{OP} OP + \psi_B BK_{Bd} - \psi_A A(S_A - K_{Ad}) + \psi_Z ZK_{Zd} \quad (8)$$

9. Soluble Phosphor (SP) mass balance

$$\begin{aligned} \frac{dSP}{dt} = & \left( \frac{SP_i}{\theta} - \frac{SP_e}{\theta} \right) - \psi_B B \left\{ Y_B \mu_B \frac{OM}{K_{BOM} + OM} \frac{DO}{K_{BDO} + DO} \frac{NH_3}{K_{BNH_3} + NH_3} \frac{SP}{K_{BSP} + SP} \left( 1 - \frac{B}{\eta_B} \right) - K_{BR} - K_{Bd} \right\} \\ & - \psi_A A \left\{ \mu_A f(T) f(pH) f(L) \frac{NH_3}{K_{ANH_3} + NH_3} \frac{SP}{K_{ASP} + SP} \left( 1 - \frac{A}{\eta_A} \right) - K_{AR} - K_{Ad} \right\} \\ & - \psi_Z Z \left\{ \mu_Z f(T) f(pH) \frac{NH_3}{K_{ZNH_3} + NH_3} \frac{SP}{K_{ZSP} + SP} \frac{DO}{K_{ZDO} + DO} \left( 1 - \frac{Z}{\eta_Z} \right) - K_{ZR} - K_{Zd} \right\} + \alpha_{OP} SP + \frac{U_r D}{d} S_A \end{aligned} \quad (9)$$

10. Dissolved Oxygen (DO) mass balance

$$\begin{aligned} \frac{dDO}{dt} = & \left( \frac{DO_i}{\theta} - \frac{DO_e}{\theta} \right) + \frac{K_L(DO_s - DO)}{d} \\ & - K \alpha_B B \left\{ Y_B \mu_B \frac{OM}{K_{BOM} + OM} \frac{DO}{K_{BDO} + DO} \frac{NH_3}{K_{BNH_3} + NH_3} \frac{SP}{K_{BSP} + SP} \left( 1 - \frac{B}{\eta_B} \right) - K_{BR} \right\} \\ & + \alpha_A A \left\{ \mu_A f(T) f(pH) f(L) \frac{NH_3}{K_{ANH_3} + NH_3} \frac{SP}{K_{ASP} + SP} \left( 1 - \frac{A}{\eta_A} \right) - K_{AR} \right\} \\ & - \alpha_Z Z \left\{ \mu_Z f(T) f(pH) \frac{NH_3}{K_{ZNH_3} + NH_3} \frac{SP}{K_{ZSP} + SP} \frac{DO}{K_{ZDO} + DO} \left( 1 - \frac{Z}{\eta_Z} \right) - K_{ZR} \right\} \end{aligned} \quad (10)$$

11. Total Coliforms (TC) mass balance

$$\frac{dTC}{dt} = \left( \frac{TC_i}{\theta} - \frac{TC_e}{\theta} \right) - K_{TC} TC \quad (11)$$

12. Faecal Coliforms (FC) mass balance

$$\frac{dFC}{dt} = \left( \frac{FC_i}{\theta} - \frac{FC_e}{\theta} \right) - K_{FC} FC \quad (12)$$

13. Biological Oxygen Demand (BOD) mass balance

$$\frac{dBOD}{dt} = \left( \frac{BOD_i}{\theta} - \frac{BOD_e}{\theta} \right) - kBOD \quad (13)$$

### 3. MATERIALS AND METHODS

#### 3.1. Development Assumptions Model

Wastewater treatment process at the WWTP unit is illustrated as a biochemical process represented as simultaneous differential equations. Dynamic modeling of water quality in the domestic waste at facultative stabilization ponds, it is assumed that the pond is not active. The process of biochemical model is illustrated as the following flowchart.

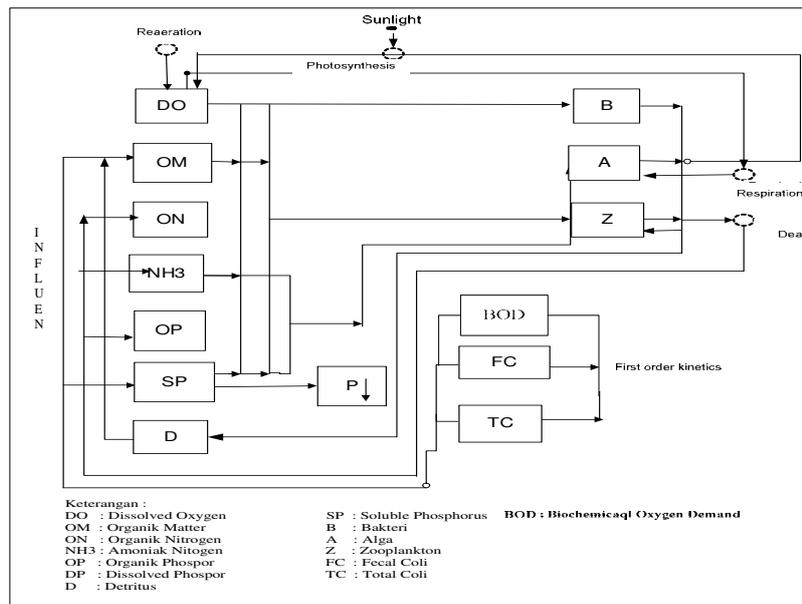


Figure 2. Flowchart The process of Biochemical Model

From Figure 2 is developed biochemical model for the rate of change / growth from variable *mass balance* equations former in system of simultaneous differential equations with index *i* is influent and *e* is effluent.

### 3.2. Runge-Kutta-Fehlberg method (RKF45) and program model

From 13 (thirteen) non-linear differential equations is solved by the method of Runge-Kutta-Fehlberg (RKF45) as integration techniques to get the concentration of each component against the time. These methods belong to the family of Runge-Kutta order-4 methods, but has the accuracy to order-5. In the 13 systems of simultaneous nonlinear differential equations contained 44 (forty-four) parameters are optimized by using the “fmincon” in Matlab (R2008a). As the initial data input is :  $B_0, A_0, Z_0, OM_0, D_0, ON_0, NH_{30}, OP_0, SP_0, DO_0, TC_0, FC_0, BOD_0$  [12].

### 3.3. Validation model

Model validation test use field measurement data and count data from the model. Field data include bacteria, algae, zooplankton, organic matter, detritus, organic nitrogen, NH<sub>3</sub>, organic phosphor, dissolved phosphor, DO, total coliform, faecal coliform and BOD. Line graphs predictions with angle 45° and tolerance of

± 20% is used for quality control of wastewater. With regression statistic analysis with confidence intervals 95% is used to observational data and count data toward the determination  $R^2$  for the validation of the model indicates the model is fit with field conditions.

### 3.4. Sample and analysis

Wastewater samples measured at 08.00, 10.00, 12.00, 14.00, and 16.00 and the model input samples is measured in facultative pond at a distance of 0 m, 25 m, 50 m and 75 m, and the inlet as well as outlet of the variable bacteria, algae, zooplankton, organic matter, detritus, organic nitrogen, NH<sub>3</sub>, organic phosphor, dissolved phosphor, DO, total coliform, faecal coliform and BOD. Sampling point presented in Figure 3. The test method of wastewater used [13] for parameters analysis of BOD, COD, DO, phosphate, nitrate, total coliform and faecal coliform. SNI test method (2004) is used for the analysis of nitrite and NH<sub>4</sub>-N, while for the analysis of phytoplankton and zooplankton used SNI test (1995).

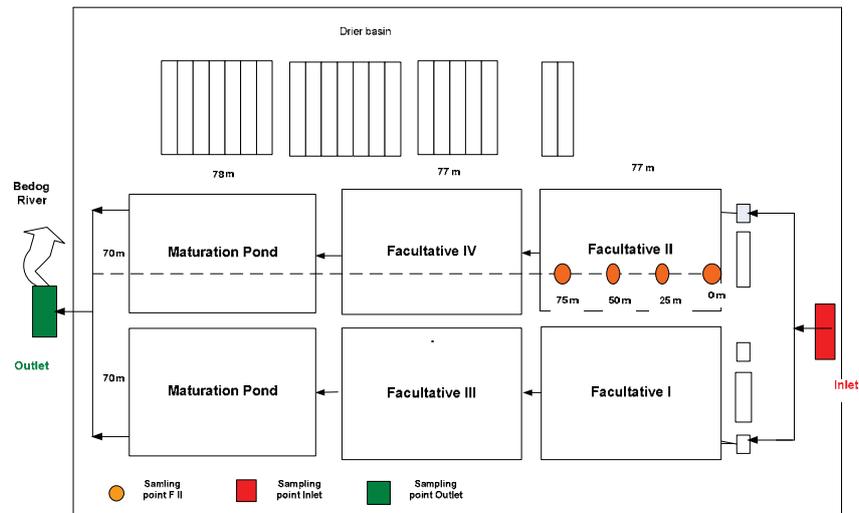


Figure 3. Sampling Point

## 4. RESULTS AND DISCUSSION

### 4.1. The waste stabilization pond

In accordance with the capacity planning Wastewater Treatment Plant (WWTP) Sewon is 15500 m<sup>3</sup>/day, based on the data quality control debit wastewater entering the WWTP amount to 10697.53 m<sup>3</sup>/day is not yet exceeded capacity planning. In practice WWTP Sewon is to serve 23,000 homes connection, with an average capacity utilization in 2010 amount to 9700 m<sup>3</sup>/day is to serve 11,000 homes connections. Urban waste is treated in the WWTP will be discharged into the river Bedog through concrete pipes and canals or open channels. River Bedog included in wastewater control unit Class II, stated in Decree of the Governor of Yogyakarta Special Region No. 214/KPTS/1991 about Standard Local Environmental BOD value output (effluent) is below 50 mg / liter ([14], [15]).

City's WWTP prevents wastes pollute rivers and groundwater that drain the city. Wastewater treatment systems biologically by using aeration facultative pond which is a very simple and aims to prevent seeds of diseases caused by waste contaminating surface water. WWTP Sewon operationally is just capable of serving 23% of the existing network. The data type of waste water quality control at the inlet of the Center WWTP Public Works Department, Housing and Energy and Mineral Resources Local Government Yogyakarta in July 2010 - December 2011 for Category II quality standard parameters for BOD, temperature, pH and DO are presented in the following figure:

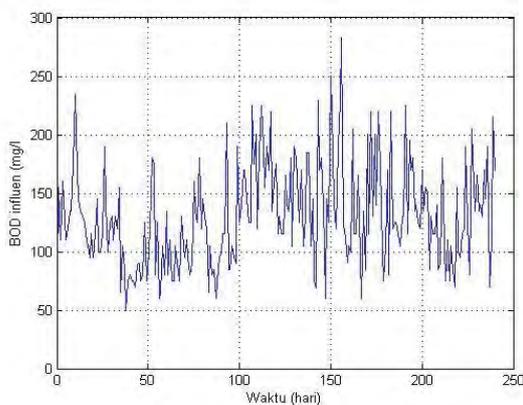


Figure 4. Typical data BOD inlet

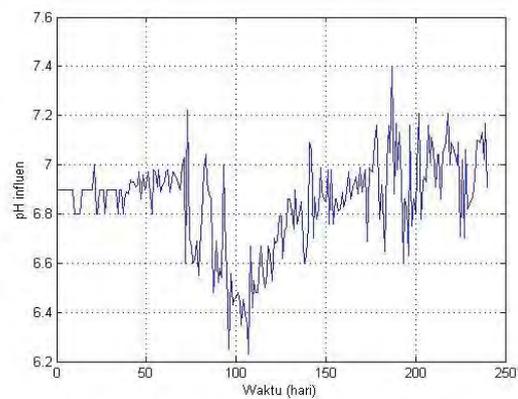


Figure 5. Typical data pH inlet

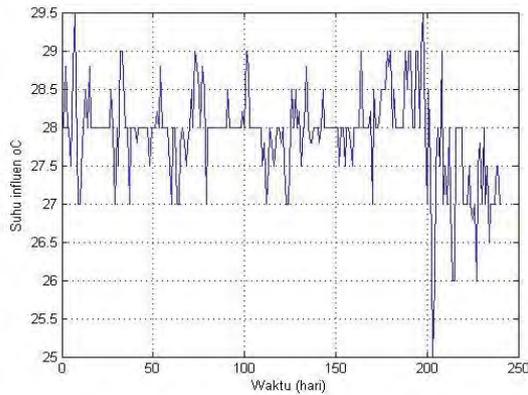


Figure 6. Typical data temperature inlet

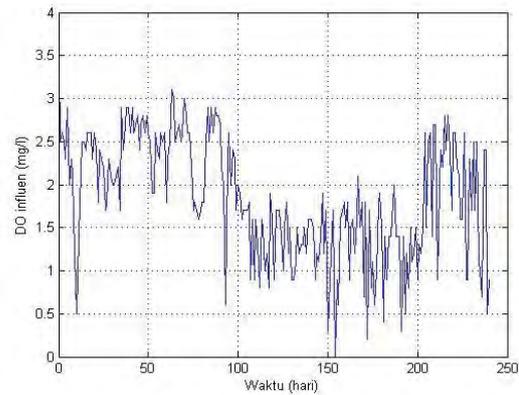


Figure 7. Typical data DO inlet

#### 4.2. Quality control pond water facultative stabilization

Based on typical data on WWTP Sewon, so it's necessary to do evaluation of the pond performance related to waste water quality standard Class II as it's established. Data measurement of pH, temperature, DO, BOD and COD are presented in the following table.

Table 1 : Wastewater quality inlet and outlet WWTP Sewon

Times	pH		Temperature ( <sup>0</sup> C)		DO (mg/l)		BOD (mg/l)		COD (mg/l)	
	inlet	outlet	inlet	outlet	Inlet	Outlet	inlet	outlet	inlet	outlet
08.00	7,09	7,12	27,8	28,8	0,9	4,2	250	16	752	48
10.00	7,19	7,28	27,5	28,0	1,5	3,4	165	20	346	72
12.00	7,19	7,14	27,0	29,5	0,8	4,2	200	18	700	70
14.00	7,19	7,18	28,0	30,5	1,7	4,2	155	19,5	364	64
16.00	7,35	7,50	28,0	30,0	1,8	3,7	130	19	368	76

Source : Primer Data, 15 February 2012

Table1. Indicates that the waste water out of the pond meets Quality Standards (BM) Group II: pH between 7.09 to 7.35 (BM = 6-9), temperatures between 28<sup>0</sup>C - 30<sup>0</sup>C (BM = 38<sup>0</sup>C), BOD between 18 mg / l - 20 mg / l (BM = 50 mg / l) and COD between 48 mg / l - 76 mg / l (BM = 100 mg / l).

The results of model simulations of the BOD concentration is order kinetics equation -1 that describes the degradation process of organic pollutants. Comparison of observational data and count data by the relative error is amount to 12,72%, it indicates that the decrease of BOD sufficiently representative in the model (Figure 8.)

The parameter *k* constitutes coefficient of rate degradation is very sensitive parameter model. In the simulation model of the *k* value is 0.6 (the calibration) after being optimized to 1.85; there are value differences amount to 1.25 that there is a substantial change in the value of *k* parameter. This indicates BOD concentration is very sensitive to the model depends on the size of the incoming wastewater stream at pond.

To determine whether the model can be applied to the concentration of BOD in the field and can be used as a performance evaluation tool of WWTP Sewon, following chart is presented in the chart tolerance of 20% for the pollutants concentration as domestic waste water quality with Class II criteria as presented in Figure 9.

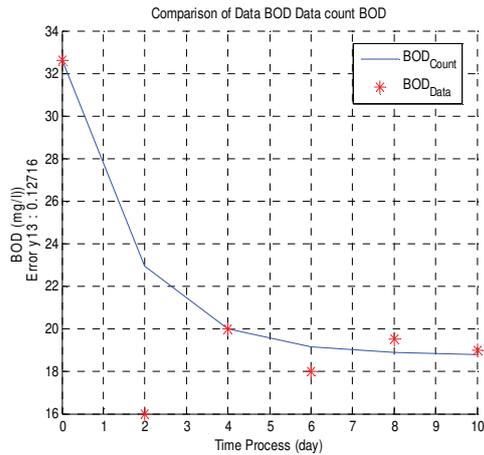


Figure 8. Comparison of data and count BOD

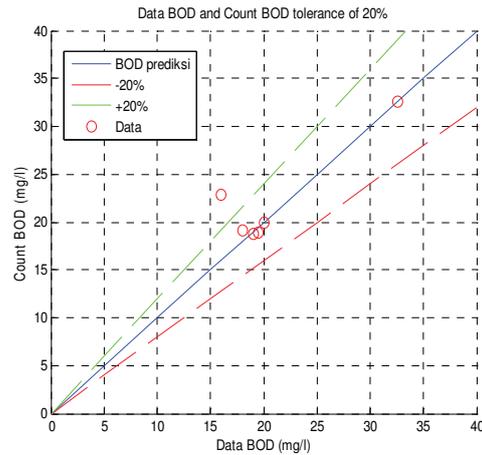


Figure 9. data and count BOD tolerance of 20%

DO concentration in the pond than, is determined by the role of these sensitive parameters to the model of the metabolism of oxygen consumption for: bacterial biomass ( $C_{BA}$ ) = 2.0 [16] and optimized to 1.2; algae ( $C_{AA}$ ) = 1.0 [16] optimized to be 1.244, and zooplankton ( $C_{ZA}$ ) = 1.244 [8] optimized to 0.5. Moreover DO concentration is also determined by 4 (four) role in the mechanism are: (a) consumption of oxygen by aerobic metabolism of the die bacteria, (b) the generation and consumption of oxygen by algae photosynthesis and respiration processes, (c) oxygen consumption by the metabolism of zooplankton and (d) reaeration between the air surface and water. Reaeration between air surface and water is  $K_L$  at 0.8566 [17].

At high DO, effect on growth of aerobic micro-organisms that will thrive and adequate nutrition is also an important factor in the growth of bacteria. DO observational data ranged from 3 to 4.2 mg / l and DO for life on the water is 2 mg / l, mean aerobic microorganisms still alive. From the results of model simulations to DO initially 3 mg / l showed that data and count DO have relative error of 12.72%, it's presented in Figure 9.

To determine whether the model can be applied to the DO concentration in the field and can be used as a performance evaluation tool of IPAL Sewon, here is presented in the chart tolerance of 20% for the concentration of pollutants as domestic waste water quality with Class II criteria as presented in Figure 10.

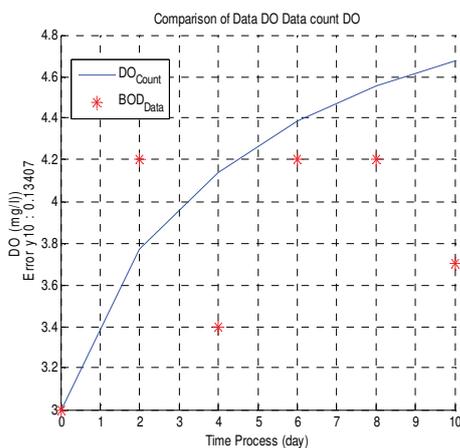


Figure 9. Comparison of data and count DO

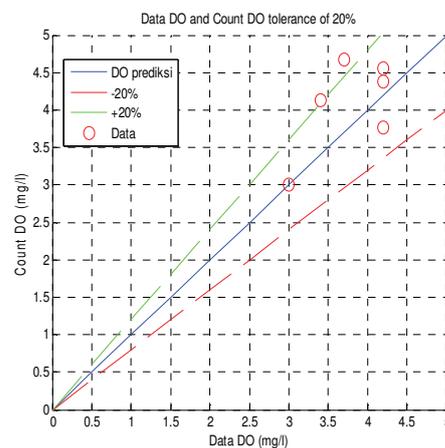


Figure 10. Data and count DO tolerance of 20%

Based on the results of model simulations to concentration of BOD, then performed statistical F-tests by using linear equation analysis to data and count BOD have determination ( $R^2 = 0.768$ , significant  $p = 0.022$ ) means the ability of the wastewater treatment process at the pond to degrade organic matter at 76, 8% and only 23.2% is influenced by other factors.

In the dissolved oxygen (DO) is the amount of oxygen contained in the water that is used as a sign of the contamination degree of the existing waste, the more oxygen is dissolved, so it shows a relatively small contamination degree. By using equation

quadratic analysis (such as model pattern), between data and count DO with determination ( $R^2 = 0.819$ , significant  $p = 0.077$ ), which means that the wastewater treatment process to DO concentration as a sign of the contamination degree of the existing waste by 81.96% and only 18.04% is influenced by other factors. This indicates the concentration of DO in the pond to the life of aerobic microorganisms is a good.

## 5. CONCLUSION

Biochemical Model with 13 (thirteen) system of simultaneous nonlinear differential equations is shown through charts time relation process with the concentration observation and count data, there are 11 (eleven) concentrations have relative error below 20%, and 2 (two) concentrations have relative error over 20% that is COD (37.06%) and faecal coliform (37.67%). In both these concentrations contained sensitive parameters to the model, that is specific growth rate of bacteria ( $\mu_{FE}$ ) and the specific growth rate of faecal coliform at a temperature of 20°C ( $\mu_{FC}$ ).

Through the charts of wastewater quality control as a line prediction on an angle of 45° as the upper and lower limits with tolerance of  $\pm 20\%$ . With chart is used as tool of evaluation of the performance WWTP with wastewater quality standard Class II. This is also demonstrated by the high determination test for BOD ( $R^2 = 76.8\%$ ,  $p = 0.022$ ), COD ( $R^2 = 57.6\%$ ,  $p = 0.08$ ), and DO ( $R^2 = 76.8\%$ ,  $p = 0.08$ ) which can describe the model in accordance with the conditions in the field.

## ACKNOWLEDGMENT

Thanks to the Leaders and staff WWTP Sewon, Public Works Department, Housing and ESDM Local Government Yogyakarta who have given permission for the research and data collection quality control wastewater WWTP Sewon.

## REFERENCES

- [1] S. Kayombo, T.S.A. Mbwette, A.W. Mayo, J.H.Y. Katima, S.E. Jorgensen, "Diurnal cycles of variation physical-chemical parameters in waste stabilization ponds". *Ecological Modelling* 18 pp 287-291, 2002.
- [2] B. Beran and K. Kargi, "A dynamic mathematical model for waste water stabilization ponds". *Ecological Modelling* 181 pp 39-57, 2005.
- [3] Lani Puspita, Ratnawati E., Suryadiputra I. N.N., *Lahan Basah Buatan di Indonesia. Wetlands International Indonesia Programme*. Ditjen PHKA. Bogor, 2005.
- [4] D.A. Mashauri, S. Kayombo, "Application of the two coupled models for water quality management : facultative pond cum constructed wetland models". *Physics and Chemistry of the Earth* 27 pp 773-781, 2002.
- [5] S. Kayombo, T.S.A. Mbwette, J.H.Y. Katima, S.E. Jorgensen, "Effects of substrate concentrations on the growth of heterotrophic bacteria and algae in secondary facultative ponds". *Water Research* 37 pp 2937-2943, 2003.
- [6] D. Mara, *Domestic Wastewater Treatment in Developing Countries*. First Published by Earthscan in the UK and USA, 2004.
- [7] Veenstra, *Wastewater Treatment*. IHE Delft, 2000.
- [8] S. Moreno-Grau, A. Garcia-Sanchez, J. Moreno-Clavel, J. Serrano-Aniorte, M.D. Moreno-Grau, "A mathematical model for waste water stabilization ponds with macrophytes and microphytes". *Journal Ecological Modelling* 91 pp 77-103, 1996.
- [9] L.M. Situma, L. Etiegni, S.M. Shitote and B.O. Oron, "Biochemical Modeling of Pan African Paper mills aerated Lagoons, Webuye, Western Kenya". African Pulp and Paper Week. 'Adding Value in a Global Industry' International Convention Centre, Durban, 8 – 11 October, 2002.
- [10] D. Dochain, S. Gregoire, A. Pauss, M. Schaeffer, "Dynamical modelling of a waste stabilization pond". *Bioprocess Biosyst Eng* 26: pp. 19-26, 2003.
- [11] Purwanto, *Permodelan Rekayasa Proses dan Lingkungan*. Badan Penerbit Universitas Diponegoro, Semarang, 2005.
- [12] Won Young Yang, Wenwu Cao, Tae-Say Chung, John Marris, *Applied Numerical Methods Using Matlab*. Wiley-Interscience. A. John Wiley & Sons. Inc. Publication, 2005.
- [13] APHA, American Public Health Association, Standard Methods for the Examination of Water and Wastewater. Washington DC.
- [14] Surat Keputusan Gubernur Istimewa Yogyakarta No. 214/KPTS/1991 tentang baku mutu lingkungan daerah.
- [15] Peraturan Daerah Kota Yogyakarta No. 6 Tahun 2009 tentang Pengelolaan Air Limbah Domestik.
- [16] G.T. Orlob, *One-dimensional models for simulation of water quality in lakes and reservoirs*. In: G.T. Orlob (Editor), *Mathematical Modeling of Water Quality: Stream, Lakes and Reservoirs*. John Wiley and Sons, Chichester, 518 pp., 1982.
- [17] R.B. Banks and F.F. Herrera, "Effect of Wind and Rain of Surface Reaeration". *J. Environ. Eng. Div.*, 103, EE3: 489 – 504, 1977.

## CHARACTERISTICS OF ENVIRONMENTAL FRIENDLY LABELED PLASTIC SHOPPING BAGS IN INDONESIA

Melanie Cornelia<sup>a)</sup>, Rizal Syarief<sup>a)</sup>,  
Hefni Effendi<sup>a)</sup>, Budi Nurtama<sup>a)</sup>

<sup>a)</sup> Natural Resources and Environmental Management, Bogor Agricultural University, Bogor 16880  
E-mail : [melanie.cornelia@uph.edu](mailto:melanie.cornelia@uph.edu)

### ABSTRACT

Plastics are synthetic polymers, made from petroleum and its derivatives which are non biodegradable. Today, more people used plastic bags to support their activities, which caused the supply of plastic shopping bags to increase in large number. Plastic bags, eventually, are usually used as garbage which would cause negative impact on the environment. Environmental friendly plastic bags are made from renewable raw materials, such as starch from cassava, corn or others. There are the ones entirely starch based such as Enviplast (biodegradable); the ones with partial mixture of starch with plastic ores such as Ecoplas (biodegradable), the ones plastic ores are formulated with additives Oxium (oxodegradable), and conventional made from plastic ores only. Distinguishing characteristics of samples plastic shopping bags were taken from domestic and abroad supermarkets can be seen from the result of FTIR, SEM, and AAS analysis along with burial in soil medium. Density of domestic plastic bag ( $1.119 \text{ g/cm}^3$ ) are 49.55% smaller than samples abroad  $2.258 \text{ g/cm}^3$ . This means that in the country, a space to hold trash bags in the same weight needed almost 2x larger. Another discovery are some plastic shopping bags are labeled eco-friendly and related but had conventional plastic characteristic.

### Keywords

Plastic shopping bags, conventional, oxodegradable, biodegradable, environmental friendly

**This paper is published in Advanced Material Research**

# Reducing CO<sub>2</sub> Emissions from Buildings and New Developments by The Strict Enforcement of Regulations Imposed by Local Authorities.

Felix Weerakkody

Faculty of Engineering, Institut Teknologi Brunei, Jalan Tungku Link Gadong BE1410 Brunei Darussalam  
E-mail : Felix.Weerakkody@itb.edu.bn

## ABSTRACT

*Numerous research studies have demonstrated the catastrophic consequences of global warming caused by unabated carbon dioxide emissions. It is acknowledged that construction and the operational aspects of buildings are significant contributors to energy consumption and have a direct impact on CO<sub>2</sub> emissions.*

*Application of concepts such as Life Cycle Analysis and Embodied Energy with a direct link to buildings and construction has been proposed by many policy makers and researchers. Furthermore there are building rating systems such as BREEAM (Building Research Establishment Environmental Assessment Method) and LEED (Leadership in Energy and Environmental Design) for evaluating the sustainability status of any proposed design. However the successful implementation of these systems in the alleviation of CO<sub>2</sub> emissions has not been fully realised.*

*This paper is an attempt to explore the possibility of Local/Planning authorities imposing mandatory requirements that would lead to sustainable environmentally friendly developments. The paper suggests that limits should be placed on the embodied energy, the operational energy and water use when issuing building permits. These steps would be just the initial steps that must be taken towards mitigating the negative impacts that accumulate from buildings during construction and their operational phase.*

### Keywords :

*Environment, CO<sub>2</sub> emissions, Life Cycle Analysis, Local Authorities, Construction*

## 1. INTRODUCTION : THE ENVIRONMENT, CO<sub>2</sub> EMISSIONS AND CLIMATE CHANGE

Climate change has now become a reality that cannot be ignored or denied. Extreme climatic events such as unprecedented heavy rainfall leading to floods and high temperatures far above the normal average temperatures which have caused destructive forest fires are now a common phenomenon in certain parts of the world. This has had its toll on agricultural crop yields and on ecosystems undermining the health and stability of all forms of life on earth.

Most scientists except for a few sceptics believe that the changes observed in the climatic conditions can be directly attributed to an increase in atmospheric greenhouse gases. That this is anthropogenic and is due to increased use of fossil fuels is acknowledged. World leaders as well as scientists in developed countries who have to balance this concern with the needs and desires of a burgeoning population as well as the commitment towards technological progress found that there were no easy solutions.

The call for concerted action resulted in the unanimous adoption of the Kyoto Protocol in 1997 by the member countries of the Framework Convention on Climate Change. The Protocol's major feature was that it set mandatory targets on greenhouse-gas emissions for the world's leading economies. The Kyoto Protocol, set binding obligations for about 35 industrialised nations to cut their greenhouse gas emissions until the end of 2012.

Unfortunately these countries have fallen far short of the proposed targets. The United Nations Climate Change Conference in Doha addressed these issues once again December 2012. But the measures taken this time were not considered to be strong enough to halt rising world greenhouse gas emissions. The Kyoto Protocol to which the environment ministers of over 200 nations were signatories, was extended until 2020. That keeps the pact alive as the sole, legally binding climate plan.

"Much, much more is needed if we are really going to address climate change and reduce emissions," said Kieren Keke, foreign minister of the Pacific island state of Nauru on behalf of the Alliance of Small Island States. "He warned against endless talk that "locks in the death of our nations and of our children" [1].

## **2.CONSTRUCTION AS A MAJOR CONTRIBUTOR TO CO2 EMISSIONS.**

Large amounts of natural resources are used in the production, maintenance, and operation of buildings. The construction industry consumes more than one-third of global resources, including 12 % of all freshwater use. Buildings also use 25–40 % of all produced energy sources, accounting for approximately 30–40 % of global carbon dioxide (CO<sub>2</sub>) emissions. In addition to natural resource consumption, buildings produce and unload 30–40 % of solid waste into the environment. [2].

Once a building is constructed and occupied it is difficult to make changes that would reduce its impact on the environment. It will not be easy to modify a building which has been originally designed for air-conditioning later for cooling through natural ventilation. Furthermore the impact that a building has on the environment is long lasting since it is a process which continues throughout the life cycle of the building which could be many years. For instance the design life of many modern buildings would be in the range of a hundred years. It is imperative then to consider the use of environmentally friendly materials, construction techniques and building operational systems that are less detrimental to the environment during its construction phase and its operational phase.

These are some of the considerations that led to the development of the concept of “Green Buildings”. A green building is a building that is designed, constructed and operated in an environmentally responsible manner. The design whilst addressing the standard concepts of comfort, utility, durability and cost will endeavour to do so with the least detrimental impact on the environment. The main strategies in green building would include the reduction of energy consumption, conservation of water and the recycling of waste.

To facilitate such design, construction and operation processes, environmental assessment methods and building rating systems have been developed. These rating tools enable the designer to judiciously select the materials, construction techniques and methods of operation which provide for a sustainable end product that will have the least non-beneficial impact on the environment. Of the more common assessment tools among many others are LCA (Life Cycle Analysis), LCEA (Life Cycle Energy Analysis), Embodied Energy and rating systems such as LEED (Leadership in Energy and Environmental Design) and BREEAM (Building Research Establishment Environment Assessment Method)

## **3. SOME OF THE ENVIRONMENTAL ASSESSMENT METHODS, RATING SYSTEMS AND THEIR APPLICATION**

LCA is defined as the assessment of environmental impacts of products, buildings or other services throughout their lifetimes. The assessment includes the entire life-cycle of a product, process or system encompassing the extraction and processing of raw materials; manufacturing, transportation and distribution; use, reuse, maintenance, recycling and final disposal.

Whereas LCA assesses the overall impact, a derivative, life-cycle energy analysis (LCEA) focuses on energy as the only measure of environmental impact of buildings or products. The purpose of LCEA is to present a more detailed analysis of energy attributable to products, systems or buildings, to enable decision-making strategies concerning energy efficiency and environmental protection. LCEA has not been developed to replace LCA but to compare and evaluate the initial and recurrent embodied energy in materials, energy used during the operational phase, and during recycling and disposal [3].

Embodied Energy is defined as the quantity of energy necessary to process and supply the material under consideration to the construction site. The energy inputs for a given material would include raw material extraction, processing and transportation to the construction site, the Embodied energy thus calculated being termed “cradle to site”. Similarly the embodied carbon is a measure of the CO<sub>2</sub> equivalents emitted from the extraction of the raw material through to the final manufacture of the product. [4].

LCEA is often used to estimate the energy use and savings over the life of the product or the building, and more importantly, to find out the energy/CO<sub>2</sub> payback period (the time spent for the initial embodied energy cost to be paid back by energy savings during operational and disposal/recycling stages). Life-cycle carbon assessment is likened to LCEA, and relies on prevailing energy structures to convert megajoules of energy to kilograms [3].

There are many data bases available in the public domain for use in a LCA or LCEA. However the problem lies in the variations in the numerous data bases due to the various assumptions that have been made in developing them. Among the more comprehensive data bases is the University of Bath’s inventory of carbon and energy. It is a more reliable data base for embodied energy and carbon associated with construction materials. Many designers who are concerned about the environment are making use of this facility to determine the carbon impact of their designs.

Two of the more common rating systems are BREEAM and LEED. BREEAM sets the standard for best practice in sustainable building design, construction and operation and has become one of the most comprehensive and widely recognized measurements of a building's environmental performance.

A BREEAM assessment uses recognized measures of performance, which are set against established benchmarks, to evaluate a building's specification, design, construction and use. The measures used represent a broad range of categories and criteria from energy to ecology. They include aspects related to energy and water use, the internal environment (health and well-being), pollution, transport, materials, waste, ecology and management processes.

BREEAM addresses wide-ranging environmental and sustainability issues and enables developers, designers and building managers to demonstrate the environmental credentials of their buildings to clients, planners and other initial parties. BREEAM uses a straightforward scoring system that is transparent, flexible, and easy to understand and supported by evidence-based science and research. It has a positive influence on the design, construction and management of buildings and defines and maintains a robust technical standard with rigorous quality assurance and certification [5].

Similarly LEED is a voluntary, consensus-based, market-driven program that provides third-party verification of green buildings. From individual buildings and homes, to entire neighborhoods and communities, LEED is transforming the way built environments are designed, constructed, and operated. LEED is comprehensive and flexible and addresses the entire lifecycle of a building. Participation in the voluntary LEED process demonstrates leadership, innovation, environmental stewardship and social responsibility. LEED provides building owners and operators the tools they need to immediately assess how their building impacts on the environment whilst providing healthy indoor spaces for a building's occupants.

LEED projects have been successfully established in 135 countries. International projects, those outside the United States, make up more than 50% of the total LEED registered square footage. LEED unites us in a single global community and provides regional solutions, while recognizing local realities.

Building projects earn points for satisfying green building criteria. Within each of the environmental LEED credit categories, projects must satisfy particular prerequisites and earn additional points. The number of points the project earns determines the level of LEED certification the project receives. Projects must earn at least 40 points on a 110-point LEED rating system scale to achieve basic certification. [6].

Although these rating systems which are not mandatory have had a positive environmental impact on the design and operation of buildings, both building rating tool systems have been deemed to be too complicated and time-consuming by certain segments of the industry which has discouraged a widespread use. This group would greatly prefer a 'quick and dirty' assessment option, one that is easily accessible, provides results instantaneously and requires little or no operator training [7].

Despite the rapid growth of building assessment schemes over the last 15 years, the construction industry is still undergoing a cultural shift towards the general use of such tools. While BREEAM and LEED Canada have been instrumental in fostering this change, these tools must continue to evolve in order to maintain the momentum developed thus far while at the same time it expands to include construction sectors and markets not currently undergoing assessment [7].

It is timely to make the available assessment tools mandatory if further impacts on the environment due to building and construction activities are to be prevented. This places a major responsibility on local planning authorities to ensure environmentally friendly building and construction. It is possible to achieve this objective by legislating for mandatory standards for the protection of the environment and for a sustainable society. Criteria could be imposed on new construction to minimize or totally negate the adverse impacts on the environment

#### **4. THE RESPONSIBILITY OF LOCAL AUTHORITIES TO ENSURE SUSTAINABILITY.**

Human behaviour in society has to be regulated by laws. Behaviour and activity has to be monitored and scrutinized to ensure compliance and punitive action taken when there is noncompliance. In civilized societies the social contract has been maintained in this manner. However where the environment is concerned there are hardly any laws to ensure a sustainable ecological footprint or to limit CO<sub>2</sub> emissions.

In 1990, global emissions were 38.2 gigatonnes, and in recent years it has been growing at a rate of three per cent per year. This increase has taken place despite the commitments by industrialised countries to reduce their emissions. For 2012 the global total of climate-disrupting emissions are estimated at 52 gigatonnes [8]. The consequences in the form of extreme temperature

and weather are a recurrent phenomenon. Sydney, Australia recorded the highest ever temperature of 46.5 degrees centigrade on Friday the 18<sup>th</sup> of January 2013 [9].

In the building construction sector at least some steps can be taken to enforce regulations targeted at minimising carbon emissions. This could be a significant step considering that building construction and operation accounts for almost 40% of the total world energy consumption.

Whenever an application is made to a local authority for the approval of a new development they must impose certain mandatory requirements. Based on the local average rainfall precipitation, it should become compulsory to harvest a minimum quantity of rainfall. A ceiling should be imposed on the treated pipe borne water that is supplied through the local authority.

An estimated value of the total operational energy per year during the operational phase of a new development should be tabled with the application process. A ceiling or cap calculated on the floor area and the use of the development should be imposed on the energy supplied through the national grid. The remainder of the operational energy requirements should be from alternate energy sources. The solar radiation in the locality could be taken into consideration and a component of this energy requirements should be supplied through the use of solar panels. Small scale wind turbines could be made mandatory. With wind turbines which generate power becoming the fastest growing alternate energy sector in the world it would be feasible to incorporate small scale wind turbines to supplement the alternate energy supplied through the solar panels.

An obligatory requirement when requesting for a building permit must include an embodied energy count for the proposed new development. The embodied energy count could be based on embodied energy values supplied by the local authority. A specific maximum value should be stipulated for a building based on its floor area and its nature as a commercial, housing or industrial construction. If the value stipulated is exceeded, the application should be rejected. The local authority could make use of the available data bases for embodied energy and modify it to suit the local conditions.

If garden space is available waste water could be directed through a simple filter and the water used for the garden. Sewage could be discharged to a septic tank soakage pit system. Small scale bio-gas units could be made mandatory if adequate space is available. A minimum area in proportion to the floor area of the building should be planted with trees and foliage. If it is a high rise building vertical gardens should be established on a specified minimum area of walling.

These are small measures that can be made without much delay. Stronger steps may have to be taken in the future if CO<sub>2</sub> emissions do not drop in the expected way.

Urbanisation has transformed the relationship between people and the planet we inhabit. Cities, built on just 2% of the world's land surface, use about 75% of its resources and discharge similar proportions of waste. In a world in which 50% of the world's people now live in cities and over 80% of the world's population live in the most industrialised countries, sustainable development has to be mainly and necessarily about sustainable urban development [10].

BedZED's (Beddington Zero Energy Development) new-build development of 83 mixed tenure homes (social, key worker, and for sale), plus some 3000m<sup>2</sup> of live/work, workspaces, retail, and leisure uses, occupies an urban brownfield site in South London. Its chosen high build-density reflects the importance of using limited land resources to the full, being based on the density needed for accommodating all the UK's projected new homes. It is built entirely on available brownfield sites, to avoid sacrificing any more limited greenfield amenity. Such high density helps build coherent communities and provides critical mass for facilities like public transport, while continuing to allow the massing and orientation needed for good passive solar and daylight access. Making the roof areas 'green' helps increase the site's ecological value and its carbon absorbing ability, as well as giving the occupants private gardens [11].

BedZED was conceived to show that in large-scale construction a high level of sustainability can be practical and cost-effective. If the sustainability concept is to have any sort of meaningful overall effect on the environment, it must move into the volume mainstream, satisfy economic and social objectives, and benefit all stakeholders. Nevertheless the ecological footprint of 4.36 ha is more than the global average of 2.4 ha but much better than the 6.19 ha for an average UK lifestyle based on a four person household [11].

It is recognized now that the ecological footprint has to be reduced for the wellbeing of humanity and that sweeping measures may have to be taken. BedZED is just a starting point. In the future it may even become necessary to ensure that all freehold land at the point of transfer on a sale or a legacy is made into a fifty year lease hold with the title passing to the local authority on the completion of the lease. Then all land will be vested with the Local Authority and they would be free to develop it in a sustainable eco-friendly manner.

Distances that need to be traversed between the home and the workplace using motor vehicles which greatly adds to the problem of pollution, cannot continue in its present form. This raises issues with respect to the concepts regarding the city, the workplace and the home which have to be rethought. Co-operation and community, social responsibility and civic sense, if it does not come naturally to people, may have to be brought about through the regulation of human activities. It may become imperative to change our habits and life styles if we are to avoid climatic catastrophes in the future and to ensure that our planet remains healthy.

The ideas suggested above which encompass the view of traditional societies albeit with a much higher input of technology, where work, home, space for leisure all remain within its own environs are worthy of consideration if we are to promote sustainable development.

Science and technology can detect the problem, and supply the solutions for remediation or management of the problem. An example can be seen in the manner in which Bio-fuels are made. The single celled blue-green algae referred to as Cyanobacteria have been used for the production of bio-fuels. It yields twenty times more biomass per day in comparison to Soyabean. This has been demonstrated by a company Bio fuel Systems in Alicante Spain. Their plant uses the CO<sub>2</sub> emitted by a neighbouring cement factory to grow the algae and is able to produce 2.5 barrels of carbon neutral crude oil per hectare of algae each day [12]. The gardens by the bay in Singapore are another excellent example of the use of science and technology to demonstrate the concept of sustainability so that its citizenry is made aware of the problem. However science and technology does not have the power to ensure a beneficial change or to protect the environment. That power lies with the legislators. It is obvious now that only the enforcement of mandatory requirements will provide for a sustainable future.

## 5. CONCLUSION

It is obvious that CO<sub>2</sub> levels are rising and global warming is a major problem confronting the world. The consequences of higher global temperatures can be seen in the changes in weather patterns, in floods hurricanes etc. that are increasingly common. The impacts from the building and construction activities that contribute to CO<sub>2</sub> emissions can be minimised in the short term if the steps outlined in this paper are implemented. Similarly in the long term, land holdings may have to be vested to the local authorities who will have to take the responsibility to design carbon neutral communities. The argument that more production is necessary to sustain larger numbers of people at a higher standard of living and that environmental degradation is collateral damage which has to be tolerated is no longer a valid argument. Environmental issues are no longer the purview of environmental activists. It is an issue that concerns everyone. What is required is for the powers that be to implement that which is necessary.

## 6. REFERENCES

- [1] Article, *Doha climate talks end with a whimper*, The AGE Melbourne Newspaper, 9th December, 2012 , <http://www.theage.com.au/environment/climate-change/doha-climate-talks-end-with-a-whimper-20121209-2b34i.html> Accessed on 30<sup>th</sup> December 2012
- [2] Kaarin Taipale, "From Light Green to Sustainable Buildings", *Worldwatch Institute Policy Brief* [http://www.worldwatch.org/system/files/SOW12%20Summary%20\(Chapter%2010\).pdf](http://www.worldwatch.org/system/files/SOW12%20Summary%20(Chapter%2010).pdf). Accessed on 2<sup>nd</sup> January 2013
- [3] G. F. Menzies, S. Turan, M. Linari, and P.F.G. Banfil, "Life-cycle assessment and embodied energy : a review," *ICE Proceedings. Construction Materials.*, issue CM 4, pp. 135–143, Nov. 2007
- [4] G. P. Hammond, C. I. Jones, "Embodied energy and carbon in construction materials," *ICE Proceedings. Energy.*, issue EN 2, pp. 87–98, May. 2008
- [5] What is BREEAM. <http://www.breeam.org/about.jsp?id=66>. Accessed on 28<sup>th</sup> December 2012
- [6] What is LEED. <http://new.usgbc.org/leed>. Accessed on 28<sup>th</sup> December 2012.
- [7] R.A. Fenner, T Ryce, "A Comparative analysis of two building rating systems Part 1 ; Evaluation" *ICE Proceedings. Engineering Sustainability*, issue ES 1, pp. 55-63 March 2008
- [8]. Stephen Leahy, *At the edge of the carbon cliff*. The Guardian Newspaper 18<sup>th</sup> December 2012. <http://www.guardian.co.uk/environment/2012/dec/18/carbon-emissions-climate-change>. Accessed on 19<sup>th</sup> December 2012.
- [9] Ilya Gridneff,, Tom Arup, Jacob Saulwick, *City sizzles in record heat*, The AGE Melbourne Newspaper 19<sup>th</sup> January 2013 <http://www.theage.com.au/data-point/city-sizzles-in-record-heat-20130118->. Accessed on 19<sup>th</sup> January 2013.
- [10] Herbert Girardet, *Creating a Sustainable Adelaide*. Adelaide Thinkers in Residence 2003. <http://www.thinkers.sa.gov.au/Reports/default.aspx> . Accessed on 30<sup>th</sup> December 2012
- [11] Chris Twinn -*Bedzed*-The Arup Journal 1-2003 -[http://www.arup.com/\\_assets/\\_download/download68.pdf](http://www.arup.com/_assets/_download/download68.pdf). Accessed on 19<sup>th</sup> December 2012.

[12]Bob Holmes,“Biofuels that’s better than Carbon neutral”.*NewScientist*issueNo 2894. Pp 34-37, 8th December 2012.

## COMPOST AS LANDFILL COVER MATERIAL AND ITS IMPACT ON LANDFILL STABILITY

**Gabriel Andari Kristanto, Djoko.M.Hartono, Irma Gusniani**

*Environmental Engineering Program, Civil Engineering Department  
University of Indonesia  
Kampus Universitas Indonesia  
Jl. Margonda Raya, Depok 16424  
Tel/Fax: 62217875031  
Email: [gakristanto@gmail.com](mailto:gakristanto@gmail.com)*

### ABSTRACT

*High economic growth in Indonesia drives development in multiple sectors triggering consumerisms which as a result increasing amount of waste generated per capita. A city of Depok originally designed as a suburb of Jakarta has a population around 1.8 millions with a total area of 200 km<sup>2</sup>. In 1998, amount of waste generated was 3400 m<sup>3</sup>/day while in 2012 has been increasing to 4,200 m<sup>3</sup>/day. With high amount of waste generation, the city of Depok develops a waste management program started in 2006 by building several material-recovery facilities (UPS /unit pengolah sampah). Activities occurs in the UPS are waste separation, recovery, and composting. With organic content on the solid waste is around 80%, it is obvious that composting is the best option to reduce amount of wastes going to landfill. However due to contamination and poor process, most of the compost produced cannot be used as organic fertilizer.*

*This study focuses to evaluate slope stability of Cipayung landfill, when compost is used as coversoil. Application of compost as coversoil will not only reduce CH<sub>4</sub> emission from the landfill but also stimulates full utilization of composts produced in Depok. The first part of the paper provides a survey of waste generation, composition, and quality of compost produced in the city of Depok. Based on the data, compost is mixed with soil which usually used as coversoil in the landfill. In addition, a simple slope stability model was analyzed. The results promotes further study on potential slumps and slides of waste mass that may cause as a significant constraint on construction and development of a landfill.*

### **Keywords:**

*compost, landfill, Depok, stability*

### INTRODUCTION

Many cities in Indonesia nowadays facing big challenges in managing the increasing generation of solid waste. The high economic growth in Indonesia is not only causing development in many sectors, but also consumerisms which at the end increasing amount of waste generated per capita. One of the city is Depok which has population around 1.8 million inhabitants with total area of 200 sq km, and actually designed as a suburb of Jakarta. In 1998, amount of waste generated is 3,400 m<sup>3</sup>/day while in 2012 increase up to 4,200 m<sup>3</sup>/day. It means almost 9% of solid waste generated per year increased.

With the high amount of waste generated, City of Depok decided to develop their waste management program. Starting in 2008, they built 30 material recovery facilities (UPS/unit pengolah sampah) in many parts of the city. The activities include in the UPS are waste separation, recovery, and composting. On the other hand, most of the activities developed in the UPS do not go according to the government plan hence wastes transported to the landfill are still high.

One particular challenge is due to the lack of separation program in the household, hence most of organic wastes are contaminated which result in low quality of compost being produced. In addition it is widely known that recycling is worthwhile only if there is only a healthy market for recycle product but since no buyers willing to use the compost, the produced compost is end up also in the landfill.

Only one landfill (TPA/Tempat Pemrosesan Akhir) serving the city of Depok, named Cipayung located 20 km from Depok. With total area of 11.2 ha and used since 1997, it is reaching capacity level. With Depok's space constraints however, there is a limit to the land and resources that can be put aside for waste disposal.

Compost as cover soil has been extensively studied (Humer and Lechner, 2001; Gebert et al, 2011, Popov, 2005)). Compost is cost effective methane reductions for existing municipal solid waste landfill since it exploit the natural process of microbial methane oxidation through improved landfill cover design. Humer and Lechner (2001) mentioned that this promising complementary strategy can be applied to mitigate methane emission of smaller or older sites where the methane production is too low for energy recovery or flaring, and installation of a gas extraction system is inefficient.

Although using compost as biocover has many advantages, but there is no study analyze its impact on the landfill stability. Many factors can trigger waste-mass instability such as high leachate levels. In Indonesia, the recorded slope failures happened several times in a year especially in large landfills such as Bantar Gebang (located in Bekasi, West Java), Lewi Gajah (located in Bandung, West Java) , and Cipayung (located in Depok, West Java) although many of them had not formally reported ([http://www.indosiar.com/fokus/tpa-bantar-gebang-longsor\\_54694.html](http://www.indosiar.com/fokus/tpa-bantar-gebang-longsor_54694.html)). Jianguo et al (2010) studied that in humid regions in China, high rainfall infiltration result in high leachate levels in waste mass. Combine with an absence of effective facilities for rainwater interception and leachate drainage, the shear strength of the waste may be greatly reduced, causing landfill instability. All of those three landfills located in a regions with high annual precipitation and with lack of proper landfill design criteria led to significant loss of life.

This study aims to evaluate the slope stability of Cipayung landfill if compost is used as coversoil. Application of compost as coversoil will not only reducing CH<sub>4</sub> emission from the landfill but also “close the loop” of the compost produced in the city of Depok. The first part of the paper provides a survey of waste generation, composition, and quality of compost produced in the city of Depok. On the basis of those data, compost is mixed with the available soil that usually used as coversoil in the landfill and the simple slope stability were analysed. The results can be used to study the potential for slump and slides within the waste mass and which may represent a significant constraint on construction and development of the landfill.

## **METHODOLOGY**

### ***Waste sampling, characterization, data recording and analysis***

The study population consisted of all waste generated in the 7 UPS that actively operated over 8 day waste audits using SNI M-36-1991-03. Each of the waste sample collected has minimum weight of 100 kg and aggregated by students involved in the study into large garbage bags.

Waste samples were sorted and weighted according to 9 primary categories (Table 1) which include plastics, metal, rubber, glass, paper, wood, residue, textile, and organics.

Completed data collection forms were checked for errors and placed into standard spreadsheet data files (excel, Microsoft, U.S.A.). Subsequent analysis included computing and analyzing the mean waste composition within each UPS.

### ***Chemical and Physical Composition of Compost and mixture of Compost and Soil Used in the Study***

In this study, soil analysis of standard method and SNI (Indonesia national Standard) were applied for chemical and physical composition of compost used in the study.

Three possible scenarios of the soil and compost mixture were applied as cover soil in the Cipayung landfill.

### ***Slope stability analysis***

Slope stability of Cipayung landfill was analysed based on the landfill design criteria which are listed in Depok City masterplan which are listed on Table 5. There are two steps of the analysis: For the first step, the actual properties at Cipayung were applied with the variability of inclination to analyse the actual safety factor. The second step is finding the safest inclination of Cipayung landfill when compost is used as coversoil. The properties of Cipayung landfill are listed in Table 5. The safety factor were calculated using GeoStudio (2007) (Geoslope International Ltd.). All analysis were carried out using Morgenstern-Price method with half-sine interslice force functions.

## Result and discussion

On average, each of the UPS received 12-30 m<sup>3</sup> of waste/day with the mean composition (% by weight) of each material type recovered from UPS waste stream presented in Table 1. Almost 80% of the waste are organics, and only 20% are inorganics. All of the organics were composted using open windrow system however due to poor processing, all of the compost produced could not be used as organic fertilizer. High contaminant concentrations are the main reason that these compost were not saleable.

Table 1. Typical composition of solid waste in Depok

Categories	Percentage (%)
Plastics	10.8
Metal	0.3
Rubber	0.2
Glass	1.2
Paper	5.3
Wood	0.1
Nonrecyclables	1.3
Textile	0.9
Organics	79.8

Table 2. Typical properties of solid waste in Depok

Parameter	Range (kg/m <sup>3</sup> )	Typical value (kg/m <sup>3</sup> )
Moisture content (%w/w)	55-80	65
Density	160-220	185

## Compost quality

Table 3. Chemical Characteristics of Compost Used in The Study

Parameter	Kompos Cilangkap	SNI: 19-7030-2004		
		Minimum	Maksimum	Satuan
Moisture	26,20	-	50	%
WHC	29	58	-	%
pH	6,82	6,8	7,49	NA
Phosphor	2,32	0,1	-	%
C organic	17,78	9,8	32	%
Nitrogen	1,58	0,4	-	%
Volatile matter	30,58	27	58	%
C / N	11,22	10	20	NA

Table 4. Physical Characteristics of Compost Used in the Study

Parameter Uji	Nilai	Satuan
Specific Gravity		
SG	1.9655	
Compaction		

Kadar air optimum	50	%
$\Gamma_{wet}$	1.3	gr/cm <sup>3</sup>
$\Gamma_{dry}$	0.851	gr/cm <sup>3</sup>
Permeabilitas		
K	$2.8 \times 10^{-5}$	cm/s
T	29	<sup>o</sup> c
K20	$2.29 \times 10^{-5}$	cm/s
Atterberg Limit		
Liquid Limit	90	%
Plastic Limit	60.09	%
Plasticity Index	29.91	
Shrinkage Limit	82.48	%
Shrinkage Ratio	108.91	%
Porositas		
Bulk Density	0.851	gr/cm <sup>3</sup>
Particle Density	1.0891	gr/cm <sup>3</sup>
Porosity	21.862	%

### Properties of cover soil

Based on the Triaxial UU test, the mixture of soil and compost with the fraction of 1:1 has the highest cohesion value while the mixture of soil and compost with the fraction of 1:2 has the lowest angle of shearing resistance or angle of internal friction. On the other hand the mixture of soil and compost with the fraction of 1:1.5 has the lowest cohesion and angle of shearing resistance.

Table 5. Design Criteria of Municipal Solid Waste Landfill Parameters

Parameter	Cipayung landfill
Average height of fill (m)	30
Average annual precipitation (mm/year)	2684
Number of rainy days per year (days)	222
Porosity of solid waste material	
Saturated unit weight of MSW (kN/m <sup>3</sup> )	500
Ketebalan daily cover (cm)	30
Final cover (cm)	50
Average height of msw (m)	2

Table 6. Soil and Compost Fraction and Properties Applied In the Study

	$\gamma$ (kN/m <sup>3</sup> )	$C$ (kPa)	$\varphi$ (°)
Soil : Compost= 1: 1	15.56	25	25
Soil : Compost = 1: 1.5	14.83	19	26
Soil : Compost = 1 : 2	15.41	22	27

### Stability analyses

Specification Analysis of Geostudio SLOPE/W and Comparison of Computed Safety Factor for Measured Slope Inclinations and Heights at Cipayung Landfills are presented in Tables 7 and 8 respectively.

Tabel 7. Specification Analysis of Geostudio SLOPE/W

No.	Type of parameter	Note
1.	<i>Analysis Type:</i>	<i>Morgensterd-Price, Bishop, Ordinary, and Janbu</i>
2.	<i>Setting: PWP Condition</i>	<i>Piezometric Line</i>
3.	<i>Slip Surface: Direction of Movement</i>	<i>Left to Right</i>
4.	<i>Slip Surface Option</i>	<i>Grid &amp; Radius</i>
5.	Grid & Radius	Determined by trial and error hence the safety factor resulted from the worst case condition

Table 8. Comparison of Computed Safety Factor for Measured Slope Inclinations and Heights at Cipayung Landfills Using Geostudio SLOPE/W

Surface length 40 m			Surface length 50 m			Surface length 60 m		
Slope angle (°)	Ratio of Soil to Compost	Safety factor	Slope angle (°)	Ratio of Soil to Compost	Safety factor	Slope angle (°)	Ratio of Soil to Compost	Safety factor
75	1 : 1	0.633	75	1 : 1	0.623	75	1 : 1	0.633
75	1 : 1.5	0.629	75	1 : 1.5	0.632	75	1 : 1.5	0.628
75	1 : 2	0.633	75	1 : 2	0.689	75	1 : 2	0.631
70	1 : 1	0.691	70	1 : 1	0.743	70	1 : 1	0.688
70	1 : 1.5	0.687	70	1 : 1.5	0.740	70	1 : 1.5	0.684
70	1 : 2	0.689	70	1 : 2	0.744	70	1 : 2	0.687
65	1 : 1	0.742	65	1 : 1	0.805	65	1 : 1	0.742
65	1 : 1.5	0.739	65	1 : 1.5	0.801	65	1 : 1.5	0.739
65	1 : 2	0.743	65	1 : 2	0.803	65	1 : 2	0.743
60	1 : 1	0.822	60	1 : 1	0.805	60	1 : 1	0.805
60	1 : 1.5	0.813	60	1 : 1.5	0.801	60	1 : 1.5	0.802
60	1 : 2	0.818	60	1 : 2	0.803	60	1 : 2	0.808

Based on the iteration, it is immediately apparent that all of safety factor values from twelve iterations are less than 1200 which means that actual condition of Cipayung landfill with slope angles of 75°, 70°, 65°, 60° and surface length of 40 m, 50, 60 m are not stable if mixture of compost and soil were applied as cover soil. In addition, there are no significant difference of the computed safety factor values for cover soil with fraction of soil and compost 1: 1, 1:1.5, and 1: 2 respectively.

The length of the surface does not influence the safety factor values but the slope angle does. For example, safety factor for the same length of surface but different slope angle resulted in almost the same values, on the other hand safety factor for the different slope angle but the same surface length give the significant difference values.

Trial and error iterations were conducted to find the slope angle that will resulted in the higher safety factor values with all of the previous conditions applied. It is found that with the slope angle of 40°, the landfill was stable and the safety factor value was 1.352.

However this analysis was limited in scope and assumed that the failure surface remains within the waste mass and any interpretation of the conclusions reached herein must be made bearing in mind these limitations.

## Conclusions

Simple slope stability analysis was applied to Cipayung landfill in Depok, Indonesia using Geoslope. Twelve possibilities of landfill conditions were used in the analysis along with mixture of soil and compost as cover material. It is found that the safety factor values for all of those twelve possibilities are lower than 1,200. Further assessment found that the highest of the slope angle is 40° if all of the design criteria will be applied according to Depok's solid waste master plan.

## Acknowledgements

The authors wish to thank the DRPM-UI for the national collaboration research funding which is granted under contract No. 1175/H2.R12/HKP 05.00 Perjanjian/2012.

## References

- [1] Dixon, N., Russell, D., Jones, V. 2005. Engineering properties of municipal solid waste. *Waste Management*, 23, [2] 205-233.
- [3] Jianguo, J., Yong, Y., Shihui, Y., Bin, Y., Chang, Z. 2010. Effect of leachate accumulation on landfill stability on [4] humid regions of China. *Waste Management*, 848-855.
- [5] Gebert, J., Groengroeft, A., Pfeiffer, E.M. 2011. Relevance of soil physical properties for the microbial oxidation of [6] methane in landfill covers. *Soil Biology and Biochemistry*, 43, 1759- 1767.
- [7] Gharabaghi, B., Singh, M.K., Inkraats, C., Fleming, I.R., McBean, E. 2008. Comparison of Slope stability in two [8] Brazilian municipal landfills. *Waste Management*, 28 (1509-1517)
- [9] Humer, M.H., Lechner, S.R. 2009. Approaches to assess biocover performance on landfills. *Waste Management*, 29, [10] 2092-2104.
- [11] Koerner, R.M., Soong, T.Y. 2000. Leachate in landfills: the stability issues. *Geotextile and Geomembranes*, 18, 293- [12] 309.
- [13] Popov, V. 2005. A new landfill system for cheaper landfill gas purification. *Renewable Energy*, 30, 1021-1029.
- [14] Tchobanoglous, G., Kreith, Frank. 2002. *Handbook of Solid Waste Management*, McGraw-Hill, Inc, New York.
- [15] Tchobanoglous, G., Theisen, H., Samuel, Vigil. 1993. *Integrated Solid Waste Management*, McGraw-Hill, Inc, New York.
- [16] SNI M-36-1991-03 (Indonesia national Standard)

## Land Use/Land Cover Classification in Urban Areas with Supervised Maximum Likelihood Classifier Method

Heri Suprpto<sup>a</sup>, Latifa Ulfah<sup>b</sup>

<sup>a</sup> Faculty of Engineering, Gunadarma University, Depok 16424  
([hsuprpto@staff.gunadarma.ac.id](mailto:hsuprpto@staff.gunadarma.ac.id))

<sup>b</sup> Faculty of Engineering, Gunadarma University, Depok 16424  
([lfa\\_wegz@yahoo.com](mailto:lfa_wegz@yahoo.com))

### ABSTRACT

*Land cover/land use classification is an effort to classify various types of land cover/land use into a similarity based on a particular method. Land cover/land use classification is used as a guideline or reference in the process of interpretation of remote sensing images for the purpose of mapping land cover/land use. Supervised classification is the process of classification which refers to the existence of classes defined as references. The usage of supervised classification used to classify land cover/land use has already got accurate field. The purpose of this research is to classify land cover/land use in urban areas from QuickBird image. The method used in the research is Supervised Maximum likelihood classifier. The results of the research show that the method is able to classify land cover/land use in urban areas with accuracy 75 % and 86.67 %.*

**Key word** : Land Use, Land Cover, Urban, Supervised, classification, Maximum Likelihood

### INTRODUCTION

Land cover/land use explore about what kinds of physical and material contained within an area. It is very useful concerning with infrastructure development and decision making in the area. In urban areas, frequently encountered obstacles in land cover/land use classification because the density and breadth of the area, so to be able to properly land cover/land use classification needed a satellite image or aerial photograph remote sensing (1). Remote sensing is a method to obtain information about an object, area, or phenomenon by conducting an analysis of the data obtained with a tool without direct contact. Remote sensing is a technique where developed to acquire and analyze information about the surface of the Earth. Remote sensing produced digital imagery that can be used to obtain information about the form of the Earth especially land cover and land use. Land use associated with the use of land within an area that encompasses with special functions, e.g. residential, green fields, catchment area, trading, industry, and others. (2).

To improve the capabilities in land cover/land use classification in urban area, Can be conducted using image with high resolution namely quickbird image. By using high resolution image, the process of separation of the image can be made more accurate because the same spectral variations can be reduce (3). The use of high resolution image spatial can help in land cover/land use classification and the result has been proved to be good accuracy. Problem that happens in image classification is the presence of disorder by clouds on existing image and similarity between each land cover/land use image. By using spectral image as well as uses the method classifications based on segmentation can increase its accuracy (4). By using multitemporal quickbird image, land cover/land use classifications can do better the problem related the occurrence of pixels nucleated can be reduced (5).

The utilization of satellite imagery to assist in land cover/land use classification, it is generally known two methods, namely supervised classification where in the process of classification refers to the existence of classes already defined before/as referrer and unsupervised classification where in the process use the classification groups of pixels image based on statistical

aspects, without the existence of classes as the referrer defined previously (6). Supervised method for land cover/land use classification already used and managed properly. Based on these studies, the accuracy in the analysis of land cover and use in urban areas is very important and became the basis of the development of the city. The purpose of this paper is to conduct land cover/land use classification on an urban area with QuickBird image.

## RESEARCH METHOD

### Supervised Image Classification Method

Supervised Classifications have the meaning classifications on certain supporting reference where category of objects in the image has been identified previously. Classifications done by inserting each pixel image into a category an object which is already known. The classification began with the study of early imagery that would be classified and compared it to the existing reference information. Based on existing reference information, then formed a set of samples of the elements consist of pixels-pixels that represent each of the categories of objects that have been identified, that is done by selecting pixels which have a great variety so that it reflects the character of the object. On a set sample, statistics value covering the average and kovarian matrix calculated for any object.

### Quickbird Imagery

Quickbird imagery is a high-resolution satellites use sensors BGIS-2000 with a resolution is 0.61 meters. Quickbird satellite have a band with diverse specifications (Table 1)

Table 1 Band specification of Quickbird *imagery*

Band	colour	Domain Spektral	Spasial resolution	Radiometrik resolution
1.	Blue	0.45-0.52 $\mu\text{m}$	2.44m-2.88m	11-bit/piksel
2.	Green	0.52-0.60 $\mu\text{m}$	2.44m-2.88m	11-bit/piksel
3.	Red	0.63-0.69 $\mu\text{m}$	2.44m-2.88m	11-bit/piksel
4.	NIR	0.76-0.90 $\mu\text{m}$	2.44m-2.88m	11-bit/piksel
Pan	VNIR	0.45-0.90 $\mu\text{m}$	0.61m-0.72m	11-bit/piksel

The Quickbird image was used because it can showing the description of the object, the Earth's surface and the symptoms that come with the appropriate layout of the actual conditions.

### Interpretation of imagery

The interpretation of imagery is examining aerial photographs or images with intent to identifying objects and estimate the importance of the object, by conducting a series of activities consisting of detection, identification and analysis. Detection is the observation of objects, identification is efforts to characterize the objects that have been detected by using a sufficient description, and analysis is the phase of collecting more information. The interpretation of imagery can be done visually or digital.

### Image Classification

Image classification is a process to obtain images or thematic map consisting of those parts of the States of an object or theme. Each object in the picture has a unique symbol that is declared with the particular color or pattern. For example Land cover/land use map consists of parts which stated area of forest, water, housing, industry, rice fields, road, etc.

#### **Maximum Likelihood Classifier Process**

Maximum Likelihood Classifier is one of method in image classification for the purpose analysis of land cover/land use classification. This method in classification process using assumption identifies features that are almost the same in class. The process land cover/land use classification in urban areas was carried out like in Figure 1.

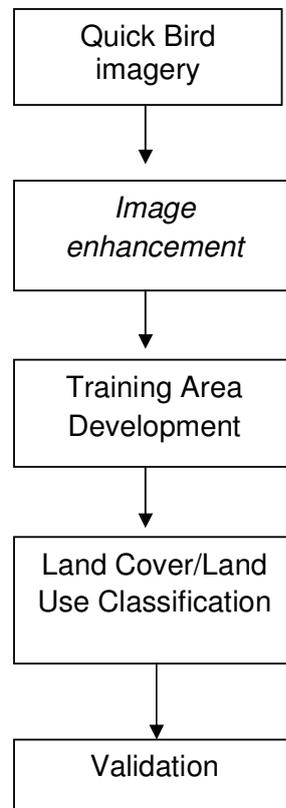


Figure 1, Supervised classification method with Maximum Likelihood Classifier Process

1. Data that uses is quickbird satellite images.
2. Repairing the quality of the image ( image ehancement ) by changing brightness, sharpening the image and etc. Image enhancement aims is to get a new image as expected for a variety of purposes of interpretation
3. On supervised classification set the sample to be used as a supporting reference, and pixels will be processed based on the sample area then bringing image pixel into a category regional sample., like the tree, settlements, asphalt and concrete
4. The use of Maximum Likelihood algorithm, in classification process, used training data as a means to estimate the mean and variance of class, then used to estimate the probability.
5. After classification process completed and produce thematic maps, then performed a test of accuracy/truthfulness (Accuracy Assessment) Supervised classification. Test accuracy/truth is used to find out how accurate the results of the classification has been carried out. Test accuracy/truthfulness is done by pasting the reference area is considered to be true and then compared with the provided class of software Erdas Imagine.

## RESULTS AND DISCUSSION

The data used in research consisting of two sample data i.e quickbird imager of Surabaya and quickbird imagery of meulaboh. The quickbird imagery used is recording in 2004. The selection of the two areas for example due because the two areas have land cover/land uses a diverse and a clear distinction between existing land use (Figure 2 and Figure 3).



**Figure 2** *Quickbir* imagery of Surabaya



**Figure 3** *Quickbir* imagery of Meulaboh

### **Improvement of Quickbird Imagery**

Imagery will be processed first improved quality using the software Matlab 7.6. As a result of improvements to the basic image is the image became more obvious differences between each class. Improvement of image make the image becomes lighter or darker, so as to make it easier in the next process.

### **Training Area**

Determination of training area is performed to retrieve the pixels-pixels on a specific area to be turned into a class. Pixel-the pixel will be a reference for other pixel whose value is almost the same. The workings of the training area that is by

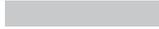
looking for the lowest pixel value and the highest value of pixels in areas that becomes reference. Other pixel values between the lowest pixel value and the highest value of this pixel will fit into one class (Figure 4).



**Figure 2 Training area development**

To perform this method of classification with supervision, for a quickbird imagery of Surabaya divided into four (4) classes based on the value of the colors of the class. The task force consists of the classes that used the green colour to represent the class tree, open land and vegetation is green, the color of purple for the class Residential, buildings and land, gray color for the class of Highway and asphalt and white color for asbestos and concrete classes as in table 2.

Table 2 description of the Class in which the area of Surabaya

No.	Class discription	colour
1.	Tree, open land and vegetation	
2.	Residential, buildings and land	
3.	Highway and asphalt	
4.	asbestos and concrete	

Supervised classification Signature Attribute display in Surabaya was like Figure 5

Class #	Signature Name	Color	Red	Green	Blue	Value	Order	Count	Prob.	P	I	H	A	FS
1	Pohon, Lahan Terbuka, Vegetasi Hijau 1	Green	0.000	0.392	0.000	1	1	23235	1.000	✓	✓	✓	✓	✓
2	Pohon, Lahan Terbuka, Vegetasi Hijau 2	Green	0.000	0.392	0.000	2	2	33265	1.000	✓	✓	✓	✓	✓
3	Pemukiman, Bangunan, Tanah	Red	0.690	0.188	0.376	3	3	50574	1.000	✓	✓	✓	✓	✓
4	Aspal, Jalan Raya 1	Grey	0.753	0.753	0.753	4	4	1235	1.000	✓	✓	✓	✓	✓
5	Aspal, Jalan Raya 2	Grey	0.753	0.753	0.753	5	5	939	1.000	✓	✓	✓	✓	✓
6	Asbes, Beton	White	1.000	1.000	1.000	6	6	635	1.000	✓	✓	✓	✓	✓



Early image

final image

Figure 5 Signature Editor Supervised Classification Of Surabaya

The results of supervised Maximum likelihood method classifier of quickbird imagery of Surabaya obtained the following results: green vegetation accuracy of the fit obtained 75% this method can clearly classify clearly and 25% are classified as urban area. In urban areas, the classification class has 75% accuracy, whereas the urban area that does not fit is 25% are classified into classes of green vegetation. The accuracy of the classification of best in show at the grade of asphalt that reaches 100%, whereas for the classification accuracy reaching 50%. From the whole class, then in its entirety to the analysis of classification on a map of Surabaya classification accuracy obtained reach 75% (table 3 and table 4).

Table 3 Description of the class of Surabaya

Class discription	Discription
Green vegetation (VH)	Tree, open land and vegetation
Urban (U)	Residential, buildings and land

Asphltl (A)	Highway and asphalt
Asbestos, concrete (AsB)	asbestos and concrete

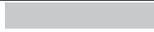
Table 4 Test Accuracy/truthfulness of Supervised Classification On Surabaya

Reference Data									
Classified Data		VH1	VH2	U	A1	A2	AsB	Total	Users Accuracy
	VH1	3	0	1	0	0	0	4	75.00%
	VH2	0	0	0	0	0	0	0	-
	U	1	1	6	0	0	0	8	75.00%
	A1	0	0	0	1	0	0	1	100.00%
	A2	0	0	0	1	1	0	2	50.00%
	AsB	0	0	0	0	0	0	0	-
	<b>Total</b>							<b>15</b>	
<b>Overall Accuracy={ (3+0+6+1+1+0)/15 } x 100 = 73.33 %</b>									

To perform quickbird imagery of Meulaboh is divided into four classes based on the value of the colors of the class. The task force consists of the classes that used the green colour to

represent the class trees, open fields and pastures, unguu colors for the class settlement, buildings and land, gray color for the class of Highway and asphalt and white color for asbestos and concrete classes as in table 5.

Table 5 Description of classification Classes of Meulaboh

No.	Class discription	colour
1.	Tree, open land and vegetation	
2.	Residential, buildings and land	
3.	Highway and asphalt	
4.	asbestos and concrete	

Display Signature Attribute classification on the Meulaboh is like a figure 6 as follows:



Class #	Signature Name	Color	Red	Green	Blue	Value	Order	Count	Prob.	P	I	H	A	FS
1	Pohon, Rumput, Lahan Terbuka 1	Green	0.000	0.392	0.000	1	1	22075	1.000	✓	✓	✓	✓	✓
2	Pohon, Rumput, Lahan Terbuka 2	Green	0.000	0.392	0.000	2	2	32747	1.000	✓	✓	✓	✓	✓
3	Aspal, Jalan Raya	Grey	0.753	0.753	0.753	3	3	8916	1.000	✓	✓	✓	✓	✓
4	Pemukiman, Tanah 1	Red	0.690	0.188	0.376	4	4	2720	1.000	✓	✓	✓	✓	✓
5	Pemukiman, Tanah 2	Red	0.690	0.188	0.376	5	5	6336	1.000	✓	✓	✓	✓	✓
6	Asbes, Bangunan	White	1.000	1.000	1.000	6	6	3308	1.000	✓	✓	✓	✓	✓



Early image

final image

Figure 6: The Signature Editor Supervised Classification on The Meulaboh

The accuracy of the supervised method of Maximum likelihood classifier to quickbird imagery of Meulaboh obtained the following results: green vegetation for the accuracy of the fit obtained 50% for green vegetation 1 and 100% for green vegetation 2. This method can be clearly classified clearly and 50% are classified as areas of green vegetation 1 and 2 green vegetation. In urban areas, the classification class has 75% accuracy, whereas the urban area that does not fit is 25% are classified into classes of green vegetation. The accuracy of the classification of best in show at the grade of asphalt that reach 100% for urban 1 and 50% for urban 2, while for the classification accuracy reaching 50%. From the whole class, then in its entirety to the analysis of classification on a map of classification accuracy reaching Meulaboh gained 86.67% (table 6 and table 7).

Table 6 Description of the class of Meulaboh

class	Discription
-------	-------------

Green vegetation (VH)	Tree, open land and vegetation
Urban (U)	Residential, buildings and land
Asphalt (A)	Highway and asphalt
Asbestos, concrete (AsB)	asbestos and concrete

Table 7. Test The Accuracy Of Classification of Meulaboh

Reference Data									
Classified Data		VH1	VH2	A	U1	U2	AsB	Total	Users Accuracy
	VH1	1	1	0	0	0	0	2	50.00%
	VH2	0	2	0	0	0	0	2	100.00%
	A	0	0	3	0	0	0	3	100.00%
	U1	0	0	0	2	0	0	2	100.00%
	U2	0	0	0	0	4	0	4	50.00%
	AsB	0	0	0	0	1	1	2	-
	<b>Total</b>								<b>15</b>
<b>Overall Accuracy</b> ={ $(1+2+3+2+4+1)/15$ } x 100 = <b>86.67 %</b>									

## CONCLUSION

The conclusions that can be produced from research on land cover classification in urban areas with Maximum

likelihood classifier supervised method overall produce a good degree of accuracy and can classify existing classes as well. Confusion in classifying in classification, there are several classes that result is still not satisfactory as there the green vegetation in class of asphalt and also asphalt or highway that is classified as a class a roof, this happens because of the similarity of the color that is in the existing quickbird imagery. With the level of precision achieved 75% and 86.67% of course these methods prospected in classification of land cover and use in urban areas.

## REFERENCES

- (1) Keuchel, J., et al., 2003. Automatic land cover analysis for Tenerife by supervised classification using remotely sensed data. *Remote Sensing of Environment*, 86(4): 530-541.
- (2) Lillesand, Kiefer, 1998. *Penginderaan Jauh dan Interpretasi Citra*, Gajah Mada University Press.
- (3) Yu, Q., P. Gong, N. Clinton, G. Biging, M. Kelly, and D. Schirokauer, 2006. Object-based detailed vegetation classification with airborne high spatial resolution remote sensing imagery, *Photogrammetric Engineering & Remote Sensing*, 72(7):799–811.
- (4) Lu, D, Hetrick, S, and Emilio, M, Land Cover Classification in a Complex Urban-Rural Landscape with QuickBird Imagery, *Photogrammetric Engineering & Remote Sensing* Vol. 76, No. 10, October 2010, pp. 1159–1168.
- (5) Al-Tamini, Salam dan Al-Bakri, J. T. 2005. Comparison Between Supervised and Unsupervised Classifications for Mapping Land Use/Cover in Ajloun Area. *Jourdan Journal of Agricultural Sciences*, Volume , No 1, 2005.
- (6) Samaniego, L, and Schulz, K, Supervised Classification of Agricultural Land Cover Using a Modified *k*-NN Technique (MNN) and Landsat Remote Sensing Imagery *Remote Sens.* 2009, 1, 875-895; doi:10.3390/rs1040875
- (7) Mutuku, F.M, Bayoh, M. N, Hightower, A. W, Vulule, J.M, Gimnig, J. E, Mueke, J.M, Amimo, F. A, Walker, E.D, A supervised land cover classification of a western Kenya lowland endemic for human malaria: associations of land

cover with larval *Anopheles* habitats, *International Journal of Health Geographics* 2009, 8:19 doi:10.1186/1476-072X-8-19

# Field Study on Undrained Shear Strength of Soft Soil around Micropiles

Yulian Firmana Arifin<sup>a</sup>

<sup>a</sup>Faculty of Engineering, University of Lambung Mangkurat, Banjarbaru 70714  
E-mail : yulianfirmana@yahoo.com

## ABSTRACT

*Micropile (Cerucuk) is widely used to increase the bearing capacity of soft soil in South Kalimantan. Some researchers have reported that the use of micropile can increase the bearing capacity of soft soil. However, most studies were conducted in laboratory. This paper discusses the influence of micropile on undrained shear strength in soft soil around the piles. The study was performed in the field.*

*In this study, cerucuk used was Galam (Malaleuca Leucadendron) that have a nature-lined leather-wrapped sticks, hard and heavy. Galam has a diameter (D) of 0,10 m and a length of 2 m. Piles were penetrated with different spacing (i.e., 2D, 3D, and 4D). Shear strength was measured directly in the field using the field vane shear. Considering time effect, measurements were made before installation, and 1, 7, 14, and 28 days after installation. The results show that the closer pile the greater the soil shear strength. The piles affect the soil shear strength at a distance up to 0.20 m from the pile. Soil shear strength increases by time up to 14 days.*

## Keywords

*Cerucuk, micropile, undrained shear strength, field vane shear test, pile distance, time effect.*

## 1. INTRODUCTION

Micropile (cerucuk) is widely used in South Kalimantan to increase bearing capacity of soft soil. It can be proved theoretically as in [1] using NAVFAC DM-7 [2] based on assumption of piles loaded laterally. However, based on laboratory model, Reference [3] reported that bearing capacity resulted in experiment was higher than that of theoretic calculation. Reference [3] also reported that the use of micropile increases the shear strength of soft soil. However, the conclusion was based on laboratory model.

Referenses [4] and [5] reported experiments on piles in the field. According to [4], the use of micropile resulted in increasing the bearing capacity of soft soil. It increases with increasing time. At the age of 4 days, bearing capacity increased by approximately 45%. The increase has reached 97% after the age of 15 days. According to [5], the distance of pile influenced the bearing capacity of pile in the field. For the same length of pile, the sorter the distance the greater bearing capacity of group piles. The study did not address changes in shear strength of the soil around the pile. In fact, this information is very important for the engineers in the calculation.

Reference [6] reported an effect of pile installation on the shear strength parameter of soil. The test was conducted in a triaxial apparatus. It was found that the cohesion and internal friction angle change due to installation of pile. It results in increasing soil strength and reducing settlement. The result was also concluded based on laboratory test. A field test to support the theoretical and experimental results is required. This paper discusses the changes in shear strength of soil around the pile. Distance and time of pile installation were considered in this study.

## 2. MATERIAL USED AND EXPERIMENTAL TECHNIQUES

### 2.1 Material Used

Micropile used in this study was the type of wood called Galam (*Malaleuca Leucadendron*). This type of wood is often used as a foundation or soil reinforcement in Kalimantan especially in South Kalimantan. The unique properties of this material is its strength maintained if submerged under water continuously. The pile used has diameter of 10 cm and length of 200 cm.

## 2.2 Soil Properties

A laboratory test was performed to the soil. The soil properties of soft soil are summarized in Table 1. According to Table 1, soil has very high water content, fine content, and compression index, and very low coarse grain, shear strength, and coefficient of consolidation. Table 1 also shows that the soil properties from depth of 0.5 to 3.0 m are similar.

Table 1: Summary of soil properties

Soil properties	Depth (m)	
	0.5-1.0	2.5-3.0
Specific gravity	2.6	2.6
Water content	% 96.8	101
Volumetric weight	Mg/m <sup>3</sup> 1.53	1.52
Grain size distribution		
Gravel	% 1.0	1.6
Coarse sand (0.6-2.0 mm)	% 0.7	1.7
Medium sand (0.2-0.6 mm)	% 0.8	1.4
Fine sand (0.05-0.2 mm)	% 4.5	3.9
Silt	% 41.7	22.7
Clay	% 51.3	68.7
Liquid limit	% 55	54
Plastic limit	% 43	46
Plasticity Index	% 12	8
Unconfined compression test		
$q_u$	kg/cm <sup>2</sup> 0.07	0.16
$q_r$	kg/cm <sup>2</sup> 0.03	0.7
$s_i$	2.13	2.34
Consolidation test		
$c_c$	0.82	0.55
$c_s$	0.09	0.14
$c_v$	cm <sup>2</sup> /s 0.02	0.01

## 2.3 Techniques and Procedures

Undrained shear strength of soil was measured using field vane shear test (FVST) apparatus. This test is the most widely used method for measuring the undrained shear strength of a soil, and is particularly appropriate for assessing very soft and sensitive clays, in case where a soil sample for laboratory testing cannot be obtained. The vane has diameter of 4 cm and height of 8 cm. The test procedures are described in ASTM Standard D-2573 [7]. The diameter effect on the  $s_u$  is included in the calculation as described in [7].

Piles were installed with the configuration as shown in Figure 1. "s" is distance of pile. Three different distance were used (i.e., 2d, 3d, and 4d, or 20, 30, and 40 cm, respectively) where d is pile diameter. FVSTs were performed in between the piles and also outside the group piles as shown in Figure 1.

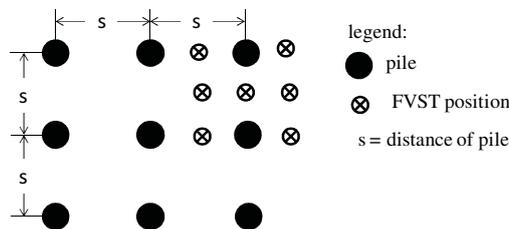


Figure 1: Configuration of pile installation and FVSTs positions

The distance of FVST is approximately 10 cm. For  $s = 20$  cm, there was one FVST in between the piles. For  $s = 30$  and  $40$  cm, there were 2 and 3, respectively (Figure 2). FVST were conducted after installation period of 1, 7, 14, and 28 days. To ensure that the soil is not disturbed, the test were performed to different group piles for different installation period. For the vertical distance, FVST was carried out each 20 cm to a depth of 200 cm as shown in Figure 2. Field procedures and calculation were performed based on ASTM standard [7].

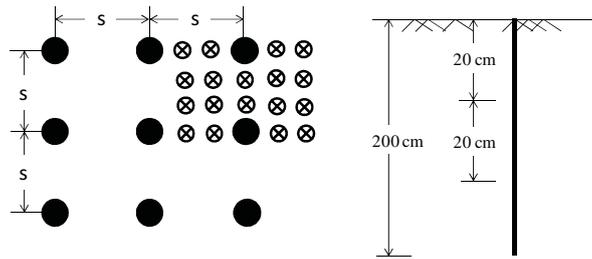


Figure 2: Configuration of pile installation, FVSTs positions, and vertical distance of FVST

### 3. RESULT AND DISCUSSION

Figure 3 shows typical undrained shear strength ( $s_u$ ) in kPa obtained from FVST per 20 cm. Sketch of nine FVSTs position is displayed in the right side of the figure. An independent measurement of FVST was performed before pile installation to obtain initial  $s_u$ . As shown in the figure, the initial  $s_u$  of the soil is approximately 1.8 to 2.0 kPa.

There are two main positions discussed in this study i.e., inside and outside group piles. Points placed inside group piles are 2, 4, 5, and 6, and points outside group piles are 1, 3, 7, and 8. Points 1 and 3 are placed about 10 cm from piles, whereas points 7 and 8 are placed about 20 cm from the piles. According to Figure 3,  $s_u$  at points 7 and 8 is similar to the initial  $s_u$ . Whereas  $s_u$  at points 1 and 3 is higher than that of initial  $s_u$ . It can be concluded that piles affect the soil at a distance of less than 20 cm. Similar result was obtained for  $s = 30$  and  $40$  cm. Figure 3 also shows that  $s_u$  at points 2, 4, 5, and 6 increases due to pile installation. Pile affects undrained shear strength of soil inside and outside group piles.

Figure 4 shows change of  $s_u$  due to installation of piles after 14 days. As shown in the figure, that  $s_u$  of soil is affected by time. Except for  $s_u$  at the points of 7 and 8, the values are not changed. This result supports previous statement that piles affect the soil at a distance of less than 20 cm.

Figure 5 shows effect of pile distance and time on  $s_u$  of soil. The data in the Figure 5(a) is the average of several measurements at the same position (i.e., in between two piles) and placed 10 cm from pile (e.g., Points 2 and 4 as shown in Figure 3). As shown in Figure 5(a),  $s_u$  slightly increases with depth. At this position, the  $s_u$  of soil is similar for different distance of piles. It seems that piles affects soil around it. Distance does not give significant effect at least up to a distance of  $4d$  (i.e., 40 cm) used in this study.

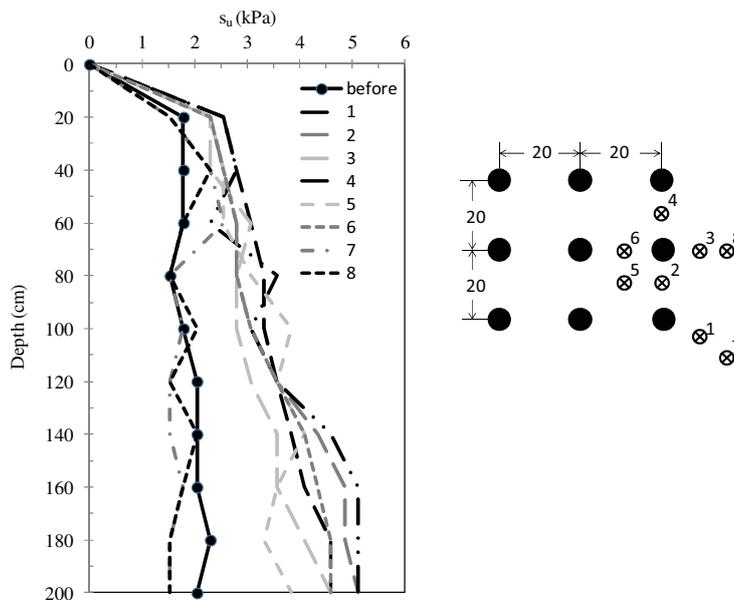


Figure 3: Undrained shear strength of soil by depth for  $s=20$ cm after 7 days

Figure 5(b) shows  $s_u$  of soil at the same position as data in Figure 5(a) performed at different time. After 1 day installation,  $s_u$  of soil is about 2 kPa. This is almost the same as  $s_u$  without pile.  $s_u$  increases to 3 kPa and 4-5 kPa after 7 and 14 days installation, respectively. After 28 days,  $s_u$  is about 4-5 kPa. The results shows that  $s_u$  of soil increases due to pile installation and influences by time. Increase of  $s_u$  is not significant after 14 days installation.

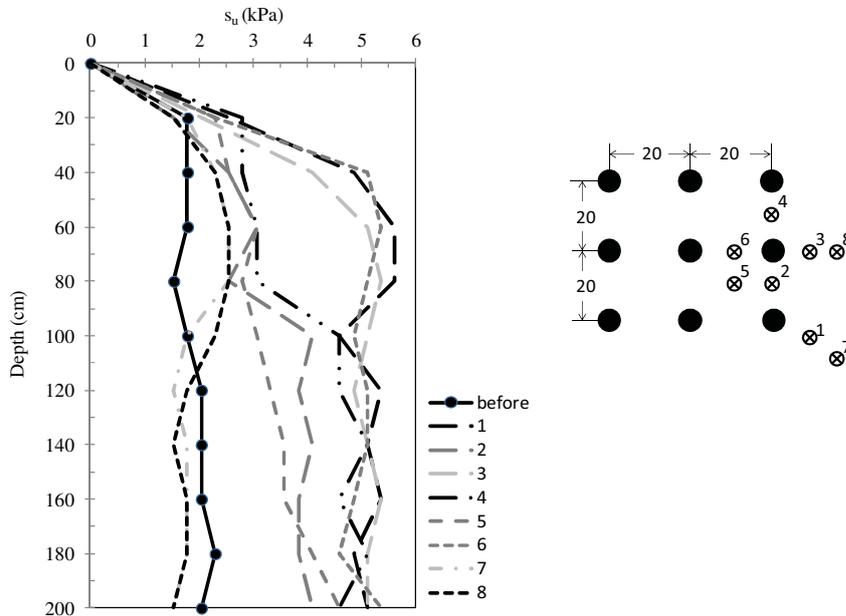


Figure 4: Undrained shear strength of soil by depth for  $s=20\text{cm}$  after 14 days

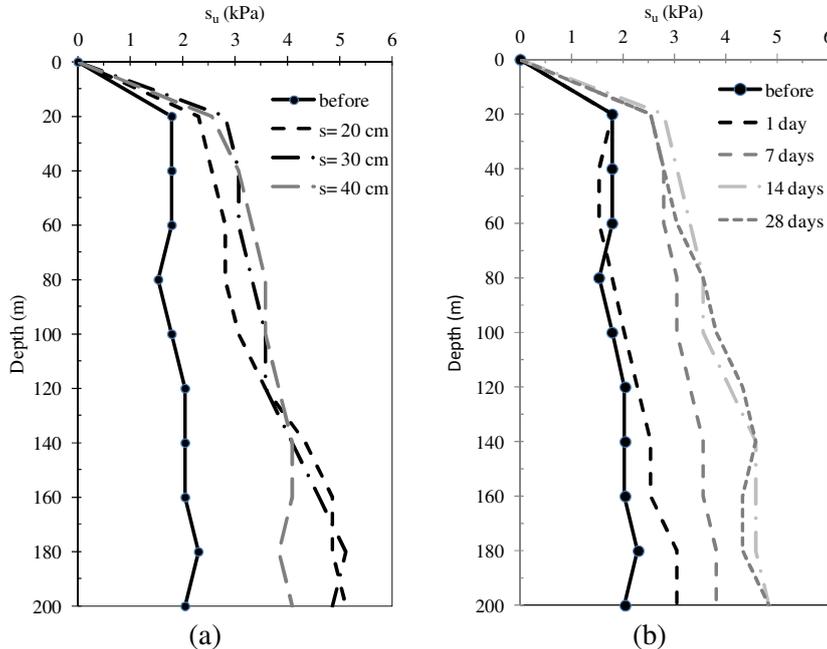


Figure 5: Undrained shear strength of soil (a) distance effect, and (b) time effect

Figure 6 shows  $s_u$  of soil as a function of time for different distance of pile. Figures 6(a) and 6(b) show average data of  $s_u$  at the same depth (i.e., 200 cm) at points 1 and 3 and at points 2 and 4 as shown in Figure 3, respectively. Figure 6(a) shows clearly that  $s_u$  increases significantly up to 4.5-5 kPa or 250% (i.e., 2.5 times the initial  $s_u$ ) up to 14 days. The similar phenomenon is shown in Figure 6(b).  $s_u$  increase significantly up to 5 kPa or 275% (i.e., 2.75 times the initial  $s_u$ ) up to 14 days.

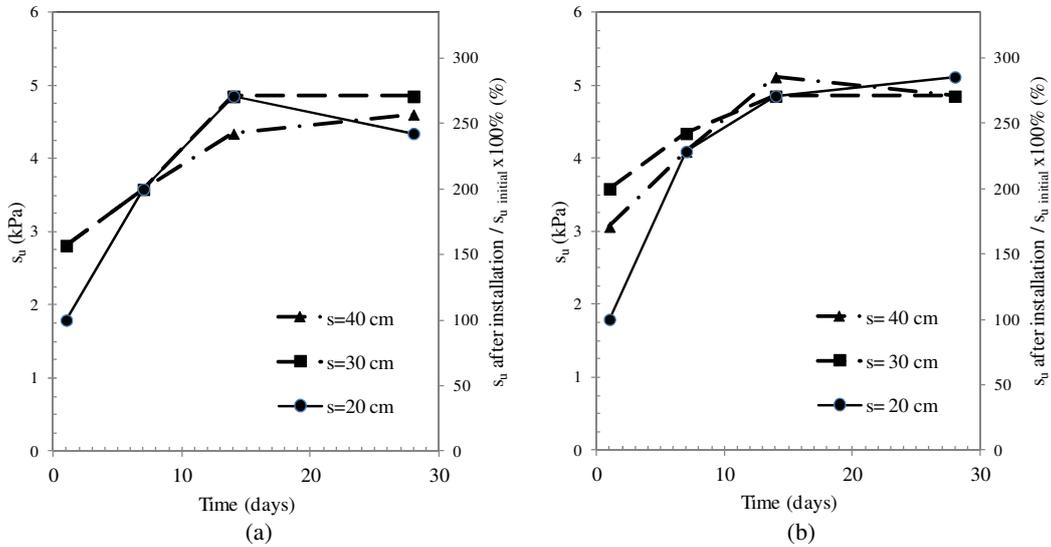


Figure 6: Undrained shear strength of soil (a) distance effect (b) time installation effect

Figures 7(a) and 7(b) shows effects of points position and pile distance on the  $s_u$  after 1 and 7 days pile installation, respectively. As shown in Figure 7(a),  $s_u$  of soil outside the group piles is less than those inside the group piles.  $s_u$  of soil in between 2 piles (points 2, 4, and 6) is relative the same as  $s_u$  of soil in between four piles (points 5). The value is slightly influenced by the distance of piles. After 7 days,  $s_u$  increases and similar for all positions inside and outside of group piles. Similar results are obtained for 14 and 28 days after installation of piles.

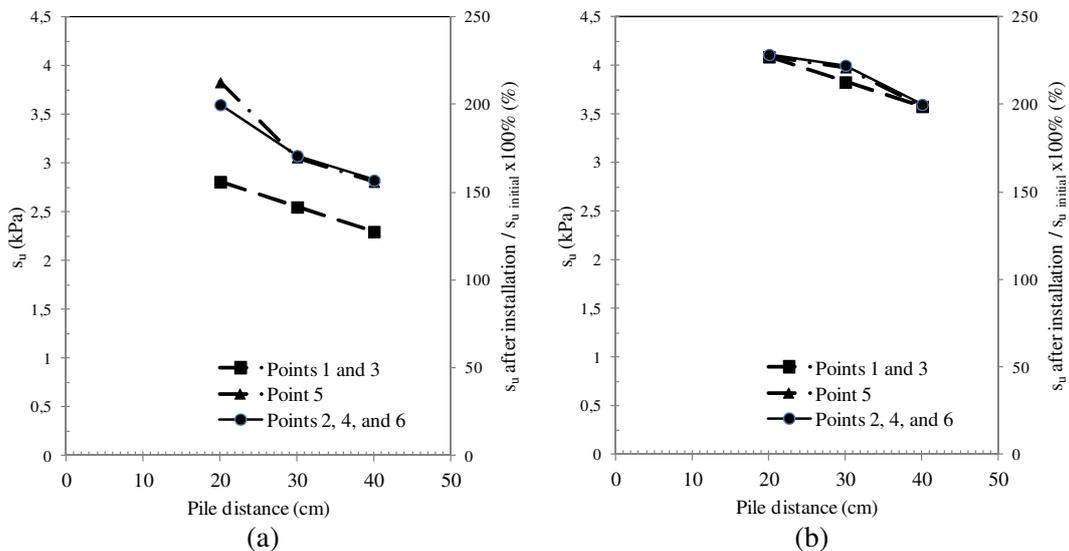


Figure 7: Effects of points position and pile distance (a) after 1 day, and (b) after 7 days installation

#### 4. CONCLUSION

Result of field test of micropiles effects on undrained shear strength of soil around the piles are presented. Distance of piles and time effect are considered in this study. The results revealed that group piles influenced the undrained shear strength of soil at a distance up to 20 cm outside the group. For soil inside the group piles, undrained shear strength increased from 2.5 to 2.75 times due to pile installation. Increase of shear strength was almost the same for different positions in the group. Pile distance influenced slightly on the values of shear strength. The closer the pile the higher shear strength of piles. Time installation

influenced significantly on the undrained shear strength of soil around the pile. The shear strength increased significantly by increasing time up to 14 days. There was no significant effect after 14 days installation.

## REFERENCES

- [1] L. Karina, and I.B. Mochtar, "Studi Model Perubahan Daya Dukung dan Settlement untuk Pondasi Dengan Pemasangan Mikropile atau Cerucuk", Tugas Akhir Penelitian S1, Jurusan Teknik Sipil, FTSP-ITS, 1995.
- [2] NAVFAC DM-7, Design Manual, Soil Mechanics, Foundation, and Earth Structures, Dept. of the Navy, Naval Facilities Engineering Command, USA, 1986.
- [3] W. Arya, and I.B. Mochtar, "Pengaruh Penambahan Cerucuk Terhadap Peningkatan Kuat Geser Tanah Lunak Pada Permodelan di Laboratorium", Tesis Magister Teknologi, Institut Teknologi Sepuluh November Surabaya, Surabaya, 2002.
- [4] Y. Yudiawati, and Ruspriansyah, "Peningkatan Daya Dukung Cerucuk Galam Sesuai Fungsi Waktu Berdasarkan Hasil Percobaan Pembebanan Lapangan", Laporan Penelitian, Politeknik Negeri, Banjarmasin, 2005.
- [5] Y. Yudiawati, and A. Marzuki, "Peningkatan Daya Dukung dan Pengurangan Penurunan Pada Pondasi Dangkal di Atas Tanah Lunak dengan Menggunakan Cerucuk Berdasarkan Percobaan Lapangan," Laporan Penelitian Hibah Bersaing, Politeknik Negeri, Banjarmasin, 2008.
- [6] D Damoerin, W. Rahayu, U. Nurhayati, "The effect of timber pile reinforcement to the shear strength of clay under consolidated undrained test", Proceeding of the 12th International Conference on QIR (Quality in Research), 2011.
- [7] ASTM, Annual Book of Standards. Volumes 04.08 and 04.09, Soil and rock, ASTM International, West Conshohocken, PA, 1997.

# Increasing the Depok Residual Soil Strength for Sub-Base Layer by Using Soil Cement Stabilization

Damrizal Damoerin<sup>a</sup>, Sigit P. Hadiwardoyo<sup>b</sup>, Fira Yolanda<sup>c</sup>, Widjojo Prakoso<sup>d</sup>

<sup>a,c</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : damrizal@eng.ui.ac.id

<sup>b,d</sup>Faculty of Engineering University of Indonesia, Depok 16424  
E-mail : sigit@eng.ui.ac.id

## ABSTRACT

The Depok residual soil has been used as sub grade layer only for road pavement. By using soil cement stabilization, the Depok residual soil can be used as a sub-base layer to substitute the sand stone material in the future. The cement stabilization can be used as 10 percent of dry weight of soil and then the soil cement sample is compacted by Modified Standard Proctor around the optimum water content of 34.12 %. The soil samples were prepared in two conditions. The first condition, the soil sample was delayed in compaction for 0, 6, 24, 72 and 168 hours and then compacted and the second condition, the soil sample was compacted and then cured for similar time. After this stage, the laboratory testing such as California Bearing Ratio (CBR) and Unconfined Compression were conducted on the samples. The result from this test indicated that the soil sample was compacted and then cured is better than the soil sample was delayed in compaction and then compacted. Using cement stabilization, the Soaked CBR value increase from 13.23 % to 37.75 %, it is adequate as sub-base layer. It was found that cement soil stabilization increased the soil strength to support vehicle load.

## Keywords:

Residual soil, cement, stabilization, soil strength, CBR, UCS

## 1. INTRODUCTION

### 1.1 General Geology

Depok city as suburb is located in the south of Jakarta city and is growing very fast in infrastructure development and population. Based on the geologic map of Jakarta – Bogor area, the Depok soil area is consist of residual soil as part of volcanic material weathering where it covered Bogor regency to south of Jakarta area [1]. The Depok residual soil is well known as lateritic soil.

### 1.2 Soil Cement

Generally, the flexible pavement may consist of surface, base, sub base course and compacted sub grade. Sub base courses may consist of variety of materials and in some cases the sub grade itself might meet the requirement for a sub base or it may be treated by means of stabilization to function as a sub base. And on the other hand, cement-treated bases have been used with success under both concrete and asphalt pavement [2]. Cement and lime treatment has been extensively used for road construction purposes resulting in increased bearing capacity of sub grade [3]. Cement stabilization is widely used for road construction and cement requirement can be used in ratio of 6 – 8 per cent of silty clay for road construction [4]. The sub-base course layer is the part of the flexible pavement laid down between the sub grade and the base course and this layer usually is sand stone material. The Depok residual soil has been used for sub grade layer of road pavement structure. By using soil cement stabilization, the Depok residual soil can be treated for a sub-base layer to substitute the sand stone material. The 10 per cent cement stabilization of dry weight of soil is added and then the soil cement mix sample is compacted by Modified Standard Proctor around the optimum water content of 34.12 %. Based on the Standard National Indonesia (SNI), the minimum standard of Soaked CBR for sub-base layer is 35 % [6].

## 2. TEST PROCEDURE

The laboratory testing such as physical properties, California Bearing Ratio (CBR) and Unconfined Compression were conducted on soil and soil cement samples [7]. The variation of cement stabilization were used as 0, 5, 10, 15, 20 and 25

percent of dry weight of soil respectively and then the soil cement samples are compacted by Modified Standard Proctor. Based on the physical properties and soil cement compaction tests, the optimal percentage of cement is 10 percent of dry weight of soil will be implied. And the next the soil cement of 10 percent of dry weight of soil is compacted by Modified Standard Proctor around the optimum water content of 34.12 %. The soil samples were prepared in two conditions: (i), the soil sample was delayed in compaction for 0, 6, 24, 72 and 168 hours and then compacted and (ii), the soil sample was compacted and then cured for similar time. After this stage, the laboratory testing such as California Bearing Ratio (CBR) and Unconfined Compression were conducted on the compacted soil cement samples.

### 3. TEST RESULTS AND ANALYSIS

#### 3.1 Physical Properties

The test result of physical properties of residual soil is shown in Table 1.

Table 1: Physical properties of residual soil.

No.	Physical parameters	Value
1.	Color	red
2.	Specific gravity	2.69
3.	Atterberg Limits:	
	• Liquid Limit, LL (%)	81.32
	• Plastic Limit, PL (%)	57.91
	• Plasticity Index, PI (%)	23.41
4.	Sieve Analysis:	
	• Sand (%)	1
	• Silt (%)	83
	• Clay (%)	16

The result of physical properties of residual soil and soil cement are shown in Table 2. The relation between Plasticity Index versus Cement Content can be seen in Figure 1.

Table 2: Physical properties of residual soil and soil cement

No	Sample type and cement content	LL %	PL %	PI %
1	Residual soil	81.32	57.91	23.41
2	Soil cement (+ 5% cement)	72.43	53.22	19.21
3	Soil cement (+ 10% cement)	71.12	52.88	18.24
4	Soil cement (+ 15% cement)	73.21	55.71	17.32
5	Soil cement (+ 20% cement)	68.88	54.67	14.21
6	Soil cement (+ 25% cement)	63.18	55.15	8.03

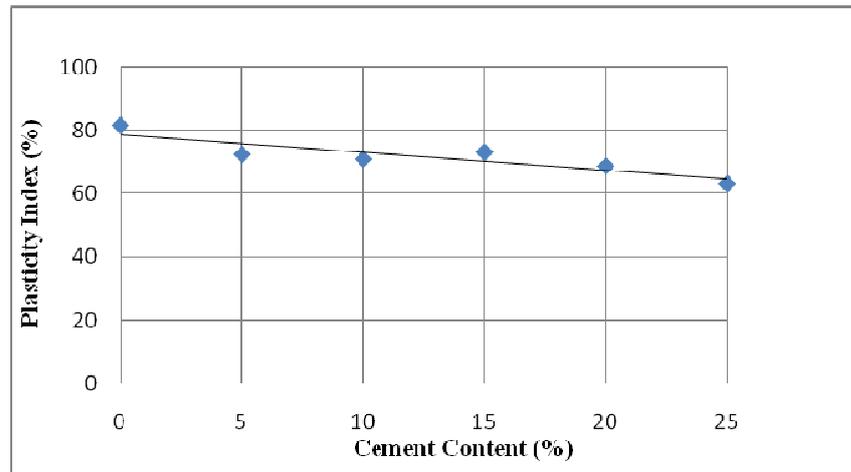


Figure 1: Relation between Plasticity Index and Cement Content

### 3.2 Soil cement

#### 3.2.1 California Bearing Ratio Tests

The relation between the Unsoaked and Soaked CBR value without Compaction Delay versus Cement Content can be seen in Figure 2. The Cement Content, Unsoaked and Soaked CBR value without Compaction Delay can be seen in Table 3. Using 10 percent cement stabilization of dry weight of soil, the Soaked CBR value increase from 13.23 % to 37.75 %. Based on the Standard National Indonesia (SNI), the minimum standard of Soaked CBR for sub-base layer is 35 %. The Soaked C.B.R. value of 10 percent cement content is met to SNI and therefore the treated soil cement may be used as sub-base layer. After preparing the soil samples, the Unsoaked and Soaked CBR tests were conducted on the compacted soil cement samples. The relation between the Unsoaked and Soaked CBR value of 10 percent cement content versus Compaction Delay/Curing Time can be seen in Figure 3 and 4 respectively. The value of Unsoaked and Soaked CBR and Compaction Delay/Curing Time, can be seen in Table 4.

Table 3: Cement Content, Unsoaked and Soaked CBR

No.	Cement content (%)	Unsoaked CBR (%)	Soaked CBR (%)
1.	0	39.57	13.23
2.	5	54.41	35.15
3.	10	46.86	37.75
4.	15	34.89	62.49
5.	20	50.77	97.89
6.	25	54.41	145.80

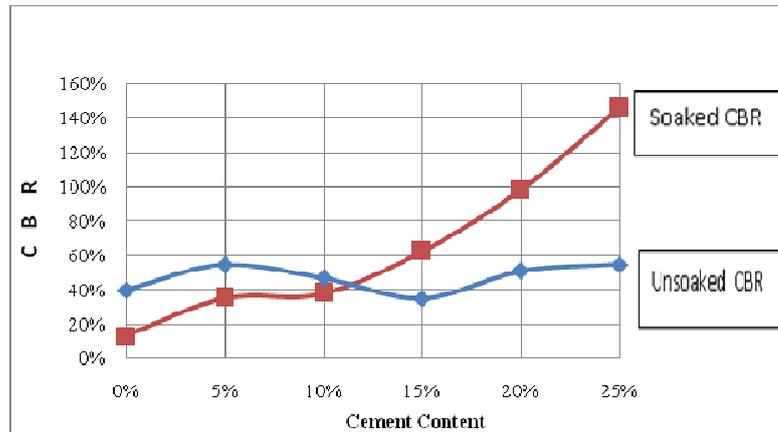


Figure 2: Relation between Unsoaked, Soaked CBR and Cement Content

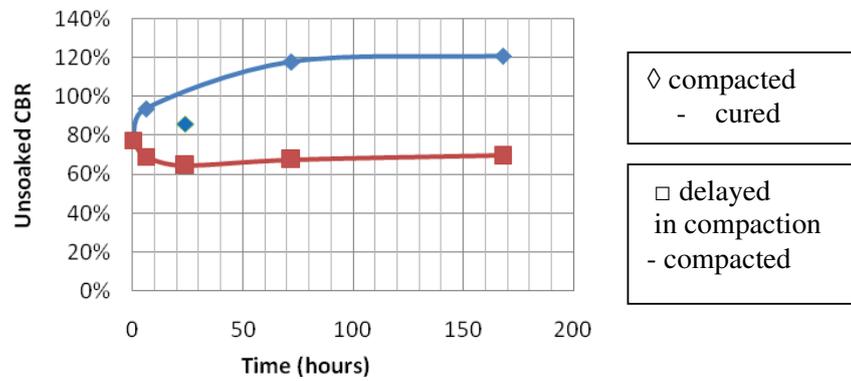


Figure 3: Relation between Unsoaked CBR of 10 percent cement and Compaction Delay/Curing Time

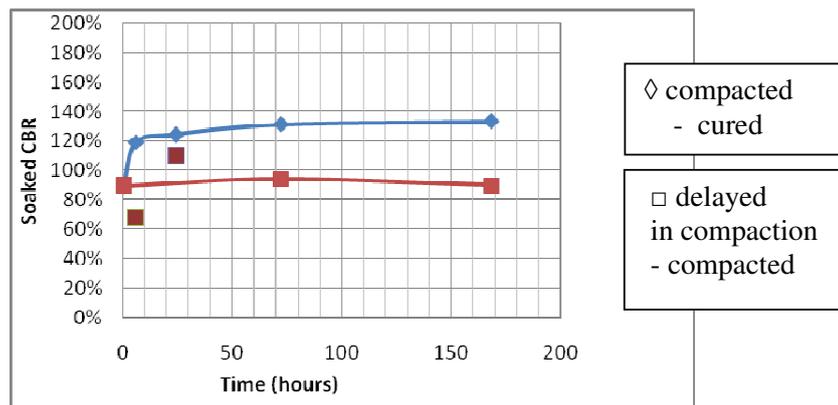


Figure 4: Relation between Soaked CBR of 10 percent cement and Compaction Delay/Curing Time

Table 4: Compaction Delay/Curing Time, Unsoaked and Soaked CBR of 10 percent cement

Sample Type	Compaction Delay /Curing Time	Unsoaked CBR (%)	Soaked CBR (%)

	( hours )		
(1) compacted	0	46.86	37.75
(2) compacted then cured	6	93.73	119.50
	24	85.92	124.19
	72	117.34	131.22
	168	121.07	133.17
(3) delayed in compaction then compacted	6	69.05	67.56
	24	64.44	104.51
	72	67.56	94.12
	168	69.51	89.92

### 3.2.2 Unconfined Compression Tests

The soil samples were prepared such as the requirement in test procedure. After this stage, the Unconfined Compression tests were carried out on the compacted soil cement samples of 10 percent cement content by using speed of 0.7 mm/minute until reached maximum of the unconfined compressive strength and reached axial strain of 6 %. The Unconfined Compressive Strength (UCS) value in unsoaked and soaked condition and Compaction Delay/Curing Time can be seen in Table 5. The Unconfined Compressive Strength value is range between 165 to 1301 kPa and the test results can be classified as low bound degree [6].

Table 5: Compaction Delay/Curing Time, Unconfined Compressive Strength on unsoaked and soaked condition of 10 percent cement

Sample Type	Compaction Delay /Curing Time ( hours )	unsoaked UCS ( psi )	unsoaked UCS ( kPa )	soaked UCS ( psi )	soaked UCS ( kPa )
(1) compacted	0	118.1	826.7	120	840
(2) compacted then cured	6	156.6	1096.2	49.6	347.2
	24 (1 day)	177.5	1242.5	109.6	767.2
	72 (3 days)	185.8	1300.6	116.5	815.5
	168 (7 days)	169.4	1185.6	89.82	624.4
(3) delayed in compaction then compacted	6	116.2	813.4	36.7	256.9
	24 (1 day)	106.4	744.8	36.7	256.7
	72 (3 days)	108.4	758.8	32.5	227.5
	168 (7 days)	111	777	23.7	165.9

## 4. CONCLUSION

- Using cement at a soil stabilization process can increase the soil strength quite significant. .
- Using cement stabilization with 10 per cent of dry weight of soil, the Soaked CBR value of Depok residual soil increase from 13.23 to 37.75 %.

- The soil cement sample was compacted and then cured is better than the soil cement sample was delayed in compaction and then compacted.
- The unconfined compressive strength value can be classified as low bound degree.

#### ACKNOWLEDGMENT

The authors would like to express the gratitude to the Soil Mechanics Laboratory and Civil Engineering Department, Faculty of Engineering, University of Indonesia for supporting this study.

#### REFERENCES

- [1] Departemen Pertambangan, *Peta Geologi Jakarta – Bogor*, 1980
- [2] Yoder, E.J., and Witczak, M.W., *Principles of Pavement Design*, John Wiley & Sons, Inc., USA, 1980.
- [3] Bergado, D.T., Anderson, L.R., Miura, N. and Balasubramanian, A.S., *Soft Ground Improvement*, Published by ASCE PRESS, New York, 1996
- [4] Ingles, O.G. and Metcalf, J.B., *Soil Stabilization Principles and Practice*, Butterwoths, Sydney, 1972.
- [5] Yolanda, F., *Stabilisasi Tanah Residual Depok Dengan Semen Sebagai Lapisan Perkerasan Sub base*, Skripsi, Fakultas Teknik, Universitas Indonesia, Depok, 2011.
- [6] Departemen Pekerjaan Umum, *Pedoman Perencanaan Stabilisasi Tanah Dengan Bahan Serbuk Pengikat Untuk Konstruksi Jalan*, Jakarta, 2010
- [7] American Society of Testing and Material, *Annual Book of ASTM Standards*, 1989.

# Study of the Mechanical Behavior of Paving Blocks made of Concrete Sludge Waste (CSW) and Coconut Fiber

Wiratama Hadi Ramanto<sup>a</sup>, Elly Tjahjono<sup>b</sup>, Essy Arijoeni<sup>c</sup>

<sup>a</sup>Student, Faculty of Engineering, University of Indonesia, Depok 16424  
 E-mail : wiratama.ramanto@gmail.com

<sup>b</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
 E-mail : elly@eng.ui.ac.id

<sup>c</sup>Faculty of Engineering, University of Indonesia, Depok 16424  
 E-mail : essy@eng.ui.ac.id

## ABSTRACT

The study was conducted to explore the feasibility of using concrete sludge waste (CSW) and coconut fiber to manufacture paving blocks. The CSW were collected from a ready-mix concrete plant, while the coconut fibers were sourced from a coconut husk processing plant. The CSW was sun-dried for two days and only aggregates passing the No. 4 sieve were used to replace natural sand at replacement levels of 25%, 50% and 100% by weight with an aggregate/cement ratio of 1:3. The untreated coconut fibers were manually cut into a fiber length of 5 cm and were used in the paving block mix at proportions of 0%, 1%, 2% and 3% by weight of cement. The compressive strength, flexural strength, absorption and abrasion resistance of the resulting paving block specimens were tested to study whether or not the paving blocks has sufficient mechanical properties that allow them to have a quality classification grade under Indonesian national standards. The results of the study indicate that the paving blocks show sufficient compressive strength and abrasion properties to achieve a quality grade of A and B, respectively. However, the absorption level turned out to be the limiting constraint, where all of the paving block specimens resulted in an absorption level above the maximum allowable level under national standards.

### Keywords

paving block, concrete sludge waste, coconut fiber, fiber content, replacement level

## 1. INTRODUCTION

Construction wastes are increasing rapidly with the growth of the construction industry. Approximately 70% of these wastes are composed of concrete wastes [1]. One such waste originates from ready-mix concrete plants: Concrete Sludge Waste (CSW). One possible solution is to recycle CSW as a substitute for natural sand in the fabrication of paving blocks. Many studies have been carried out on the feasibility of using recycled fine aggregates as a replacement for natural sand and results regarding their strength properties have showed that they are suitable for low-strength concrete applications [2,3].

Cheap and locally available natural fibers, such as coconut fiber, can also be used for the fabrication of paving blocks. Extensive studies have been done that show that the use of coconut fibers helps improve the mechanical properties, such as compressive strength and durability, of concrete products [4,5,6]. Therefore, its use in the manufacture of paving blocks has the opportunity to increase the strength of the resulting mix and increase the block's grade classification.

According to SNI 03-0691-1996, paving blocks are building materials composed of a mixture of Portland cement or other hydraulic binders, water and aggregates with or without admixtures that do not reduce the quality of the paving block. Paving blocks shall have physical properties as seen in Table 1; where Grade A paving blocks can be used for roads, Grade B can be used for parking lots, Grade C can be used for pedestrian walkways and Grade D can be used for parks and other uses.

Table 1: Paving block grade-based physical properties requirements [7]

Grade	Compressive Strength (MPa)		Abrasion (mm/minute)		Av. Water Absorption (%)
	Mean	Min.	Mean	Min.	
A	40	35	0.090	0.103	3

B	20	17	0.130	0.149	6
C	15	12.5	0.160	0.184	8
D	10	8.5	0.219	0.251	10

The objective of this study is to explore the feasibility of using CSW and coconut fiber to manufacture paving blocks and whether the resulting paving blocks have sufficient compressive strength, absorption level and abrasion to allow them to have a quality classification grade under SNI 03-0691-1996. The flexural strengths and densities of the paving block specimens were also studied.

## 2. MATERIALS AND PRELIMINARY TESTS

### 2.1 Materials

CSW was retrieved from PT. Adhimix Indonesia's Ready-mix Concrete Plant in Lenteng Agung, Jakarta, Indonesia. The retrieved CSW were still in the form of sludge, or concrete slurry, and large chunks or lumps of semi-dried/hardened concrete. The CSW were transported out of the plant and were spread out on a non-absorbent surface and sun-dried for two days; reaching a moisture content slightly above a saturated surface dry condition. Some of the smaller lumps of concrete, that have not completely hardened, were crushed with a hammer during the first day of drying. The aggregates were then sieved, where only aggregates passing No. 4 sieve were used, and stored in non-absorbent bags until testing and fabrication of paving blocks.



The coconut fibers were retrieved from a coconut husk processing plant in Jl. H. Dimun No.2, Sukamaju, Depok. When retrieved, the fibers were already dried and processed (separated from the coconut's shell and outer skin). The fibers were then separated and cut up manually into lengths of  $5 \text{ cm} \pm 1 \text{ cm}$ . The fibers were untreated and stored in a styrofoam container until the fabrication of the paving blocks. Portland Composite Cement (PCC) was used and Jebrot Sand (a type of river sand found locally) was used as natural sand.

### 2.2 Tests on fine aggregates

Tests were performed to determine the properties of both the recycled and natural aggregates. These tests were performed in order to compare the properties of the recycled and natural aggregates; this in turn will aid the identification of the causes in the difference in the resulting paving block properties. All tests were performed on both CSW and natural sand. Only aggregates passing through sieve No. 4 were tested. The tests performed were: specific gravity and absorption (ASTM C128-12), bulk density (ASTM C29/29M-09), sieve analysis (ASTM C136-06), materials finer than No. 200 sieve (ASTM C177-04) and Organic Impurities (C40/C40M-1).

### 2.3 Trial-mix

Trial-mixes were performed in order to determine the cement-aggregate ratio that will be used for the paving block mix design. 50-mm cube specimens were used to evaluate the 7-day compressive strengths of mixes involving different cement-aggregate ratios (ASTM C109/C109M-11b). The cement-aggregate ratios that were tested are 1:3, 1:3.5, 1:4, 1:4.5 and 1:5. Only CSW were used as aggregates in the trial-mixes. The ratio that resulted in the highest average compressive strength was then used as the cement-aggregate ratio for the paving block mix proportions. Coconut fiber was not included in the trial mix. The amount of mixing water used during the trial mix was determined using the flow table test (ASTM C1437-07) as to produce a mortar flow of  $105 \pm 5 \%$ . The amount of mixing water is expressed as a weight percent of cement.

Table 2: Results of trial-mix

Cement-Aggregate ratio	Water/Cement	Av. Density (kg/m <sup>3</sup> )	Compressive Strength (MPa)		
			Min	Max	Average
1 : 3	0.75	1756	9.00	11.16	10.06
1 : 3.5	0.825	1759	8.88	10.17	9.53
1 : 4	0.85	1799	7.74	8.29	8.09
1 : 4.5	1.025	1757	6.13	6.72	6.38
1 : 5	1.075	1748	5.70	6.87	6.02

As it can be seen in Table 2, the water/cement ratio needed to maintain a flow value between 100%-110% increases as the proportion of CSW increases, which may be caused by the high absorption level of the CSW. It can also be seen in Table 2, the average compressive strength of the 50-mm cube specimens decreases as the proportion of CSW increases. This can be attributed to the increase in w/c with the increase in the proportion of CSW. The highest resulted from a cement-aggregate ratio of 1:3, corresponding to 7-day average compressive strength of 10.06 MPa. Therefore, a cement-aggregate ratio of 1:3 will be used as the cement-aggregate ratio for the paving block mix design.

### 3. EXPERIMENTAL METHOD

#### 3.1 Mix proportion

Table 3 shows the paving block mix proportions in order to manufacture 24 paving block for each paving block type. The mix proportion assumes that a 21 cm x 10.5 cm x 6 cm paving block has a mass of 3250 g and, as previously discussed, the mix uses a cement-aggregate ratio of 1:3.

Table 3: Paving block mix proportions

Paving Block Type	Cement (g)	CSW (g)	Natural sand (g)	Coconut fiber (g)	Water (mL)	Water/Cement
A-I	19,500	58,500	0	0	11,500	0.590
A-II	19,500	29,250	29,250	0	10,500	0.538
A-III	19,500	14,625	43,875	0	8,000	0.410
B-I	19,500	58,500	0	195	12,000	0.615
B-II	19,500	29,250	29,250	195	11,000	0.564
B-III	19,500	14,625	43,875	195	8,500	0.436
C-I	19,500	58,500	0	390	12,500	0.641
C-II	19,500	29,250	29,250	390	11,000	0.564
C-III	19,500	14,625	43,875	390	9,000	0.462
D-I	19,500	58,500	0	585	13,000	0.667
D-II	19,500	29,250	29,250	585	12,000	0.615
D-III	19,500	14,625	43,875	585	9,500	0.487

As it can be seen in Table 3, there are 12 different combinations of paving block specimens. The specimens have varying amounts of coconut fiber (0%, 1%, 2%, 3%) and varying mixtures of natural sand and CSW. The amount of coconut fiber used is expressed as a mass percent of cement and the rest of the mix design used in this study are also proportioned by mass. Therefore, a type D-III paving block has an aggregate content consisting of 25% CSW and 75% natural sand and a coconut fiber content of 3% of the mass of cement, while a type A-I paving block uses 100% CSW as its aggregate and no coconut fiber content. The amount of mixing water used in the paving block mix was determined during the fabrication of the paving block specimens. Since the fabrication of the paving block uses a machine that gives a combined vibrating and compacting action, the mixes were prepared with only sufficient water to produce a cohesive mix but with no slump/workability.

#### 3.2 Paving block fabrication

The paving block specimens were fabricated in a paving block plant located in Cileungsi, Bogor. All paving blocks in this study were fabricated using a machine capable of giving a compacting and vibrating action located at a paving block plant. The machine holds a mold that is able to produce 4 paving blocks at a time with dimensions of 21 cm x 10.5 cm x 6 cm.



Figure 2: Picture of machine and mold (left) and resulting paving block specimens (right)

The paving blocks were fabricated in batches based on combination type. First, the cement and aggregates were poured and mixed inside a mixer that is located on site. Sufficient water was then added until the mix has reached sufficient workability. For mixes containing coconut fiber, the fibers were added to the mix in small amounts along with small addition of water to maintain workability. The author found some difficulty maintaining a uniform mix for mixes with 2% and 3% fiber contents. The mix has the tendency accumulate to one side of the mixer, requiring manual mixing. There was also difficulty molding paving blocks with 3% fiber content, since the fiber has the tendency to get stuck in between the metal compactor.

After fabrication, the paving specimens were air cured for a day at the paving block plant, avoiding any direct contact with the sun. The blocks were then transported to the Department of Civil Engineering Universitas Indonesia where the specimens were moist cured (covered with moist fabrics) for 7 days and air cured then after until testing. Several tests required the specimen to be sawn. Any sawing was done on or after the specimens has reached a 28-day of age.

### 3.3 Paving block tests

The paving block compressive strength test is performed in accordance with SNI 03-0691-1996. Three types of specimens were used to perform this test for each paving block combination: eight whole paving block specimens, eight 6-cm sawn test cubes and three 4-cm sawn test cubes. Orientation of loading reflected orientation of loading of blocks when in use. The paving block absorption level test is performed in accordance with SNI 03-0691-1996. Five whole paving block specimens were used from each combination to perform this test.

The paving block abrasion test is performed in accordance with SNI 03-0691-1996 using calculations described in SNI 03-0028-1987 and following the procedures described in ASTM C944/C944M-99, using an abrasion process length of 6 minutes and an abrasion surface area of 49.48 cm<sup>2</sup>. The test uses a rotating cutter machine. Three whole paving block specimens were used from each combination to perform this test. These whole paving blocks were sawn in half, thus creating six test specimens. Leftover pieces from the abrasion test were cut into small cube specimens to be used to determine the density of the paving block specimens. The paving block flexural strength test is performed in accordance with ASTM C78/C78M-10, using third-point loading. Four whole paving block specimens were used from each combination to perform this test.

## 4. RESULTS AND DISCUSSION

### 4.1 Results

Table 4: Results of all paving block tests

Paving Block Type	Density (g/cm <sup>3</sup> )	Absorption level (%)	Abrasion (mm/minute)	Compressive Strength (MPa)			Flexural Strength (MPa)	
				Block	6-cm cube	4-cm cube	Crack	Failure
A-I	1.78	21.7	0.129	25.32	10.57	10.94	-	4.47
A-II	1.87	14.5	0.063	30.03	16.31	14.23	-	4.51
A-III	1.95	11.4	0.037	35.06	23.86	21.28	-	4.51
B-I	1.76	20.1	0.106	36.00	13.49	11.17	-	3.89
B-II	1.86	16.2	0.060	35.25	17.05	17.07	-	3.17
B-III	1.96	12.3	0.044	37.13	24.02	22.43	-	4.51
C-I	1.72	21.6	0.128	30.90	11.22	9.14	2.94	4.73
C-II	1.85	15.9	0.085	31.65	11.69	8.64	2.98	5.12
C-III	1.96	12.8	0.037	39.00	24.46	23.56	3.29	5.50
D-I	1.74	21.6	0.116	25.72	12.46	8.39	2.21	5.09
D-II	1.82	17.8	0.088	24.83	14.43	9.33	2.97	9.26
D-III	1.92	14.1	0.051	33.98	15.57	15.39	3.14	10.96

### 4.2 Absorption

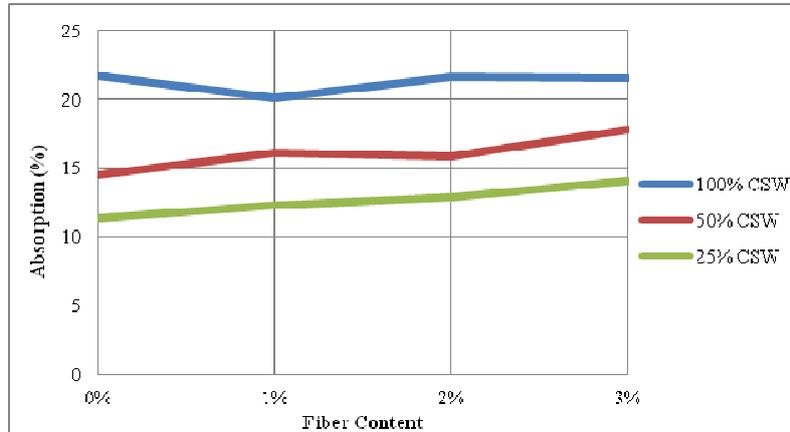


Figure 3: Absorption level vs. fiber content for different CSW replacement level

As it can be seen in Table 4 and Figure 3, there is an increasing trend in absorption level with an increase in fiber content for paving blocks with 25% and 50% CSW replacement level. However, this trend is very weak. Paving blocks with 100% CSW replacement level has a more horizontal trend compared to the other two. However, there is a slight decrease in absorption level from 0% to 1% fiber content for 100% replacement level. This may be caused by the difference in absorption levels between CSW and coconut fiber. It can also be seen that as the CSW replacement level increases, the paving block absorption level increases. However all paving block combinations resulted in absorption levels that are higher than the maximum allowed (10%), thus not enabling any of the resulting paving blocks to receive a quality grade under national standards.

### 4.3 Abrasion and density

As it can be seen in Table 4, there is generally a decreasing trend in density level with an increase in fiber content. This is specifically true for paving block with 50% CSW replacement level. However, the trend is slightly more ambiguous for paving blocks with 100% and 25% CSW replacement level. On the other hand, with closer inspection the difference in density values with increasing fiber content are smaller than  $0.05 \text{ g/cm}^3$ . Therefore, the introduction of coconut fiber into the mix has very little effect on the paving block's density. However, it can clearly be seen that as the CSW replacement level increases, the density decreases. The resulting difference in densities resulting from different replacement levels of CSW is comparatively larger than that resulting from different fiber contents.

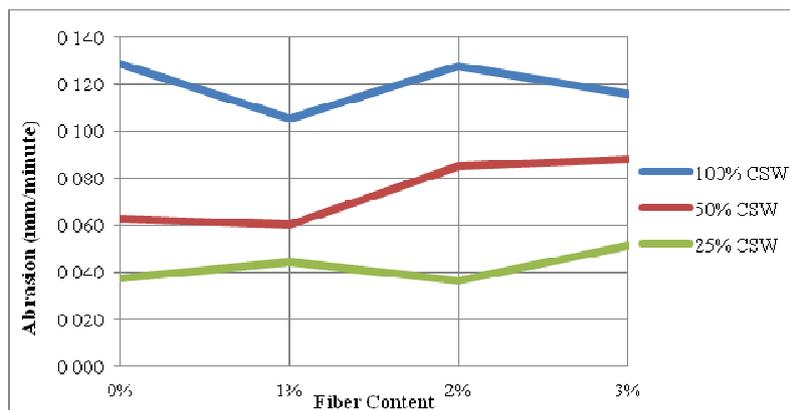


Figure 4: Abrasion vs. fiber content for different CSW replacement level

As it can be seen in Table 4 and Figure 4, it can clearly be seen that as the CSW replacement level increases the abrasion of the paving block increases. It can also be seen that there is no clear trend in abrasion with an increase in fiber content. However, any decrease or increase in abrasion with a change in fiber content (among paving blocks with the same CSW replacement level) is not big enough to change the quality classification of the paving block under national standards

#### 4.4 Flexural strength

When the flexural strength tests were done for Type C and D paving blocks, the author noticed two stages of failure for the specimens. The first is fracture in the tension face of the mortar and the second is complete failure, where the specimen broke into two halves. It seems the fibers embedded in the specimens prevented the specimen from breaking in two, even with significant mortar fracture. Therefore, the author decided to have two separate columns to distinguish these failures (as it can be seen in Table 4). These two stage failures were not observed for Type A blocks and the difference in loads for Type B blocks were too close which prevented the second stage to be detected.

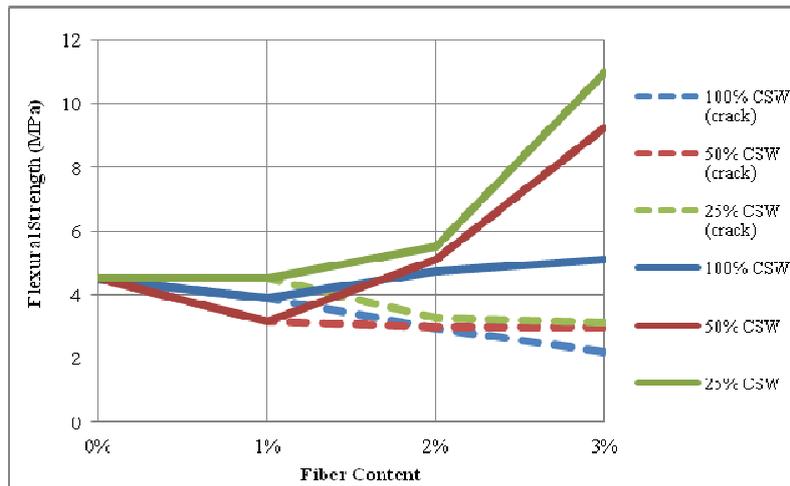


Figure 5: Flexural strength vs. fiber content for different CSW replacement level

As it can be seen in Figure 5, there is generally a decreasing trend in mortar failure for all CSW replacement level with increasing fiber content. This is caused by a decrease in mortar surface area that comes with an increase in fiber content. However, there is an increasing trend in flexural strength for block failure for 2% and 3% fiber contents. This increase is very substantial for both 50% and 25% CSW replacement level, compared to the lower increase involved with 100% CSW paving blocks.

#### 4.5 Compressive strength

As it can be seen in Table 4 and Figure 6, all CSW replacement levels show an increase and then decrease in compressive strength. However, the decrease in compressive strength for 50% and 100% replacement level occurred after 1% fiber content, whereas the decrease for 25% replacement level occurred after 2% fiber content. However, any decrease or increase in compressive strength with a change in fiber content is not big enough to change the quality classification of the paving block. All paving block combinations received a quality classification of B (based on compressive strength alone). A 25% CSW replacement level and 2% fiber content resulted in the highest paving block compressive strength.

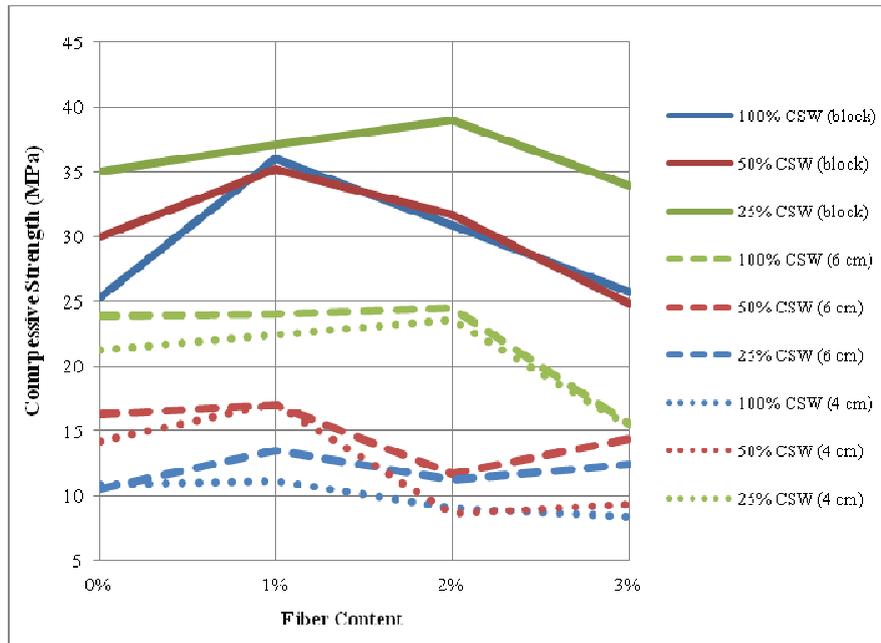


Figure 6: Compressive strength vs. fiber content for different CSW replacement level

For full block specimens, 25% CSW replacement levels show an increase and then decrease in compressive strength. This decreased occurred after 2% fiber content. The highest compressive strength for a 25% replacement level is at 2% fiber content. However, for 50% and 100% replacement level there is an increase after a decrease in compressive strength (for 2%-3% fiber content). The compressive strength for 2% and 3% fiber content is not lower than the compressive strength for 100% replacement level when there is no fiber present. However, The compressive strength for 2% and 3% fiber content is lower than the compressive strength for 50% replacement level when there is no fiber present.

There is a significant difference in the values and shape of the graphs for block specimens and 6-cm cube specimens. The difference in shape may be brought about by the difference in fiber behavior when the blocks are cut into smaller specimens. However, there is a significant difference in compressive strengths for specimens with 0% fiber content. Since the specimens do not contain any fiber, the effects of the presence of fiber cannot explain this difference. This may be brought about by a size factor or an effect brought about by the sawing process.

The compressive strength of 4-cm cube specimens has a similar shape to that of the 6-cm cube specimens. However, the 4-cm cube specimens have a slightly lower compressive strength than that of the 6-cm cube specimens. This confirms that the compressive strength (in terms of stress) of a specimen decreases with a decrease in specimen dimensions. This may imply that specimens with smaller dimensions are subjected to more disturbances due to sawing.

## 5. CONCLUSION

Based on the results of this study, the following conclusions can be drawn:

- The addition of coconut fiber to a paving block mix resulted in no clear trend to the paving block's abrasion resistance. However, any decrease or increase in abrasion with a change in fiber content (up to 3%) is not big enough to change the quality classification of the paving block under national standards. The resulting abrasion values were able to achieve a quality grade of A under national standards.
- The addition of coconut fiber to a paving block mix resulted in, generally, an increase to the paving block's absorption level.
- All paving block combinations resulted in absorption levels that are higher than the maximum allowed (10%), thus not enabling any of the resulting paving blocks studied to receive a quality grade under national standards. However, the resulting paving blocks may still be used in places that are exposed to no rain.
- A 2% and 3% fiber content resulted in paving blocks with high ductility (in terms of flexural strength and behavior).
- The density of the paving block decreases as the amount of CSW used increases.

- Paving block specimens with 25% CSW replacement level resulted in the best abrasion, absorption and compressive strength properties (as compared to specimens with 50% and 100% CSW replacement level) for all tested fiber contents.
- Paving block specimens with 25% replacement CSW replacement level and 2% fiber content resulted in the highest compressive strength (for all dimensions), which corresponds to a quality grade of B under national standards.

The author recommends to further study the mechanical behavior of paving blocks using CSW and coconut fibers using fiber lengths less than 5 cm (i.e. 2.5 cm), a cement:aggregate ratio of 1:3.5, fiber contents in the range of 1% to 2% by weight of cement and using paving blocks with height of 8 cm and 10 cm, in order to see the occurrence of a size factor. The author also recommends the finding of another added material that will lower the absorption level of paving blocks using CSW and coconut fibers.

## REFERENCES

- [1] Ahmad, S., & Aimin, X. (2003). *Performance and Properties of Structural Concrete made with Recycled Concrete Aggregate*. ACI Mater. J., Vol. 100: 371–380.
- [2] Sheba B. (2012). *Study of Compressive Strength for Mortars Containing Rice Husk Ash (RHA) and Concrete Sludge Waste (CSW) with Composition Cement, Aggregate 1: 3*. Thesis. Universitas Indonesia, Depok.
- [3] Giwangkara R.P. (2012). *Study of Mechanical Behaviors of Paving Block Made of Concrete Sludge Waste and Palm Fiber*. Thesis. Universitas Indonesia, Depok.
- [4] Ali, M., et al. (2010). *Effect of Fibre Content on Dynamic Properties of Coir Fibre Reinforced Concrete Beams*. Department of Civil and Environmental Engineering, The University of Auckland, NZ.
- [5] Ali, M., et al. (2012). *Mechanical and Dynamic Properties of Coconut Fibre Reinforced Concrete*. Construction and Building Materials, Vol. 30: 814-825.
- [6] Ali, M., et al. (2013). *Experimental Investigations on Bond Strength Between Coconut Fibre and Concrete*. Materials and Design, Vol. 44: 596-605.
- [7] SNI 03-0691-1996. *Bata Beton (Paving Block)*. Badan Standardisasi Nasional, Jakarta, 1996, ICS 91.100.30.

# Estimation of Land Development Induced Subsidence in Northern Jakarta Areas

Widjojo A. Prakoso<sup>a</sup>

<sup>a</sup>Civil Engineering Department, Universitas Indonesia, Depok 16424  
 E-mail : wprakoso@eng.ui.ac.id

## ABSTRACT

Land subsidence has been identified as one of major geological hazards of Jakarta, and some areas in northern Jakarta are of great concern (subsidence maximum value and rate: 0.8 m and 0.28 m/year, respectively). The hypothesis of this paper is that the subsidence is primarily due to the compression of the normally consolidated, very soft to soft silt-clay deposits induced by the land development of the areas. Some recent geotechnical data from west Ancol to Kamal were compiled, and soil parameters along with their statistical properties were evaluated. The estimation of land subsidence is performed using the Terzaghi's 1-D consolidation theory and the secondary compression theory, coupled with the Monte Carlo approach. Ranges of estimated values, as well as their relevant statistical properties, were identified. The simulation results (final settlement: 1.6 m  $\pm$  0.7 m, subsidence rate: 0.22  $\pm$  0.16 m/year) were in the same range of field geodetical measurements confirming the paper hypothesis.

**Keywords:** compressibility, consolidation, time dependence, land subsidence, statistical analysis

## 1. INTRODUCTION

Land subsidence has been identified as one of major geological hazards of Jakarta. Geodetical measurements (MUBA, MUTI, and PIKA, see Figure 1) indicate that some areas in northern Jakarta are of great concern (e.g., [1]). The GPS-derived maximum subsidence between December 1997 and September 2007 is 0.8 – 0.9 m for MUTI and 0.3 – 0.4 m for PIKA, and the subsidence rates for the three stations are given in Table 1. These rates have been also observed using other satellite-based data and interpretation techniques (e.g., [2-4]). Natural consolidation, groundwater extraction, and land development related loads are identified as the major causing factors of the subsidence. In this paper, it is hypothesized that the subsidence is primarily due to the compression of the normally consolidated, very soft to soft silt-clay deposits induced by the land development of the areas. To confirm this hypothesis, the land development induced subsidence is estimated and subsequently compared to the measured subsidence. The focus areas are from west Ancol area in the east to Kamal area in the west which have relatively thick very soft to soft clay-silt soil deposits. It is noted that near surface groundwater extraction of the areas is assumed to be insignificant because the groundwater is brackish.

Table 1: Subsidence rate for GPS stations MUBA, MUTI, and PIKA (Source: [1])

Period	Subsidence Rate (m/year)		
	MUBA	MUTI	PIKA
2007-2008	0.28	0.15	0.18
2008-2009	0.14	0.10	0.11
2009-2010	0.15	0.08	0.07



Figure 1: Locations of GPS stations and geotechnical data

## 2. ESTIMATION METHOD

The estimation method consists of three subsequent steps. The first step is to compile and analyze the recent field and laboratory geotechnical data available from the area. The normally consolidated, very soft to soft silt-clay deposits are to be identified based on their N-SPT values; Kulhawy and Mayne [5] indicate that this type of deposits typically have N-SPT less than 4 blows/0.3m. The second step is to perform the estimation analysis using the Terzaghi's 1-D consolidation theory and the secondary compression theory described in [6]. The consolidation settlement is estimated by the following:

$$s_{\text{consol}} = CR \cdot H_{\text{soft}} \cdot \log \left( \sigma'_{\text{final}} / \sigma'_{\text{initial}} \right) \quad (1a)$$

$$\sigma'_{\text{initial}} = (\gamma_{\text{soft}} - \gamma_{\text{water}}) \cdot (H_{\text{soft}} / 2) \quad (1b)$$

$$\sigma'_{\text{final}} = \sigma'_{\text{initial}} + \gamma_{\text{fill}} \cdot H_{\text{fill}} \quad (1c)$$

in which CR = compression ratio,  $H_{\text{soft}}$  = thickness of very soft to soft soil layer,  $\gamma_{\text{soft}}$  = saturated unit weight of very soft to soft soil layer,  $\gamma_{\text{water}}$  = water unit weight,  $\gamma_{\text{fill}}$  = unit weight of fill materials, and  $H_{\text{fill}}$  = fill thickness. The time required to reach a certain consolidation time is estimated by the following:

$$t = T_v \cdot (H_{\text{soft}} / 2)^2 / c_v \quad (2)$$

in which  $T_v$  = theoretical time factor and  $c_v$  = coefficient of consolidation. The theoretical relationship between the degree of consolidation  $U$  and the time factor  $T_v$  proposed by Terzaghi [6] is adopted. The settlement due to the secondary compression at time  $t$  is estimated by the following:

$$s_{\text{secondary}} = C_{\alpha\epsilon} \cdot H_{\text{soft}} \cdot \log \left( t / t_p \right) \quad (3)$$

in which  $C_{\alpha\epsilon}$  = coefficient of secondary compression and  $t_p$  = time for completion of consolidation. The last step is to calculate the subsidence rate which is given by the following:

$$\text{Subsidence Rate} = [s_{\text{consol}}(t_2) - s_{\text{consol}}(t_1)] / (t_2 - t_1) \quad (4a)$$

$$\text{Subsidence Rate} = [s_{\text{secondary}}(t_2) - s_{\text{secondary}}(t_1)] / (t_2 - t_1) \quad (4b)$$

in which  $t_1$  and  $t_2$  = earlier time and latter time, respectively. It is noted that three implicit assumptions were made in the above equations for simplicity. First, as indicated by Equation 1b, the groundwater table is assumed to be at the ground surface level, and this assumption is reasonable for the northern Jakarta areas. Second, as indicated by Equation 1c, the land development induced load is due to placement of the fill layer only; building and surcharge loads are not considered because pile foundations are typically used to support those loads in the northern Jakarta areas. Third, as indicated by Equation 2, that only vertical consolidation drainage is considered, and the effect of prefabricated vertical drains is to be considered indirectly in the analysis.

As shown in Figure 1, the considered areas are vast and therefore it is expected that the actual soil conditions would vary. To consider this variation, the probabilistic approach is adopted and combined with the above equations; all soil parameters are to be considered as probabilistic variables, and the probabilistic approach to be employed is the Monte Carlo simulation approach.

## 3. GEOTECHNICAL DATA

The surface geology of the area is alluvial deposits, consisting of mangrove swamp deposits and nearshore marine deposits [7]. The geotechnical data for Sites 1 to 3 were collected from the library of Soil Mechanics Laboratory of Universitas Indonesia and author's file. The soil boring and N-SPT logs of all sites are shown in Figure 2, and the very soft to soft silt-clay deposits are identified as well in the logs. For each soil boring, the soil layer above the very soft to soft silt-clay deposit is assumed to be the fill layer. The thickness variation of the very soft to soft silt-clay  $H_{\text{soft}}$  and the fill layer  $H_{\text{fill}}$  is shown in Figure 3. The unit weight of both soil layers is given in Table 2. The compression ratio CR and the coefficient of consolidation  $c_v$  of the very

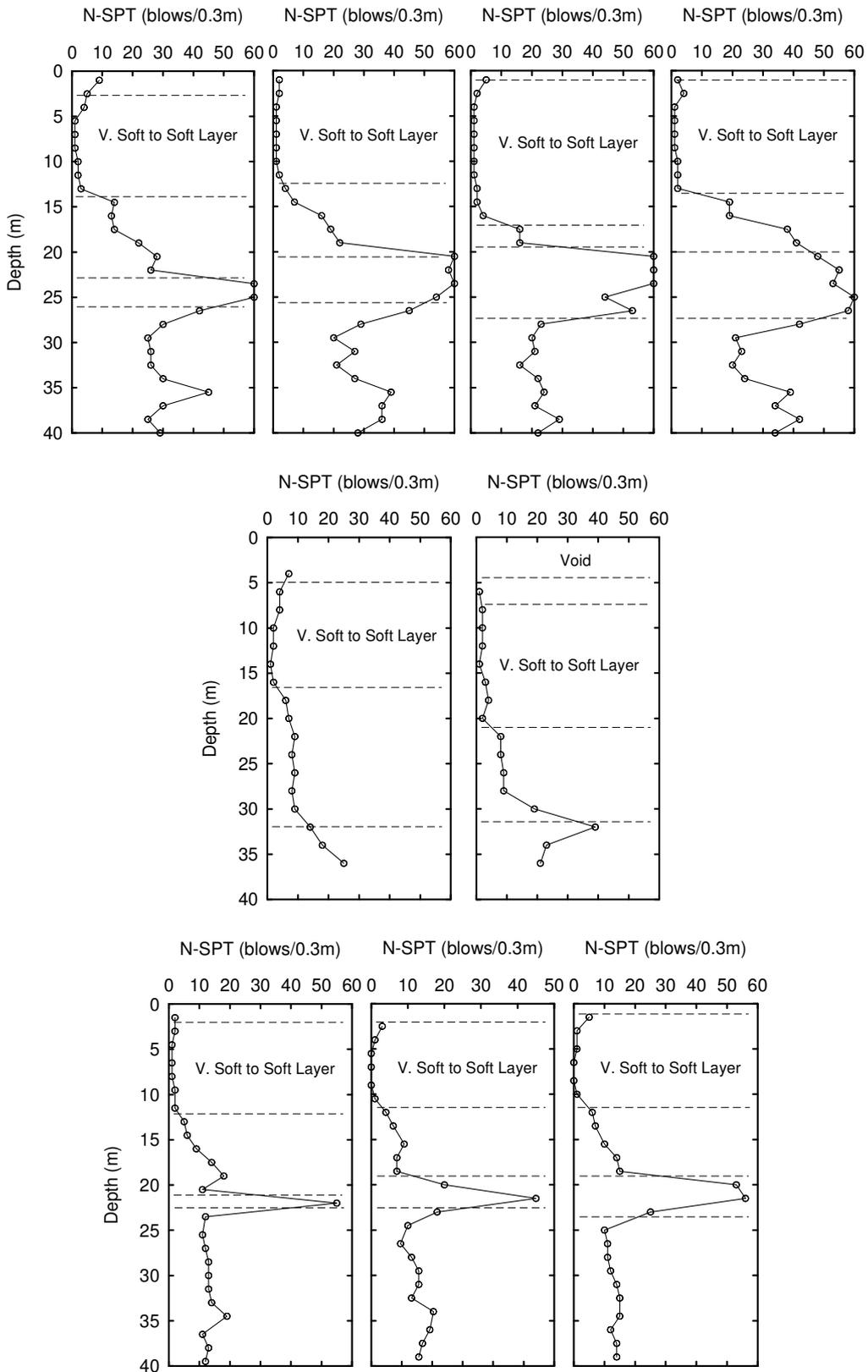


Figure 2: Soil boring and N-SPT logs (top row: Site 1, middle row: Site 2, bottom row: Site 3)

Table 2: Unit weight of soils

	Unit Weight (kN/m <sup>3</sup> )	
	Very Soft to Soft Soils	Fill Materials
No. Data	21	3
Mean	14.3	16.4
Standard Deviation	1.0	0.6
Coefficient of Variation	7.1%	3.8%
Minimum	12.6	15.7
Maximum	16.3	16.8

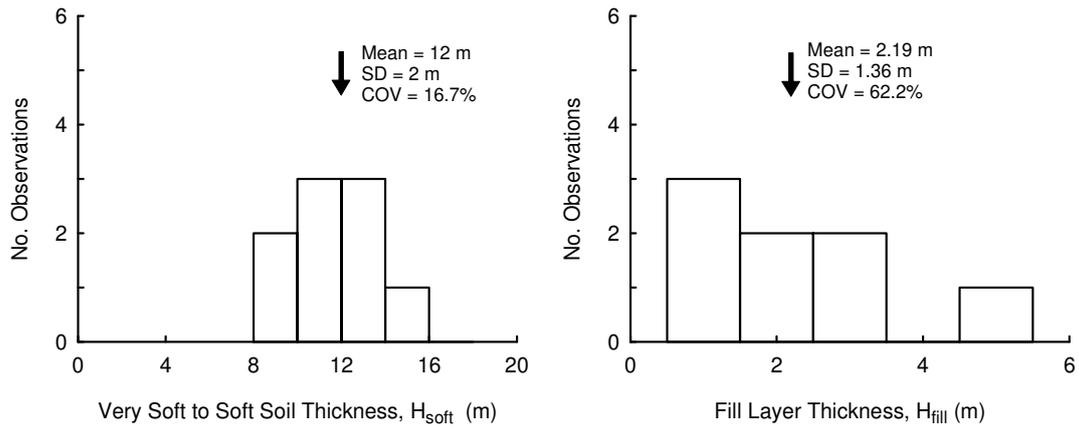


Figure 3: Thickness of very soft to soft soil layers and fill layers.

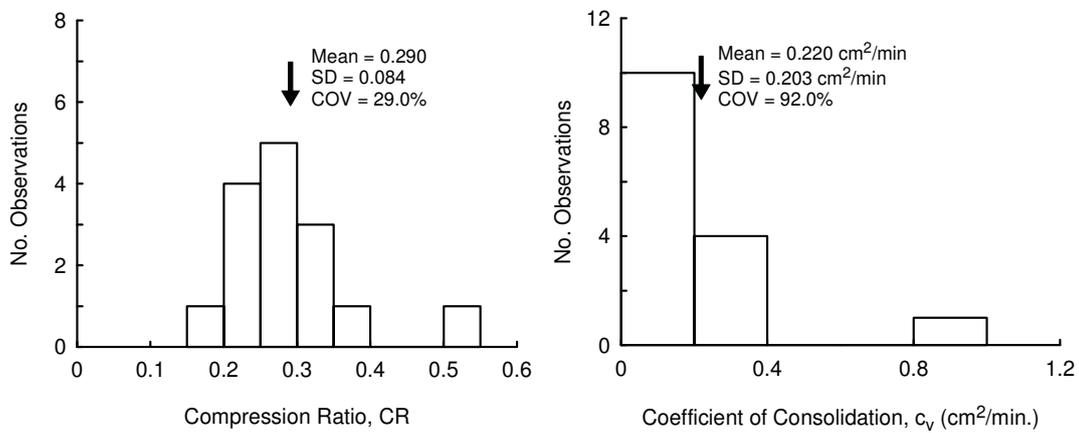


Figure 4: Consolidation parameters of very soft to soft soil layers

soft to soft silt-clay are shown in Figure 4. The silt-clay coefficient of secondary compression was determined based on the range of natural water contents and the correlation developed by Mesri and Godlewski [8] as shown in Figure 5. For each soil parameter, the data histogram and the mean, standard deviation (SD), and coefficient of variation (COV = SD / mean) values are given.

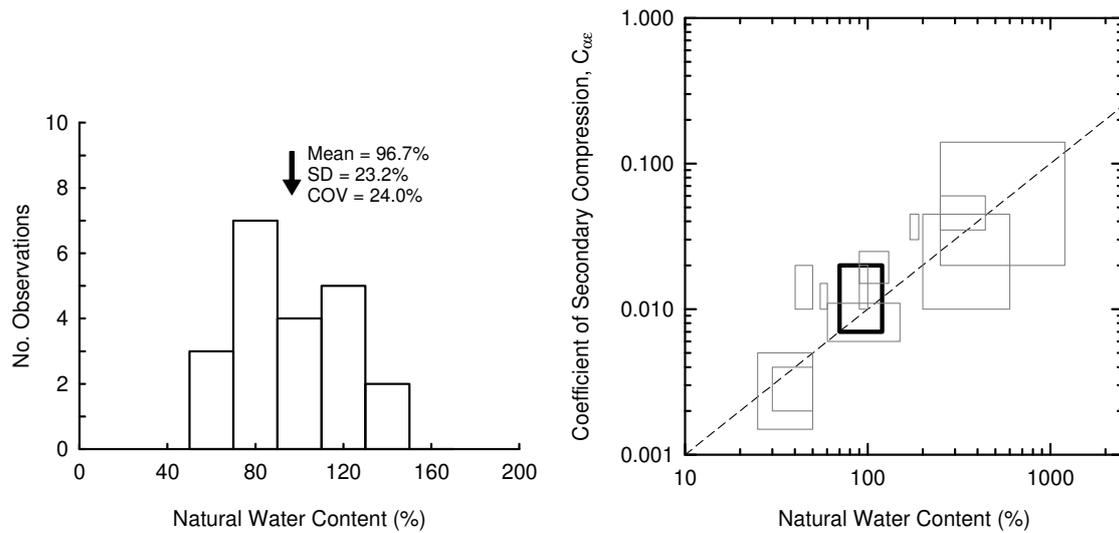


Figure 5: Estimation of coefficient of secondary compression (basic source of right figure: [8]).

Table 3: Input soil parameters

Probabilistic Distribution	Very Soft to Soft Soil					Fill	
	$H_{soft}$ (m)	$\gamma_{soft}$ (kN/m <sup>3</sup> )	CR	$c_v$ (cm <sup>2</sup> /min.)	$C_{\alpha\epsilon}$	$H_{fill}$ (m)	$\gamma_{fill}$ (kN/m <sup>3</sup> )
Uniform							
Minimum	-	-	-	0.05	0.007	1	-
Maximum	-	-	-	0.40	0.020	5	-
Normal							
Mean	12	14.3	0.290	-	-	-	16.4
Average	2	1.0	0.084	-	-	-	0.6

#### 4. ANALYSIS AND RESULTS

The analysis was conducted using the equations given above, and all seven parameters were treated as probabilistic variables. Based on the observed data distribution shown in Figures 3 to 5, the probabilistic properties of the soil parameters given in Table 3 were determined. The uniform distribution was used for two soil parameters, while the normal distribution was used for the remaining five soil parameters. As the Monte Carlo simulation approach was adopted, 1,000 random numbers were used for each variable, and the analysis was performed using MS-Excel<sup>TM</sup>. Random numbers generated were between 0 and 1, and they were transformed to their respective soil parameters using a linear relationship for soil parameters having uniform distribution and using the NORMINV function of MS-Excel<sup>TM</sup> for soil parameters having normal distribution.

The probability density function of final consolidation settlement  $s_{consol}$  is shown in Figure 6. The mean and standard deviation are about 1.6 m and 0.7 m, respectively. The mean and standard deviation of consolidation settlement from 56 to 96 percent degree of consolidation (or on average from year 1 to year 5 after fill placement) are about 0.65 m and 0.28 m, respectively. The validity of the estimation approach was checked by comparing final settlement  $s_{consol}$  to fill layer thickness  $H_{fill}$ , and it is found that the condition of  $s_{consol} < H_{fill}$  indicating relatively dry ground surface after consolidation is observed in about 96 percent of simulation results. The simulation results are in the same order of magnitude as the range of observed subsidence of from 0.3 – 0.4 m for PIKA up to 0.8 – 0.9 m for MUTI.

The probability density function of subsidence rate from year 1 to year 5 after fill placement (from 56 to 96 percent degree of consolidation) is shown in Figure 6. The rate varies from less than 0.05 m/year to about 1.0 m/year, but about 88 percent of the simulation results indicates a rate less than 0.4 m/year. The mean and standard deviation are 0.22 m/year and 0.16 m/year, respectively. The simulation results are in the same range as the observed subsidence rates for the three GPS stations ranging from 0.07 to 0.28 m/year [1] and the rates observed by other techniques [2-4]. It is argued that the results imply that the observed subsidence would be predominantly due to the land development of the area.

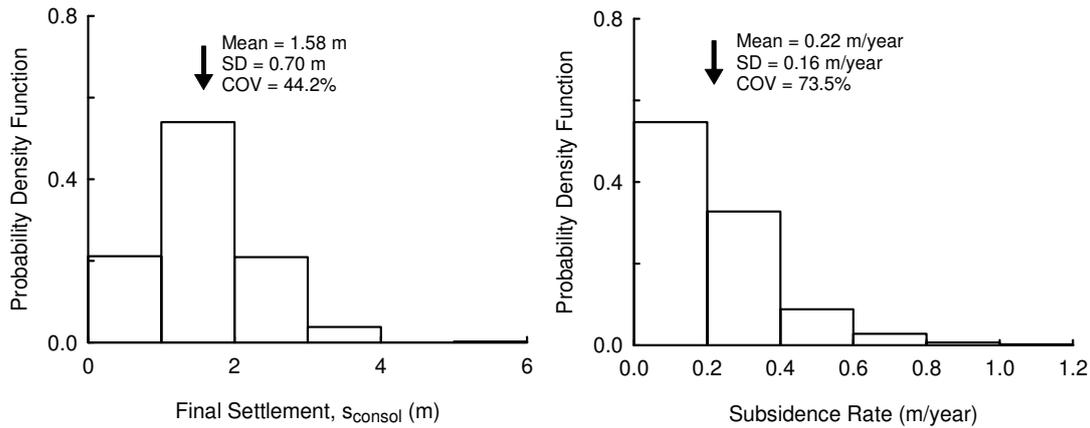


Figure 6: Probability density function of final settlement and subsidence rate for period between years 1 and 5

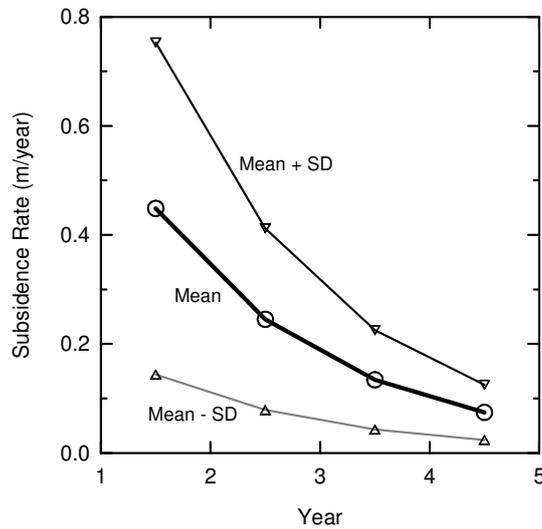


Figure 7: Subsidence rate for different periods

The observed subsidence rate tends to decrease with time, and additional analyses were conducted to evaluate this trend. Subsidence rates for the period between year 1 and 2 (from 56 to 76 percent degree of consolidation) through the period between year 4 and 5 (from 93 to 96 percent degree of consolidation) were individually analyzed. As shown in Figure 7, the general trend is that the subsidence rate decreases with time; for the period between year 1 and 2, the mean and standard deviation are 0.45 m/year and 0.30 m/year respectively and, between year 4 and 5, the mean and standard deviation are 0.07 m/year and 0.05 m/year, respectively. It is postulated that the period between year 1 and 2 after fill placement would likely be the construction period, and that the estimated subsidence rate would not be observed as the ground surface level might be adjusted during construction. However, the subsequent values of subsidence rate of 0.25 m/year to 0.07 m/year are in the same range as the observed subsidence rates of 0.07 to 0.28 m/year. These results would support the argument that the observed subsidence would be predominantly due to the land development of the area.

In addition, prefabricated vertical drains were used to accelerate the consolidation of the very soft to soft soil layers in many land development projects in northern Jakarta. The 90 percent degree of consolidation would be typically achieved in less than 6 months. This condition is equivalent to the period between year 3 and 4 which has the subsidence rate mean and standard deviation values of 0.13 m/year and 0.09 m/year, respectively.

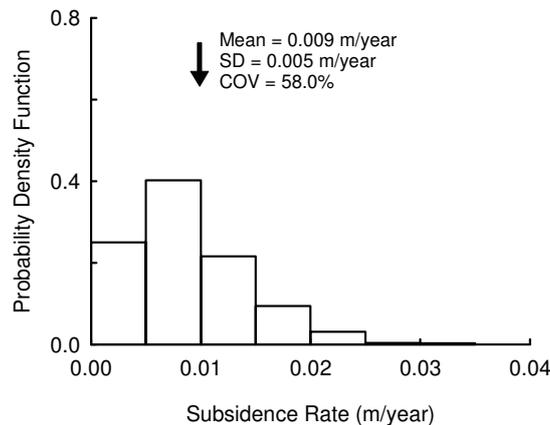


Figure 8: Probability density function of long term settlement rate

The long term subsidence rate was estimated assuming that the secondary compression theory applies and no additional loads are imposed. The probability density function for such condition in the period of between year 5 and 20 is shown in Figure 8. The mean and standard deviation are about 0.01 m/year and 0.005 m/year, respectively. The probability of subsidence rate of greater than 0.02 m/year is only less than 5 percent. These simulation results suggest that some degree of land subsidence would still be observed although the land development has finished for a period of time.

## 7. CONCLUSION

Land subsidence has been identified as one of major geological hazards of Jakarta, and the subsidence maximum value and rate observed in the area between west Ancol and Kamal, North Jakarta vary up to 0.8 m and 0.28 m/year, respectively. The hypothesis of this paper was that the subsidence is predominantly due to the compression of the normally consolidated, very soft to soft silt-clay deposits induced by the land development of the areas. Recent geotechnical data from three sites in the area were compiled, and field and laboratory soil parameters including their statistical properties were evaluated. The estimation of land subsidence was performed using the classic Terzaghi's 1-D consolidation and secondary compression theories, coupled with the Monte Carlo approach to consider the soil parameter variabilities. The statistical properties of all seven soil parameters used in the simulations were determined based on the compiled geotechnical data. Ranges of estimated values, as well as their relevant statistical properties, were presented. The final settlement mean and standard deviation values were 1.6 m and 0.7 m, respectively, while the subsidence rate mean and standard deviation values for a period between year 1 and 5 were 0.22 m/year and 0.16 m/year, respectively. In addition, it is suggested that some degree of land subsidence (< 0.02 m/year) would still be observed long after the completion of the land development. The simulation results were in the same range of field geotechnical measurements supporting the hypothesis of this paper.

## REFERENCES

- [1] H.Z. Abidin, H. Andreas, I. Gumilar, Y. Fukuda, Y.E. Pohan, and T. Deguchi, "Land subsidence of Jakarta (Indonesia) and its relation with urban development", *Natural Hazards*, vol. 59, pp. 1753–1771, 2011.
- [2] L. Bayuaji, J.T.S. Sumantyo, and H. Kuze, "ALOS PALSAR D-InSAR for land subsidence mapping in Jakarta, Indonesia", *Canadian Journal of Remote Sensing*, Vol. 36, No. 1, pp. 1–8, 2010.
- [3] A.H.-M. Ng, L. Ge, X. Li, H.Z. Abidin, H. Andreas, and K. Zhang, "Mapping land subsidence in Jakarta, Indonesia using persistent scatterer interferometry (PSI) technique with ALOS PALSAR", *International Journal of Applied Earth Observation and Geoinformation*, vol. 18, pp. 232–242, 2012.
- [4] L. Bayuaji, R.F. Putri, and J.T.S. Sumantyo, "Combination of L, C and X-band SAR data for continuous monitoring of land deformation in urban area by using DInSAR technique", *IEICE Technical Report SANE2012-70*, pp. 77–82, 2012.
- [5] F.H. Kulhawy and P.W. Mayne, *Manual on Estimating Soil Properties for Foundation Design – EL-6800*, Palo Alto, CA: EPRI, 1990.
- [6] K. Terzaghi, R.B. Peck, and G. Mesri, *Soil Mechanics in Engineering Practice*, Ed. 3., New York, NY : John Wiley & Sons, 1996.
- [7] Pusat Penelitian dan Pengembangan Geologi, *Quarterinary Geology Map (1:250,000)*, 1995.
- [8] G. Mesri and P.M. Godlewski, "Time and stress – compressibility interrelationship", *Journal of the Geotechnical Engineering Divisions*, vol. 103, no. GT5, pp. 417–430, 1977.

## Buildup of Cyclic Pore-Water Pressure of Yogyakarta's sand Using Cyclic Shear Strain Testing

**R. Kusumawardani<sup>ab</sup>, K.B. Suryolelono<sup>b</sup>, B. Suhendro<sup>b</sup>, A. Rifa'i<sup>b</sup>, L. Laloui<sup>c</sup>**

<sup>a</sup>Faculty of Engineering, State University of Semarang, Semarang 50229  
 E-mail : rini\_kusumawardani@yahoo.com

<sup>b</sup>Faculty of Engineering, Gadjah Mada University, Yogyakarta 55581

<sup>c</sup>Laboratory Soil Mechanics, Ecole Polytechnique Federale de Lausanne, Switzerland

### ABSTRACT

Liquefaction phenomenon could be analysed using strain-controlled loading method where informations about sands pore water pressure build-up were presented. Maintaining small deformation values whenever the soil is subjected to cyclic loading, this non-destructive method presents clearly the information about the increasing sands pore water pressure. It is concluded that liquefaction occurs whenever the pore water pressure reaches the same value with the soil effective stress ( $\sigma_3'$ ). Strain-controlled loading method introduces a fundamental parameter for undrained cyclic loading tests on fully saturated sands: shear strain treshold ( $\gamma_t$ ). This parameter divides the pore water pressure into two distinct zones, namely the constant pore water pressure and the increasing one. When cyclic shear strain amplitude ( $\gamma_c$ ) was set up lower than  $\gamma_t$  then pore water pressure remained constant. Contrastly, if specimen was subjected  $\gamma_c$  larger than  $\gamma_t$ , it obtained the increasing of pore water pressure. During the test, when Yogyakarta's sands as a material tested was performed in variation of relative density ( $D_r$ ) 25 %, 60 % and 80%, thereafter was applied an effective cell pressure  $\sigma_3' = 100$  kPa and frequency ( $f$ ) applied were 0.05 Hz and 0.1 Hz, shows it obtained  $\gamma_t = 1.5 \cdot 10^{-2}$  %. Whilst other test using  $D_r = 60\%$  and  $f = 0.1$  Hz confirmed that  $\gamma_t = 1.5 \cdot 10^{-2}$  % ( $50 \leq \sigma_3' \text{ (kPa)} \leq 100$ ) and  $\gamma_t = 5 \cdot 10^{-2}$  % ( $\sigma_3' = 200$  kPa). Last test using  $D_r = 60\%$  and  $f = 0.05$  Hz revealed  $\gamma_t = 1.2 \cdot 10^{-2}$  % ( $50 \leq \sigma_3' \text{ (kPa)} \leq 100$ ) and  $\gamma_t = 2 \cdot 10^{-2}$  % ( $\sigma_3' = 200$  kPa).

#### Keywords :

Threshold shear strain, dynamic loading, liquefaction, pore water pressure, sands

### 1. INTRODUCTION AND OBJECTIVES

There are a lot of research were done to analyze the liquefaction behaviour toward soil mass. Some methods which are usually used are cyclic shear-strain controlled, cyclic shear-stress controlled, and strain energy concept. Cyclic strain controlled testing is considered as a method which can describe the real condition of the soil. This method can predict the liquefaction occurrence based on the soil information about the behaviour of the pore water pressure. One of the key parameters in this method is the determination of threshold shear strain ( $\gamma_t$ ) because it can provide the information about the minimum value of cyclic shear strain which can cause the increasing of pore water pressure when cyclic loading is applied on fully saturated soils. The basic concept of cyclic shear strain method is by maintaining the soil's small deformation when it subjected the cyclic loading. Small deformation analysis which is caused by cyclic loading in the daily life can be represented as the effect of earthquake loading, pile driving vibration, traffic loading, ocean wave storm, machine foundation vibration, and other cyclic loading sources.

Table 1. Summarizes of some research of  $\gamma_t$  on some types of soils.

Study conducted by	Soil type	Plasticity Index, PI (%)	Cyclic threshold shear strain range, $\gamma_t$ (%)	Testing method
Ladd et al., 1989	Clean sand	NP	0.011	Undrained cyclic triaxial
Hsu et al., 2006	Cohesive soil	14 - 30	0.024 - 0.06	Direct simple shear
Uchida et al., 2001	Toyoura sand	NP	-	Undrained monotonic triaxial

Many researchers have tried to study the value of  $\gamma_t$  of different types of soil both to the clean sand and cohesive soils (Ladd et al., 1989; Hsu et al., 2006; Uchida et al., 2001). Based on the literature review study, the value of  $\gamma_t$  of the cohesive soil is higher than the clean sand. Hsu (2006) in his publication states that the value of  $\gamma_t$  on the cohesive soil was influenced by soil plasticity index (PI). Table 1 above summarizes the result of some research about the value of  $\gamma_t$  on some types of soils.

## 2. SOIL TESTED

The soil sample was collected from University of Muhammadiyah Yogyakarta's area and some of soil laboratory tests were conducted to identify the initial conditions of the soil sample. The results of the tests are as follows:

Table 2. Initial condition of Yogyakarta's sand.

No	Variables	Unit	Test Results
1	Water contents ( $w$ )	%	22.3
2	Density relatives ( $D_r$ )	%	64
3	Specific gravity ( $G_s$ )	-	2.66
4	Void ratio ( $e$ )	-	0.59
5	Dry density ( $\gamma_d$ )	gr/cm <sup>3</sup>	1,67
6	Wet density ( $\gamma_b$ )	gr/cm <sup>3</sup>	1,92

To get a more detail understanding about the physical soil characteristic, some advanced soil laboratory tests were taken. Visually, the soils used were assumed as granular soils with grain size distributions as shown in Figure 1. From that figure, it can be seen that the soils were categorized in a range which were potential for occurrence liquefaction. Further, according to *USCS* standard, the soils were classified as medium sands.

Table 3. Physical characteristics of soil sample.

No	Variables	Units	Test results
1.	Maximum void ratio ( $e_{max}$ )	-	0.810
2.	Minimum void ratio ( $e_{min}$ )	-	0.48
3.	Maximum dry density ( $\gamma_{dmax}$ )	gr/cm <sup>3</sup>	1.8
4.	Minimum dry density ( $\gamma_{dmin}$ )	gr/cm <sup>3</sup>	1.47
5.	Maximum wet density ( $\gamma_{bmax}$ )	gr/cm <sup>3</sup>	2.13
6.	Minimum wet density ( $\gamma_{bmin}$ )	gr/cm <sup>3</sup>	1.47
7.	Coefficient of uniformity ( $C_u$ )	-	4.34
8.	Coefficient of gradation ( $C_c$ )	-	1.14
9.	Atterberg limit	-	Non plastic
10.	Soil classification ( <i>USCS</i> )	-	SW

## 3. EXPERIMENTAL PROGRAM

Saturated specimens of Yogyakarta's sand were performed in 56 undrained strain-controlled cyclic triaxial tests to determine the pore water pressure build-up behaviour of sand. Variation of confining pressure ( $\sigma'_3$ ), density relative ( $D_r$ ) and frequency ( $f$ ) were applied to the specimen as a parameter which affected the behaviour of pore pressure build up. The shear strain threshold is the key parameter in shear strain controlled method which could determine the applied loading during the testing by using triaxial machine. The experimental program was formulated step by step by gradually increasing the value of cyclic shear strain amplitude ( $\gamma_c$ ). Some important parameters which will be researched are threshold shear strain ( $\gamma_t$ ), modulus degradation ( $G/G_1$ ) over a number of cycles ( $N$ ).

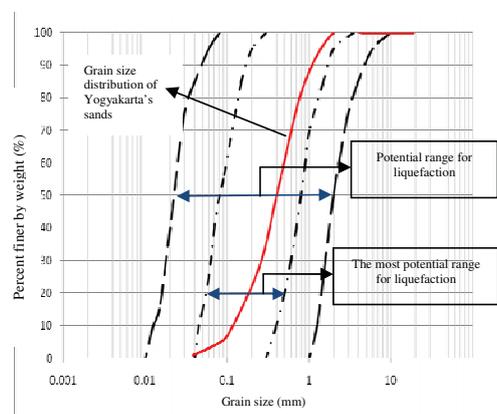


Figure 1: Result of the distribution grain test analysis of Yogyakarta's sand.

## 4. TESTING TECHNIQUE

This research was conducted by using cyclic triaxial apparatus which was equipped with a set of controller, consisted of controller axial load, a controller confining pressure, and a controller of backpressure. A remoulded sample was chosen to facilitate the preparation of the test specimen before the test was started.

### 2.1. Sample Preparation

This paragraph explains about the details of sample preparation. Some important points considered in the sample preparation are explained as follows:

1. The method of the sample preparation was dry pluviation by placing the mold soil sample of 50 mm internal diameter and 100 mm height by enclosing a rubber membrane which was then attached on the porous stone in the triaxial cell base. Water and sand were prepared adjusted to the value of  $D_r = 25\%$ ,  $60\%$ , and  $80\%$ . Then, the dry soil which already prepared was dropped into the mold through the air. During this process, the soil will absorb the water slowly. After the specimen has been prepared, then it was transferred to the triaxial cell. Before it was starting the next process, the triaxial cell must be fully fulfilled using de-aired and de-mineralized water.

2. Then, the specimens were isotropically consolidated which aim to uniform the pore pressure inside the specimen. This process was done for one night in triaxial cell by applying the cell pressure 50 kPa, 100 kPa, and 200 kPa. This stage was considered done if the volume change of specimen remained constant. The next stage was saturation process.

3. During the saturation process was applied, the back pressure and cell pressure gradually increased until reached the Skempton value greater than 0.95. Skempton value is the parameter which is proposed to ensure the sample used in the research is in the fully saturated condition.

### 2.2. Determination of the threshold shear strain ( $\gamma_t$ )

The value of threshold shear strain ( $\gamma_t$ ) is determined using the method introduced by Ladd et al. (1989) with undrained cycling testing stages as follows:

#### 1). Measurement using Very Small Strain

In this stage, a very small strain  $10^{-3} - 10^{-2}\%$  was used to identify the value of residual pore water pressure. Cyclic loading was applied 10 times then it was stopped. The measurement result obtained in this stage was  $\Delta u_r = 0$ . Thus, it can be said that the measurement in this stage was a non destructive one.

#### 2). Measurement of $\gamma_t$

In this stage, the value of  $\Delta u_r$  during and after the measurement was recorded. The number of the cyclic loading applied was in the same value as it was applied in the previous stage, but with a higher value of  $\gamma_c$  around  $1.10^{-2}\% < \gamma_c < 2.10^{-2}\%$ . It showed that the value of  $\Delta u_r$  increased although in a small value.

#### 3). Measurement of $\gamma_c > \gamma_t$

The value of cyclic shear strain amplitude applied in this stage was higher than stage 2. The number of the cyclic loading was done 100 cycles or the test was stopped when the soil meet the initial liquefaction. It revealed that the value of  $\Delta u_r$  increased significantly at this stage.

## 5. DATA INTERPRETATION

### 5.1. Threshold cyclic shear strain

Deleted:

Figure 2 shows the result of the research on Yogyakarta's sand which applying the effective confining stress ( $\sigma'_3$ ) = 100 kPa on the sample with different relative density 25%, 60% and 80% respectively. The difference between the two figures is the frequency ( $f$ ) of loading applied, which were 0.1 Hz (a) and 0.05 Hz (b). For those two frequencies, it shows that the increasing of the pore water pressure takes place when the threshold cyclic shear strain ( $\gamma_t$ ) reaches  $1.5 \cdot 10^{-2}$  %. The value of the relative density does not influenced the value of  $\gamma_t$  if the value of  $\sigma'_3$  applied was in the same value. From both figures, it can be obtained an information that if  $\gamma_c > \gamma_t$  was applied for every value of relative density, it can be reached a different residual pore pressure ratio value. Comparison between two condition of soil, soil on the loose state, the value of  $\gamma_c$  slightly greater than  $\gamma_t$ , and the residual pore water pressure will increase more significantly than dense soil.

Figure 3 provides the information about  $\gamma_t$  of Yogyakarta's sands in the condition  $D_r = 60\%$  and  $f = 0.1$  Hz and 0.05 Hz. The value of  $\Delta u_r$  was recorded on the different variation of  $\sigma'_3$ . This figure shows that  $\gamma_t$  has the same value around  $50 < \sigma'_3 < 100$  kPa. However, when the value of  $\sigma'_3 = 200$  kPa was applied, and then the value of  $\gamma_t$  will be higher. It can be assumed that by applying a higher confining stress, the soil strength to resist the shear stress will be higher. Thus, the cyclic shear straining amplitude needed is higher. The smaller the frequency of loading applied, and then the value of  $\Delta u_r$  also will be smaller. Thus, it can be said that if the frequency is smaller, there will be a lag time for soil for to neutralize the pore water pressure there will be no build up of pore water pressure.

### 5.2. Shear Modulus ( $G$ )

Shear Modulus is the parameter which represents soil resistance toward the shear stress applied to it. Figure 4 shows the relation between  $G$  and  $\gamma$  with  $D_r = 60\%$  and first loading cycle ( $N = 1$  cycle) and the  $\sigma'_3$  is applied in a different value of 50 kPa, 100 kPa and 200 kPa respectively. It shows there is a correlation between  $\sigma'_3$  and  $G$ . The level of  $\sigma'_3$  applied affect to soil resistance which is described by parameter  $G$ . More higher  $\sigma'_3$  applied, it means that the cyclic shear strain amplitude needed by the soil to meet the initial liquefaction will also be higher.

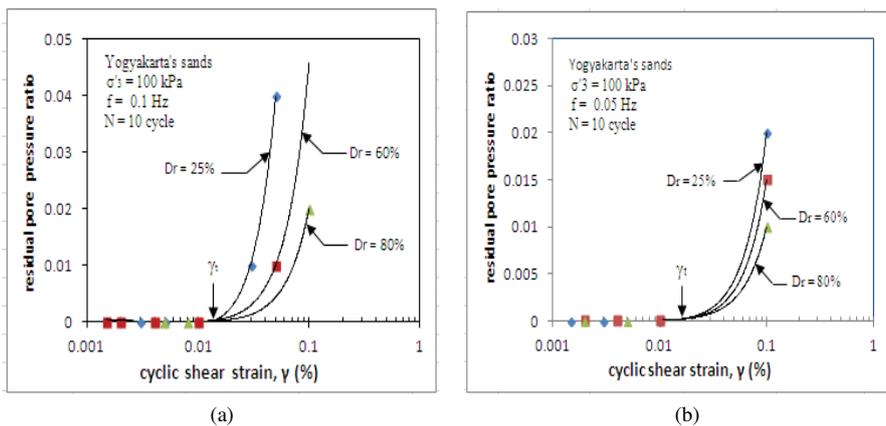
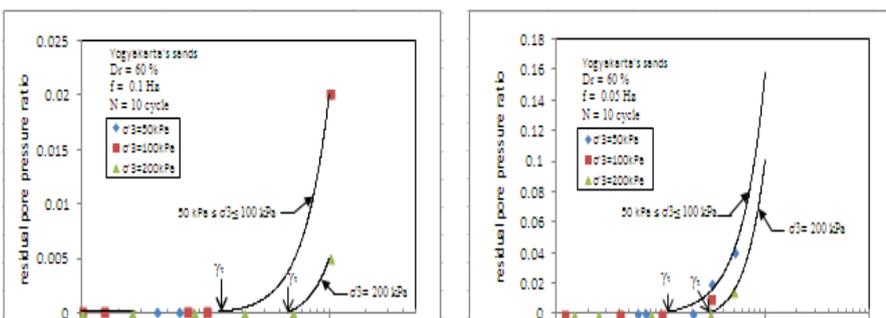


Figure 2:  $\gamma_t$  of Yogyakarta's sand for various density and frequency



## 6. CONCLUSION

The value of cyclic shear strain  $\gamma_t$  is the fundamental parameter because it can be used to find out the limit of the shear strain amplitude  $\gamma_c$  which is applied during the testing. Thus, it can be used to know the increasing of excess pore water pressure. If  $\gamma_c < \gamma_t$  is applied, then the pore water pressure will not be increased, but if the  $\gamma > \gamma_t$  is applied then the pore water pressure will be gradually increased.

From a set of research done to find out the value of threshold cyclic strain  $\gamma_t$  on Yogyakarta's sand, it results that the sands with cyclic frequency of loading ( $f$ ) were 0.05 and 0.1 Hz and  $\sigma_3' = 100$  kPa were obtained  $\gamma_t = 1.5 \cdot 10^{-2} \%$  for  $D_r = 25 - 80\%$ . For the sands  $\sigma_3' = 50 - 100$  kPa with  $D_r = 60\%$ ,  $f = 0.1$  Hz were obtained  $\gamma_t = 1.5 \cdot 10^{-2} \%$ , while for  $\sigma_3' = 200$  kPa was obtained  $\gamma_t = 0.05 \%$ . Moreover, for  $f = 0.05$  Hz shows  $\gamma_t = 1.2 \cdot 10^{-2} \%$  ( $50 \leq \sigma_3' \text{ (kPa)} \leq 100$ ) and  $\gamma_t = 2 \cdot 10^{-2} \%$  ( $\sigma_3' = 200$  kPa).

## 7. ACKNOWLEDGMENT

The writer would like to thank the Laboratory Soil Mechanics of Ecole Polytechnique Federale de Lausanne, Switzerland for giving the permission using the equipment for the cyclic triaxial cell test.

## 8. REFERENCES

- [1] C.C. Hsu, and M. Vucetic, "Threshold Shear Strain for Cyclic Pore Water Pressure in Cohesive Soils," *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 132, No.10, pp 1325-1335, October 2006
- [2] K. Uchida, and J.D. Stedman, "Liquefaction Behavior of Toyura Sand Under Cyclic Strain Controlled Triaxial Testing," *Proceedings of the Eleventh International Offshore and Polar Engineering Conference*, pp 350-356, June 2001

- [3] R.S. Ladd, R. Dobry, P. Dutko, F.Y. Yokei, and R.M. Chung, "Pore-Water Pressure Buildup in Clean Sands Because of Cyclic Straining," *Geotechnical Testing Journal*, Vol. 12 No.1, pp 77-86 , March 1989

# Development A Simple Model for Preliminary Evaluation on Extreme Rainfall Induces Shallow Slope Failure

Agus Setyo Muntohar <sup>a</sup>, Jazaul Ikhsan <sup>b</sup>

<sup>a</sup> Geotechnical Engineering Research Group (GERG), Department of Civil Engineering, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia. Tel. +62-274 387656 (Ext. 229). Fax. +62-274 387646  
Email: [muntohar@umy.ac.id](mailto:muntohar@umy.ac.id)

<sup>b</sup> Water Resources and Hydraulic Engineering Research Group (WHERG), Department of Civil Engineering, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia.

## ABSTRACT

*A simple method is developed in this paper to evaluate rainfall induces slope instability. The method dealt with one dimensional infiltration on the shallow slope. The study was focused on the study of the effect of rainfall pattern, duration, soils type and slope angle on the stability of slope. Two soil types, those were low and high permeability, and slope angle were selected to examine the proposed model. The results of the study show that the proposed model was simple model and suitable to assess rainfall induced slope instability especially shallow landslides type. The proposed model enable to estimate the infiltration and slope stability during the rainfall as the FEM results was more conservative. Infiltration was strongly affected by rainfall pattern, inclination of slope and the hydraulic properties of soil.*

**Keywords:** rainfall, infiltration, slope failure, seepage

## 1. INTRODUCTION

The climate change has been the worldwide issues including the extreme rainfall. This rainfall triggered many slopes and caused catastrophic disaster in many places in the world. Rainfall infiltration induced landslides are traditionally analyzed by using the two-dimensional limit equilibration numerical analysis. Attempts have been made to analyze the rainfall induces landslides by using coupling analysis of seepage and slope stability analysis. The common model to evaluate slope stability during rainfall was incorporated transient pore water pressure during the infiltration Modeling the infiltration and pore water pressure during rainfall was a complex analysis. Several investigators applied numerical modeling such as finite element method (FEM) to assess rainfall induces landslides [1-3]. However, the results of FEM were affected by several factors and much effort were required for performing calculation [5]. For practical purpose, a simple method is required as a rapid tool to assess the slope stability triggering by rainfall. Physically-based models coupling the infinite slope stability analysis with Green-Ampt infiltration modeling was developed in this research. Some investigators [6-8] have verified that the Green-Ampt equation could generate results, which were in good agreement with rigorous models such as Richard's equation. Hence, premier researches have been carried out on the shallow landslides analysis under steady and unsteady infiltration by applying the Green-Ampt equations [9-12]. In this paper, the effect of rainfall intensity and duration (rainfall pattern) on shallow landslides was investigated using the developed model. The study was focused on the study of the effect of rainfall pattern, soils type and slope angle on the stability of slope.

## 2. METHOD AND MODEL DEVELOPMENT

The method improved the previous model of Muntohar and Liao [11]. The improvement of analysis was made for calculation the pore water pressure (Part B) and slope stability analysis (Part C). The theoretical and derivation of the model has been clearly described in Muntohar and Liao [11,12]. The algorithm of the proposed model is presented in Figure 1. Principally the proposed model was based on the Green-Ampt infiltration model. The model was assumed one dimensional water flow through the slope. The slope stability analysis was modeled as infinite slope. In this study, the proposed model was then verified by using available numerical coupling model of SEEP/W and SLOPE/W [13-14]. The modeling of slope and boundary conditions are shown in Figure 2 for verification using two-dimensional finite element method. Three synthetic rainfall distributions including delayed, centralized, and advanced were selected to examine the effect rainfall pattern on the slope failure. The maximum rainfall intensity was 100 mm/h with total rainfall about 1250 mm. Two soil types, those were low and high permeability, and slope angle were selected to examine the proposed model. The soil properties are presented in Table 1. The hydraulic conductivity and soil water characteristic curves of the soil were illustrated in Figure 3.

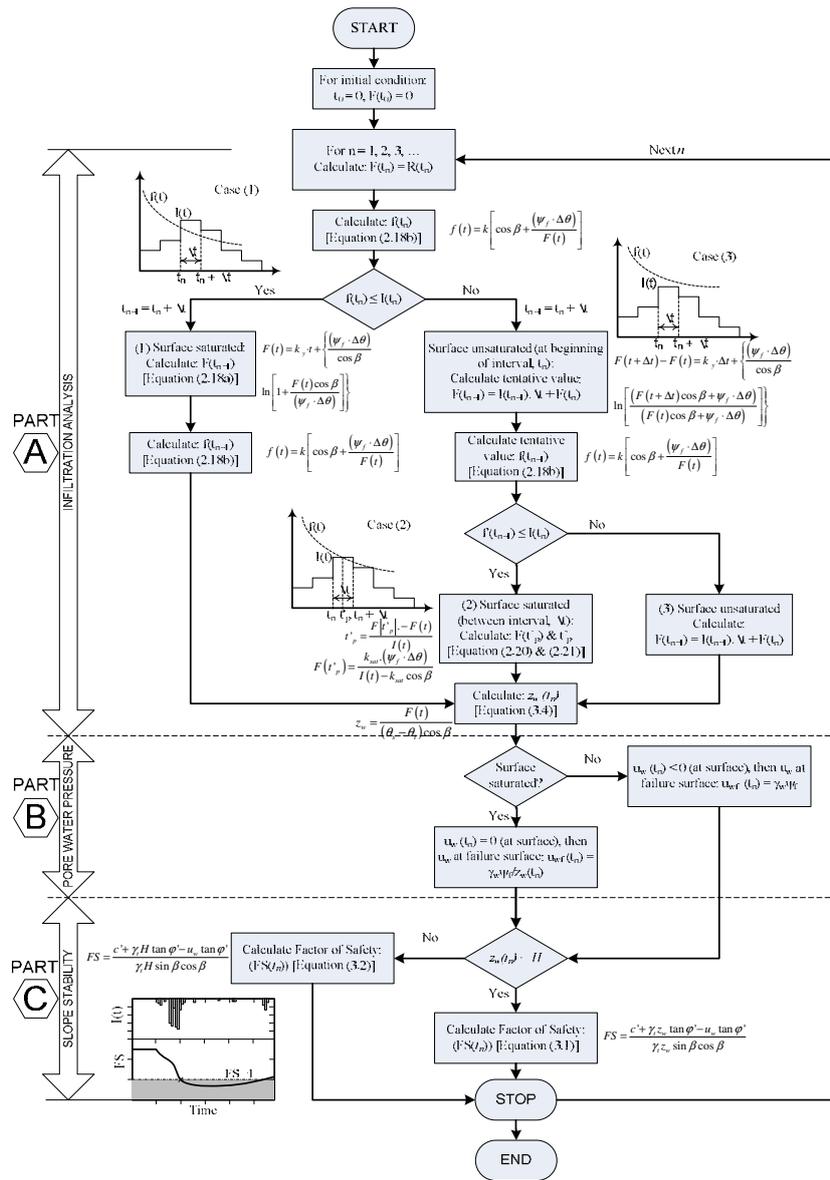


Figure 1 The algorithm for calculation the rainfall infiltration, water pressure, and slope stability

Table 1 Soil properties of the slope

Parameters	High Permeability Slope (K1)	Low Permeability Slope (K2)
Depth of bedrock, $H$ (m)	5	5
Slope angle, $\beta$	20°, 40°	20°, 40°
Cohesion, $c'$ (kPa)	0	5
Internal friction angle ( $\phi'$ )	30	30
Unit weight, $\gamma$ (kN/m <sup>3</sup> )	21.8	21.8
Saturated permeability, $k_s$ (m/s)	$1.0 \times 10^{-4}$	$1.0 \times 10^{-5}$
Deficit volumetric water content, $\Delta \theta_w$	0.225	0.235
Suction head at wetting front, $\psi_f$ (m)	0.5	1

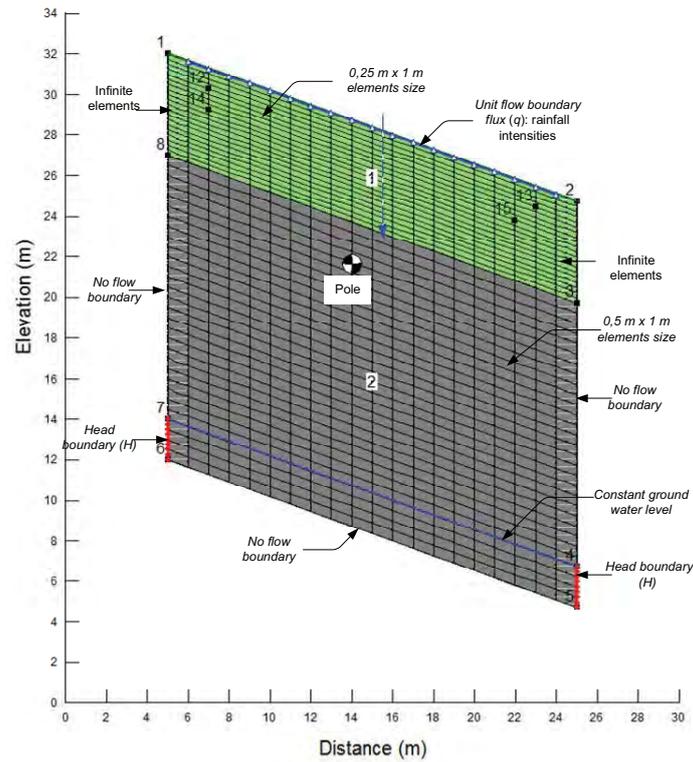


Figure 2 The modeling of slope and boundary condition for verification analysis

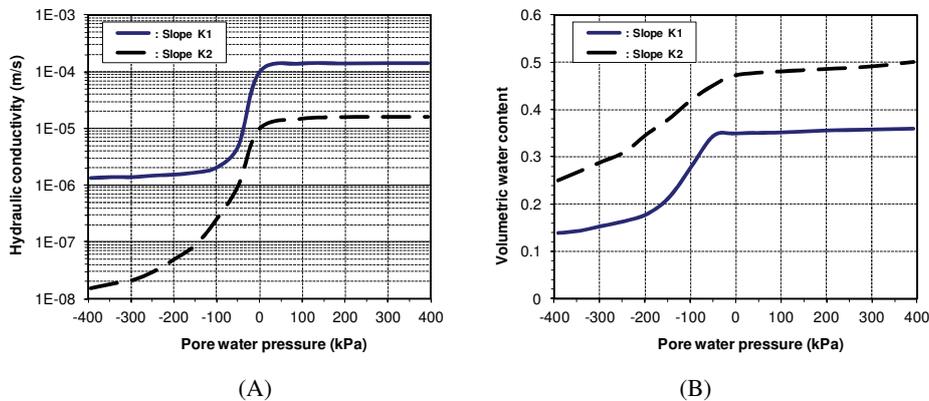


Figure 3 The hydraulic properties of the soil (A) hydraulic conductivity curve, (B) soil-water content characteristics curve

### 3. RESULTS AND DISCUSSION

#### 3.1 Infiltration Characteristics

Typical the result of analyses are illustrated in Figure 4. It was clearly observed that the infiltration in high permeability slope (K1) was the same with rainfall intensities. The infiltration pattern was the same with the rainfall pattern. In contrast with the low permeability slope (K2), the infiltration is affected by the rainfall pattern. Delayed and centralized rainfall pattern show a similar infiltration pattern as shown in Figure 4(A,D, C,F). The infiltration is the same with the rainfall intensity at the beginning of rainfall, then decrease gradually after certain elapsed time of rainfall.

It was observed clearly from the figure that for high permeability slope (K1), the infiltration of the Green–Ampt (GA) was in agreement with the FEM computation. It is because of the rainfall intensity ( $I_t$ ) is lower than the saturated hydraulic conductivity of the soils ( $k_{sat}$ ),  $I_t < k_{sat}$ . Simulation using FEM has shown that the slope surface was unsaturated during the rainfall. Hence, all the rainwater infiltrate into the slope. For the case of low permeability slope (K2), the rainwater infiltration is controlled by the saturation at the slope surface. Saturation at slope surface will occur when the  $I_t$  is higher than the  $k_{sat}$  ( $I_t >$

$k_{sat}$ ). For this condition, the figures illustrated that the amount of rainwater infiltration from the proposed model was slightly difference with the FEM at the onset time of rainfall. The difference may be caused from initial suction head and volumetric water content at the initial state of the computation. In the GA infiltration model, the suction at slope surface and volumetric water content was assumed to be constant during the infiltration, while the FEM considered the change of suction, volumetric content and hydraulic conductivity during the calculation. But, after the slope surface saturated, the infiltration pattern for both model was the same. The deviation of infiltration from GA model and FEM was lesser for a slope with greater inclination as shown in Figure 4(D to F). The results indicated that the GA model is applicable for a sloping ground. The result is in agreement with Chen and Young [15]. It was observed in Figure 4(E) for K2 slope that the infiltration from GA model and FEM computation is relatively the same. The result indicated that the GA model is in good agreement when the slope surface is saturated at the beginning of rainfall.

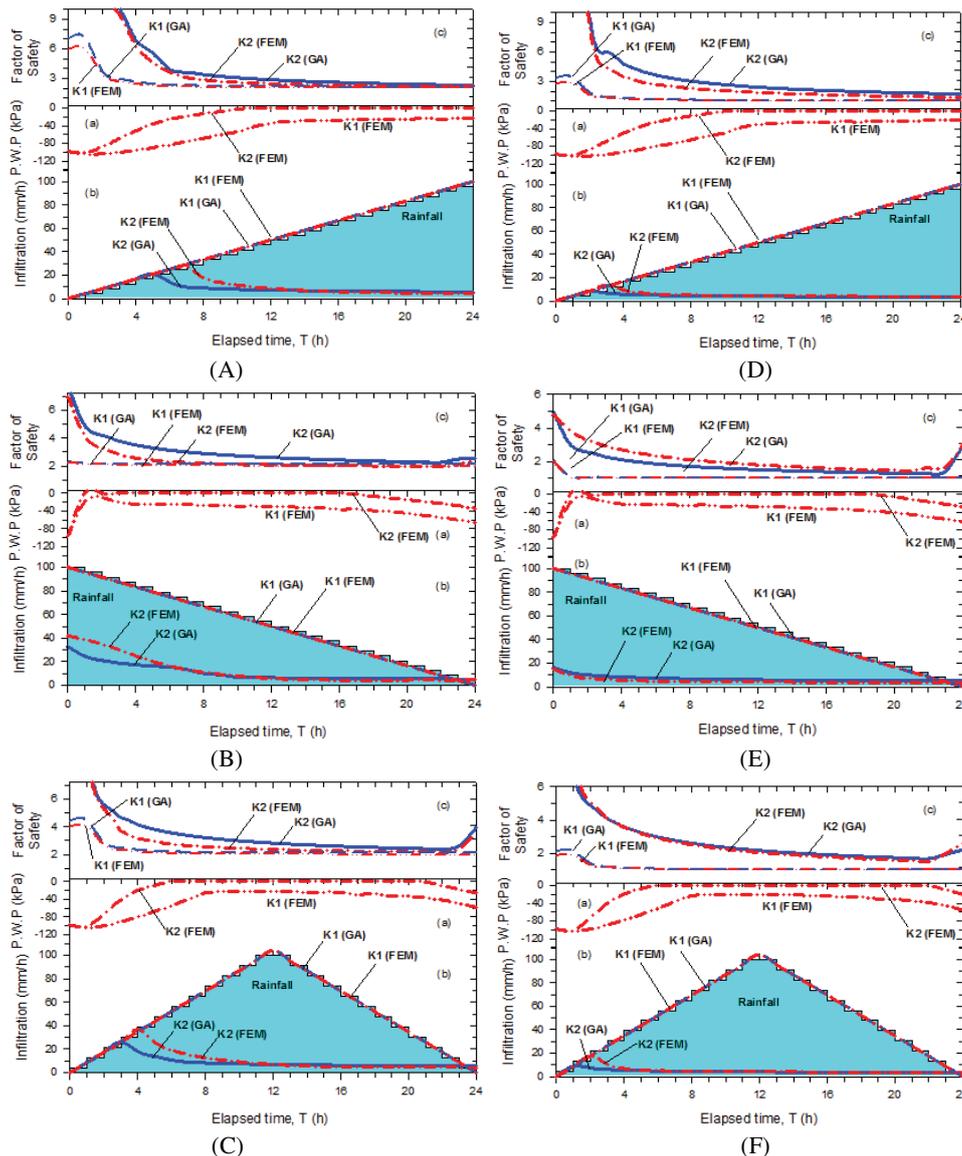


Figure 4 Typical of the result of the proposed model and two dimensional finite element analyses (A, D) delayed rainfall pattern, (B, E) advanced rainfall pattern, (C, F) central rainfall pattern.  
 Note: (A – C) for slope angle 20°, (D – F) for slope angle 40°.

### 3.2 Slope Stability

Slope stability is commonly represented by the factor of safety (FS). In the deterministic analysis, a slope will fail if the FS value is lower than one ( $FS < 1$ ). The results illustrated in Figure 4 show that the advanced rainfall pattern resulted in the

lowest minimum factor of safety for the given slope. Advanced rainfall generated rapid saturation on the slope surface at the beginning of rainfall, since the accumulated rainfall is greater than the saturated hydraulic conductivity of the slope. As the result, the pore water pressure increased drastically from 98.1 kPa to zero on the slope surface. Hence, the FS decreased significantly with the elapsed time of rainfall. It was observed for the delayed and centralized rainfall pattern, the factor of safety tend to increase at the end of rainfall. It was because of the decreasing of pore water pressure. The results indicated that rainfall pattern affected the slope instability. Slope failure rapidly occurred after the advanced rainfall pattern, while centralized and delayed rainfall pattern will generate a delayed slope failure. This finding is supported the research carried out by Tsai and Wang [16].

The effect of slope inclination was also observed from the relationship in Figure 4. For the slope inclination smaller than  $20^\circ$ , the estimated factor of safety from the FEM was more conservative than the results obtained from the proposed model for both K1 and K2 slopes. The analysis given in Figure 4 showed that the K1 slope was more prone to failure than the K1 slope subjected to the same rainfall intensities and duration. For the slope angle  $40^\circ$ , the factor of safety was observed to be dependent on the rainfall pattern. The factor of safety obtained from the proposed model was 5% lower than the results obtained from the FEM computation. In contrast with the K1 slope, the proposed model yield a lower factor of safety for K2 slope if compared to the FEM calculation. This result was completing the findings from the other research [1-3].

## 7. CONCLUSION

The proposed model has successfully estimated the infiltration and slope stability during the rainfall as wells as analysis of the FEM. Overall results were alluding to conclude that the proposed model was simple model and suitable to assess rainfall induced slope instability especially shallow landslides type. Infiltration was strongly affected by rainfall pattern, inclination of slope and the hydraulic properties of soil. For a high permeability slope which the saturated hydraulic conductivity of the soils ( $k_{sat}$ ) is greater than the rainfall intensity ( $I_t$ ),  $k_{sat} > I_t$ , infiltration was independent to the rainfall pattern. But for a low permeability slope, which the saturated hydraulic conductivity of the soils ( $k_{sat}$ ) is lower than the rainfall intensity ( $I_t$ ),  $k_{sat} < I_t$ , the rainwater infiltration is dependent to the rainfall pattern. The rainfall pattern controlled the saturation at the slope surface. For the slope angle smaller than  $20^\circ$ , the estimated factor of safety from the FEM was more conservative than the results obtained from the proposed model for both high and low permeability slopes. For the slope angle  $40^\circ$ , the factor of safety was observed to be dependent on the rainfall pattern. The factor of safety obtained from the proposed model was 5% lower than the results obtained from the FEM computation. In contrast with the high permeability slope, the proposed model yield a lower factor of safety for the low permeability slope if compared to the FEM calculation

## ACKNOWLEDGMENT

This paper was part of the research "Experimental and Numerical Model on Rainfall Infiltration Induces Slope Failure Slope". The research was granted by the Ministry of Education and Culture, The Republic of Indonesia for the financial support through Fundamental Research scheme in 2011-2012. Authors are thankful for the funding provided.

## REFERENCES

- [1] C.W.W. Ng, Q. Shi, "A Numerical investigation of the stability of unsaturated soil slopes subjected to transient seepage," *Comp Geotechnics* 22(1): 1-28, 1998.
- [2] I. Tsaparas, H. Rahardjo, D.G. Toll, E.C. Leong, "Controlling parameters for rainfall-induced landslides," *Comp Geotech* 29: 1-27, 2002.
- [3] L.M. Lee, N. Gofar, H. Rahardjo, "A simple model for preliminary evaluation of rainfall-induced slope instability," *Eng Geol* 108, pp. 272-285, 2009.
- [4] H. Rahardjo, A.S. Nio, E.C. Leong, N.Y. Song, "Effects of groundwater table position and soil properties on stability of slope during Rainfall." *J Geotech Geoenviron Eng* 136(11), pp. 1555-1564, 2010.
- [5] J.M. Duncan, "State of the art limit equilibrium and finite-element analysis of slopes." *J Geotech Eng* 122(7), pp. 577-596, 1996.
- [6] V. Clauinitzer, J.W. Hopmans, J.L. Starr, "Parameter uncertainty analysis of common infiltration models," *Soil Sci Soc Am J* 62:1477-1487, 1998.
- [7] S.M. Hsu, C.F. Ni, P.F. Hung, "Assessment of three infiltration formulas based on model fitting on Richard's equation." *J Hydrol Eng* 7(5):373-379, 2002.
- [8] R.V. Kale, B. Sahoo, "Green-Ampt infiltration models for varied field conditions: A revisit," *Water Resour Management*, 25(14), pp. 3505-3536, 2011.
- [9] M.W. Xie, T. Esaki, M.F. Cai, "A time-space based approach for mapping rainfall-induced shallow landslide hazard," *Environ Geol*, 46(7), pp. 840-850, 2004
- [10] T.L. Tsai, J.C. Yang, "Modeling of rainfall-triggered shallow landslide," *Environ Geol*, 50(4), pp. 525-534, 2006.
- [11] A.S. Muntohar, H.J. Liao, "Analysis of rainfall-induced infinite slope failure during typhoon using a hydrological-geotechnical model." *Environ Geol* 56(6), pp. 1145-1159, 2009.
- [12] A.S. Muntohar, H.J. Liao, "Rainfall infiltration: infinite slope model for landslides triggering by rainstorm," *Nat Haz* 54(3), pp. 967-984, 2010.
- [13] J. Krahn, *Seepage modeling with SEEP/W*. Geo Slope Internat Ltd., Canada, 2004.

- [14] J. Krahn, *Stability modeling with SLOPE/W*. Geo Slope Internat Ltd., Canada, 2004
- [15] L. Chen, M.H. Young, "Green-Ampt infiltration model for sloping surface," *Water Resour Res* 42, pp.1-9, 2006.
- [16] T.L. Tsai, J.K. Wang, "Examination of influences of rainfall patterns on shallow landslides due to dissipation of matric suction," *Environ Earth Sci* 63, pp. 65-75, 2011.

## Geogrid as Asphalt Pavement Reinforcement

Sri Widodo <sup>a</sup>, Bambang Sugeng Subagio <sup>b</sup>, Bagus Hario Setiadji <sup>c</sup>

<sup>a</sup> Doctoral Program of Civil Engineering, Diponegoro University, Semarang 50241  
E-mail : swdd.ums@gmail.com

<sup>b</sup> Doctoral Program of Civil Engineering, Diponegoro University, Semarang 50241  
E-mail : bssubagio@yahoo.com

<sup>c</sup> Doctoral Program of Civil Engineering, Diponegoro University, Semarang 50241  
E-mail : bhsetiadji@yahoo.com

### ABSTRACT

Previous researches have shown that geosynthetic used as a reinforcement of asphalt pavement layer was able to hold propagation of crack and rut. However, in those researches, initial strain of the geosynthetic was not included as a parameter affecting the performance of asphalt pavement layer. The purpose of this study is to analyze the effect of strain on the service life of asphalt pavement layer; the influence of density of asphalt concrete on the modulus of elasticity; and the effect of initial strain and location of geogrid in the asphalt pavement layer on its ability to resist fatigue due to repetitive loads. This research is conducted on asphalt pavement layer type of Asphalt Concrete Wearing Course (ACWC) using Beam Fatigue Apparatus. The specimens in this test are the asphalt concrete beams reinforced with geogrid. The research results show that the increasing of strain in the ACWC layer decreases service life. The ACWC density affects the modulus of elasticity in a parabolic way. The result reveals that ACWC fatigue life becomes greater by increasing the initial strain of the geogrid placed in the layer of ACWC. The geogrid located at 2/5 thickness of the ACWC base layer provides the ability to hold repeated loads greater than the geogrid located in the middle layer of the ACWC.

**Keywords :** geogrid, asphalt concrete, initial strain, service life, modulus of elasticity

### 1. INTRODUCTION

Technology of reinforcement on overlay of asphalt pavement to resist reflection cracking has been developed in South Africa and America. Polyester nonwoven geosynthetic paving fabric has been used to hold the crack propagation in the upper layer of asphalt pavement that had block cracked on overlay work in South Africa in 1980 [5]. The use of polypropylene nonwoven geosynthetic types as interlayer had succeeded to prevent crack propagation in overlay work on the old road that has been crack [4] and [6]. Geosomposite put under layers of asphalt concrete pavement can increase the resistance to rutting [2]. The optimum layout of geotextile reinforcement in the asphalt pavement layer is at 1/3 the thickness of the layer [7].

These studies demonstrate the ability of geosynthetic ever to reinforce asphalt pavement layer. Geosynthetic is a sheet-shaped material and has good tensile strength. Geosynthetic tensile strength when installed will be effective if the condition is in a state of tension. Provision of initial strain at the time of installation of geosynthetic can strengthen the bond among the aggregates in the asphalt mixture. Geosynthetic tensile strength can help in restraining the resistance of asphalt tensile stress.

In previous studies the initial strain factor of geosynthetic not included as parameters that will affect the performance of asphalt concrete reinforced with geosynthetic. In this article will be presented results of the research, including (1) Effect of the strain on the service life of asphalt concrete layer (2) Effect of the density of the asphalt concrete on modulus of elasticity (3) Effect of geogrid initial strain in the asphalt pavement layer on its ability to resist fatigue due to repetitive loads (4) effect of the location of geogrid in asphalt concrete layer to its ability to resist fatigue due to repetitive loads.

Fatigue is reducing performance of building materials due to receive repeated load even though the same amount of load. Similarly, asphalt pavement materials will be fatigue after receiving the repeated vehicle load. Asphalt mixture is said to be flexible if it has a good long fatigue. Characteristics of asphalt mixtures fatigue is related to the modulus of elasticity. Modulus of elasticity is the ratio of stress to strain when the asphalt mixture receives bending loads.

Asphalt is a visco-elastic material. If the material is received stress, the shape will change. Changes in shape is a function of temperature and loading time [3]. At high temperatures and long loading time, it will be viscous liquids. In contrast to the low temperature and a short loading time, the asphalt will be elastic but brittle. Thus the modulus of elasticity of the asphalt mixture will depend on the temperature and time of loading. The characteristics of the asphalt mixture will also affect the modulus of elasticity. Density will also affect the modulus of elasticity of the asphalt mixture. The instrument used to test the

elasticity modulus of asphalt mixtures in this study is the Beam Fatigue Apparatus. The operating procedures of the tool is in accordance with AASHTO T321-1 [1].

Asphalt concrete mixture used in the study is asphalt concrete wearing course (ACWC) fine graded by the properties of the mixture as in Table 1.

Table 1. The properties of asphalt concrete wearing course

Mixture properties	Test result	Specification
Bitument content (%)	6.7	min. 5.1
Void in the mix (%)	4.6	3.5-5.0
Void in mineral aggregate (%)	19.5	min. 15
Void filled with bitument (%)	77	min. 65
Marshall stability (kg)	2.000	min. 800
Flow (mm)	3.4	min. 3
Marshall quotient (kg/mm)	580	min. 250

As the layers of asphalt concrete reinforcement material used Miragrid GX 60/60 which has a stress strain diagram as Figure 1. Geogrid has a tensile strength of 60 kN/m in longitudinal and transverse directions. The use of geogrid is expected to increase the tensile strength ACWC. Geogrid will effectively strengthen ACWC if the conditions is strained.

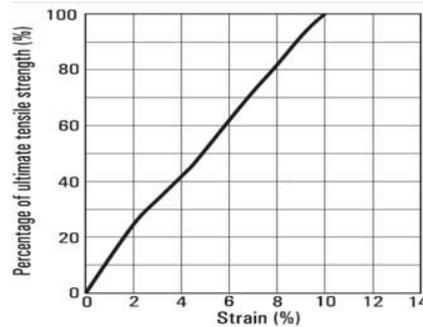


Figure 1: Relation between tensile strength and strain geogrid [8]

## 2. RESEARCH METHODOLOGY

### 2.1. Apparatus

1. Apparatus for making specimen (Figure 2). This apparatus is for making specimen by press system, so that the desired density of specimen can be created. In addition the specimen can also be made in two stages, allowing installation and giving the initial strain of geogrid placed in the asphalt concrete layer. Specimen is asphalt concrete beam with dimension 380 mm length, 63 mm width, and 50 mm thick. Geogrid placed 2 cm from the base of the specimen.
2. Beam Fatigue Test (Figure 3). Apparatus to measure the values of tensile stress, tensile strain, flexural stiffness, modulus of elasticity, and the dissipated energy of the asphalt mixture during receiving the repeated load. These apparatus is equipped with computer that can provide graphs the relationship between the number of loading cycles and the performance of asphalt mixture. This appliance test procedures in accordance with AASHTO T321-1 [1].



Figure 2: Apparatus for making specimen



Figure 3 : Beam Fatigue Apparatus

## 2.2. Procedure

Specimens loaded in 2 places with horizontal spacing 119 mm centre to centre. Load worked repeatedly with the 5-10 Hz frequency. In this test load used frequency of 10 Hz or 10 strokes per second. Load can also be set so as to provide a constant tension or constant tensile strain. This research used the load to provide a constant tensile strain. The parameters measured in this study is the tensile stress, flexural stiffness, modulus of elasticity, and the dissipated energy.

To determine the effect of the amount of load on the durability of asphalt ACWC, the specimen tested with 3 kinds of loading. The amount of loading on the test is not expressed with heavy loads carried on specimen, but expressed with a constant amount of strain that is given to the specimen. The bigger load is done, strain that occurs will be greater. This research used three control strain with the amount of each is 500  $\mu\epsilon$ , 600  $\mu\epsilon$ , and 700  $\mu\epsilon$ . The durability of asphalt mixtures is expressed by the number of loading cycles that cause the mixture flexural stiffness decreased to 50% of the initial flexural stiffness. By these criteria the specimen is considered to have significant decreasing of quality, and the service life has ended [1].

To determine the effect of the asphalt mixture density on the modulus of elasticity, fatigue beam tests performed with various values of specimen density. Modulus of elasticity was measured at 99% density (2.293 gr/cm<sup>3</sup>), 95% (2.20 gr/cm<sup>3</sup>), and 90% (2.08 gr/cm<sup>3</sup>). The tests carried out at a temperature of 25°C.

## 3. RESEARCH RESULTS AND DISCUSSION

### 3.1. Testing Results of ACWC without Geogrid

The results of testing the durability of ACWC as shown in Figure 4. From Figure 4. seen that the greater the strain acting on the ACWC the fewer number of load cycles can be received. The relationship between strain and the number of loading cycles is a linear equation :  $y = -268.39x + 193,599$ , with  $y =$  number of loading cycles, and  $x =$  strain that work in ACWC.

The results of testing the influence of the density on the modulus of elasticity is as shown in Figure 5. Elasticity modulus and density relationships is parabolic equation:  $y = -26,479x^2 + 120,396x - 134,792$ , with  $y =$  modulus of elasticity, and the  $x =$  density of asphalt concrete. The value of the coefficient of determination ( $r^2$ ) = 1. It indicates that the modulus of elasticity of ACWC strongly influenced by the value of density. With a parabolic equation, it means there is an optimum density will result the maximum modulus of elasticity. Figure 5 shown that the value of optimum density is 2.28 gram/cm<sup>3</sup> and the maximum modulus of elasticity of ACWC is 2.100 MPa.

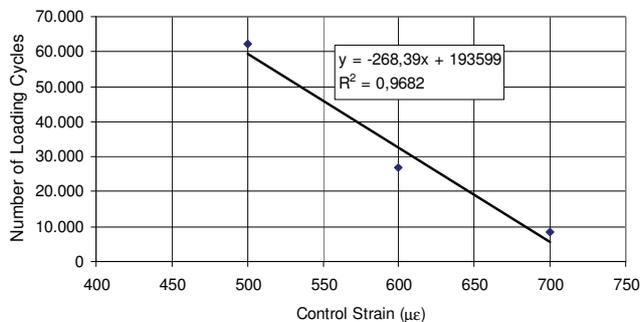


Figure 4 : Influence of strain on number of load cycles

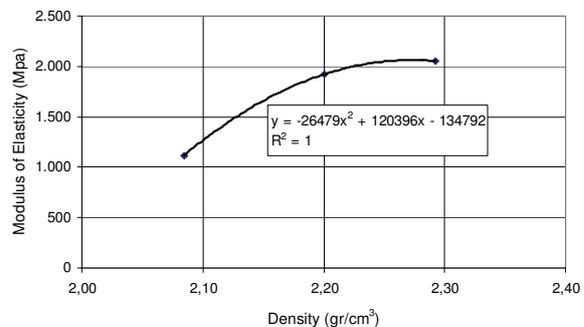


Figure 5 : Influence of density on modulus of elasticity

### 3.2. Fatigue Testing Results of ACWC Reinforced with Geogrid

The results of fatigue testing of ACWC for the control strain 500  $\mu\epsilon$  as shown in Figure 6., while the testing results for the control strain 600  $\mu\epsilon$  as shown in Figure 7. Figure 6 and Figure 7 shows the influence of initial strain and location of geogrid on the number of loading cycles of ACWC has reinforced with geogrid. Initial strain of geogrid 0% is ACWC layer without using geogrid reinforcement.

Both Figure 6. and Figure 7. show that the geogrid able to increase the resilience of the ACWC layer to repeated load. The number of loading cycles ACWC reinforced with geogrid greater than ACWC without geogrid reinforcement. The greater initial strain of geogrid, the number of load cycles can be held ACWC layer also increases. This is due to the additional of initial strain of geogrid will effect the increasing of tensile strength of geogrid that working in ACWC layer. With increasing geogrid tensile strength, the ability to withstand fatigue ACWC layer longer, so that the number of load cycles which can be held by ACWC also increases.

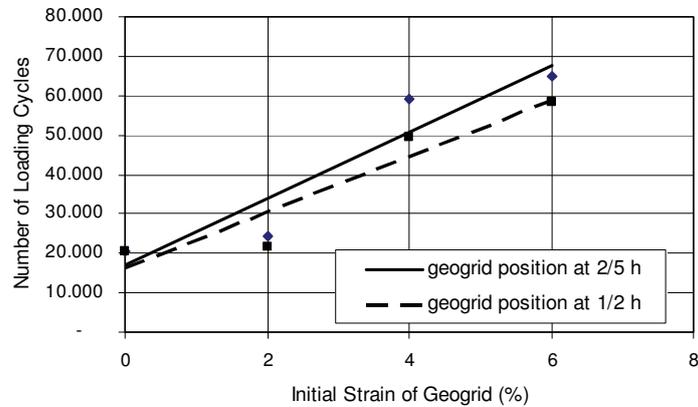


Figure 6: Influence of initial strain of geogrid on number of loading cycles at control strain 500με

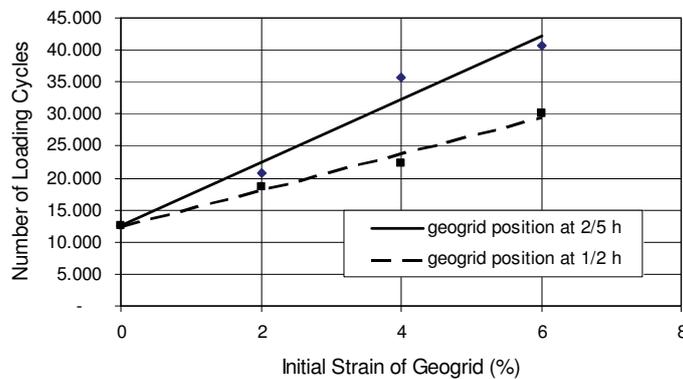


Figure 7: Influence of initial strain of geogrid on number of loading cycles at control strain 600με

The position of geogrid layers also affects reinforcement of geogrid to ACWC. The position of geogrid at 2/5 thick more effectively to give the reinforcement to ACWC layer if compared to the geogrid at 1/2 of a thick layer of ACWC. It's not much different from research results done by Moussa [7] and Khodaii [6]. It's concluded that the position of the geosynthetic reinforcement of asphalt concrete placed at 1/3 thick is the optimum position..

The amount of strain acting on ACWC layer will affect the service life ACWC layer. Strain aligned with the load acting on the lining ACWC. The greater the load acting on the layer, the greater the strain ACWC working on the ACWC layer. Thus automatically increasing the strain suffered by ACWC layer, the service life or number of cycles of load that can be supported by ACWC layer decreases.

Based on regression equations were created, the relationship between initial strain of geogrid and the number of loading cycles that can be retained by ACWC asphalt mixture is linear. In control strain 500 μ ε, equation relationship between initial strain and the number of loading cycles are as follows:

- a.  $y = 8,428x + 16,921$  for the position of geogrid at 2/5 thick, and
- b.  $y = 7,085x + 16,205$  for the position of geogrid at 1/2 thick

While in control strain 600 μ ε, equation relationship between initial strain of geogrid and the number of cycles the track are as follows:

- a.  $y = 4,964.5 x + 12,489$  for geogrid position at 2/5 thick, and
- b.  $y = 2,819.1 x + 12,426$  for geogrid position at 1/2 thick

The variable x is the amount of initial strain of geogrid, while the variable y is number of loading cycles that can be retained by ACWC layer.

From the regression equation obtained, it shows that the position of geogrid at 2/5 thick provide greater reinforcement compared to the geogrid at 1/2 thick. This applies to the control strain 500 με and 600 με .It can be seen from the slope of the

regression equation. The slope for the position of geogrid 2/5 thick greater than the slope for the position of geogrid 1/2 thick, both for the control strain 500  $\mu\epsilon$  and 600  $\mu\epsilon$ .

The layer ACWC receiving 500  $\mu\epsilon$  strain is able to serve a greater number of load cycles than that receiving strain of 600  $\mu\epsilon$ . It can be seen that the slope coefficient of the regression ACWC receiving strain 500  $\mu\epsilon$  larger than that receiving strain 600  $\mu\epsilon$ . This fact is true for both geogrid position at 2/5 thick and the position of 1/2 thick

#### 4. CONCLUSIONS AND RECOMMENDATIONS

##### 4.1. Conclusions

From the results of research carried out on Asphalt Concrete Wearing Course (ACWC) with geogrid reinforcement can conclude the following :

1. The greater strain that occurs in the layer of ACWC, the service life ACWC layer decreases linearly according to the equation  $y = -268.39 x + 193,599$
2. ACWC density affect the properties of the modulus of elasticity according to the parabolic equation  $y = -26,479 x^2 + 120,396 x - 134,792$
3. The greater the initial strain geogrid placed in layers ACWC will linearly enhance the ability of the ACWC layer to resist fatigue due to repetitive loads.
4. Location of geogrid at 2/5 thickness of the base layer provides the ability to support repeated loads greater than the location of geogrid at the middle of the ACWC layer.

##### 4.2. Recommendations

Base on the research results, further research are still needed to refine these research results. These researches include the following:

1. The effect of temperature on the modulus of elasticity of concrete pavement and asphalt concrete ability to support repeated loads.
2. Effect of asphalt concrete reinforcement with other types of geosynthetic on its ability to support repeated loads.
3. Effect of number of tack coat used between two layer of asphalt concrete reinforced with geosynthetic on its ability to support repeated loads.
4. Effect of asphalt concrete reinforced with geosynthetic on its ability to support rutting

#### REFERENCES

- [1]. AASHTO, 2008. "Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Part 2 : Tests." AASHTO, Washington D.C.
- [2]. Austin, R.A. and Gilchrist, A.J.T., 1996, "Enhanced Performance of Asphalt Pavements Using Geocomposites", Geotextiles and Geomembranes 14 pp.175-186, Elsevier Science Limited, Ireland.
- [3]. Brown, S., 1990. *The Shell Bitumen Handbook*. Shell Bitumen U.K.
- [4]. Carver, C., Sprague, C.J., 2000, "Asphalt Overlay Reinforcement", Geotechnical Fabric Report Magazine
- [5]. Hibbeler, R.C., 1999. *Structural Analysis*. Prentice-Hall, Inc., Upper Saddle River, New Jersey.
- [6]. James, G.M., 2004, "Geosynthetic Materials As Asphalt Reinforcement Interlayers : The Southern African Experience", Proceeding of the 8<sup>th</sup> Conference on Asphalt Pavements for Southern Africa (CAPSA'04), Sun City, South Africa
- [7]. Khodaii, A., Fallah, S., Nejad, F.M., 2009, "Effects of Geosynthetics on Reduction of Reflection Cracking in Asphalt Overlays", Geotextiles and Geomembranes, pp.1-8, Elsevier, Miamisburg United States.
- [8]. Moussa, G.K.M., 2003, "The Optimum Location of Geotextile Reinforcement in Asphalt Layers", Alexandria Engineering Journal Vol.42 No.1 pp.103-111, Faculty of Engineering Alexandria University, Egypt.
- [9]. TenCate Miragrid, 2011. *Description of Miragrid Geogrids*. TenCate Geosynthetics Asia Sdn.Bhd., Selangor, Malaysia

# Pile Spacing and Length Effects Due To the Additional Modulus of Sub Grade Reaction of the Nailed-Slab System on the Soft Clay

Anas Puri<sup>a</sup>, Hary Christady Hardiyatmo<sup>b</sup>, Bambang Suhendro<sup>c</sup>, and Ahmad Rifa'i<sup>d</sup>

<sup>a</sup>Department of Civil Engineering, Islamic University of Riau, Pekanbaru 28284  
Doctoral Candidate, Civil Engineering, Gadjah Mada University, Yogyakarta 55281  
Email: anaspuri@yahoo.com

<sup>b</sup>Department of Civil and Environmental Engineering, Gadjah Mada University, Yogyakarta 55281  
E-mail: harychristady@yahoo.com

<sup>c</sup>Department of Civil and Environmental Engineering, Gadjah Mada University, Yogyakarta 55281  
E-mail: bbsuhendro@yahoo.com

<sup>d</sup>Department of Civil and Environmental Engineering, Gadjah Mada University, Yogyakarta 55281  
E-mail: ahmad.rifai@tsipil.ugm.ac.id

## ABSTRACT

The new method to handle the problem of rigid pavement on soft soils has been proposed. It is called nailed-slab system. An advantage of this method is that the system makes the rigid pavement to keep contact with sub grade. Experimental modeling and analytical study have been done for nailed-slab system on soft clay to learn the effects of pile spacing and pile length due to the additional modulus of sub grade reaction. The models are presented as strip section of rigid pavement. The theory of beams on elastic foundation is used to calculate the slab deflection by using equivalent modulus of sub grade reaction  $k'$  then compared also with 2D numerical model developed in Plaxis 8.5 finite element analysis. Result show that the nailed-slab system tends to be stiffer by closer the pile spacing. The additional modulus of sub grade reaction tends to increase by decreasing the pile spacing. Pile length affects also the stiffness of the nailed-slab system. Longer the pile length increases the depth of reinforced soil. It gains stiffness of the nailed-slab system and reflects higher additional modulus. Significant effect is gained for centric loads.

**Keywords:** rigid pavement, soft clay, Nailed-slab System, modulus of sub grade, pile spacing, pile length, deflection.

## 1. INTRODUCTION

In order to gain the efficiency of construction implementation, Hardiyatmo [1] proposed the changing of the shell of fondasi cakar ayam (hen's claw foundation) by short-friction piles. The piles are installed under the slab. The slab has double functions: as pavement structures and all at once as pile cap. It is called Nailed-slab System. This method is utilized to apply in reinforcing the rigid pavement slab. The rigid pavement slab is nailed to the sub grade by short piles. And the composite system is made which consist of slab, piles, and soils surrounding the piles and slab. The installed piles under the slab increase the slab stiffness and make the slab keeps contact with the soils [2]. Hence, the height of slab is decreased. The decreasing of slab height can reduce the weight of the structure and will be beneficial for soft soils [3].

Experimental modeling and analytical study have been done for soft soils ([3], [1], [4], [5], [6], [7], [8], [2], [9], [10]). Deflection analysis of a nailed-slab by using equivalent modulus of sub grade reaction has been done by Hardiyatmo ([4], [5]) and Puri, et.al. ([9], [10]). This modular is the cumulative of modulus of sub grade reaction from plate load test ( $k$ ) and additional modulus of sub grade reaction due to pile installing ( $\sigma k$ ). Reduction of pile resistance is one of aspects that need to be considered in determining  $\sigma k$ . It is included in the relative displacement between the pile and soil. Hardiyatmo [5] used the additional modulus of sub grade reaction based on the relative displacement between the piles and soil and considered the reduction of pile resistance. Since the determining of these parameters for design purpose are difficult, Puri, et.al. [10] proposed a new approach where pile friction resistance is fully mobilized and the tolerable settlement is considered. Perhaps, more ease in designing the Nailed-slab System will be obtained. Puri, et. al. [10] concludes that the deflection analysis of the nailed-slab based on the additional modulus of sub grade reaction which considered the tolerable settlement, resulting in deflection fines in good agreement with observed deflections. Designing of the Nailed-slab System based on an analysis of the one row pile will produce a safe design. It is caused by higher pile group resistance and increases in slab stiffness according to multiple-row of piles installation. In practice, the Nailed-slab System would be constructed by multiple row piles.

This paper is aimed to discuss the effect of pile spacing due to the additional modulus of sub grade reaction. The experimental was conducted by model tests of one row pile nailed-slab system.

## 2. ADDITIONAL MODULUS OF SUB GRADE REACTION

The analytical approach in determining equivalent modulus of sub grade reaction ( $k'$ ) is given as follows ([5], [7], [9], [10]):

$$k' = k + \Delta k \quad (1)$$

Where  $k$  : modulus of sub grade reaction from plate load test ( $\text{kN/m}^3$ );  $\sigma k$  : additional modulus of sub grade reaction due to pile installing ( $\text{kN/m}^3$ ).

Fig. 1 shows the soil bearing pressure under an individual nailed-slab system. Hardiyatmo [5] proposed Eq. (2) in determining the additional modulus of sub grade reaction ( $\sigma k$ ). The relative displacement between pile and soil is considered.

$$\Delta k = \frac{\delta_0 A_s}{\delta^2 s^2} (a_d c_u + p_0 K_d \tan \phi_d) \quad (2)$$

Where  $\delta_0$  : relative displacement between pile and soil (m);  $\delta$  : deflection of surface of plate (m);  $A_s$  : surface area of pile shaft ( $\text{m}^2$ );  $s$  : pile spacing (m);  $a_d$  : adhesion factor (non-dimensional);  $c_u$  : undrained cohesion ( $\text{kN/m}^2$ );  $p_0$  : average effective overburden pressure along of pile ( $\text{kN/m}^2$ );  $K_d$  : coefficient of lateral earth pressure in pile surroundings (non-dimensional);  $\phi_d$  : soil internal friction angle (degree). The relation between  $\delta_0/\delta$  and slab deflection from pile model with a 4 cm diameter is also given by Hardiyatmo [5].

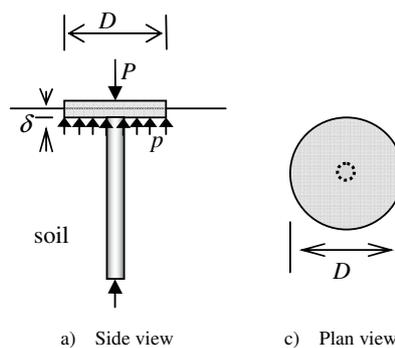


Fig. 1. Soil bearing pressure under individual nailed-slab [5].

In case of nailed-slab designing, the relative displacement between pile and soil is difficult to define. Puri, et.al. [10] obtained Eq. (3) to define the additional modulus of sub grade reaction which considered the tolerable settlement of rigid pavement slab ( $\sigma_a$ ). This approach is called Modified Hardiyatmo method.

$$\Delta k = \frac{0.4 f_s A_s}{\sigma_a A_{ps}} \quad (3)$$

Where  $\sigma_a$  : tolerable settlement of rigid pavement slab (m);  $f_s$  : ultimate unit friction resistance of pile shaft ( $\text{kN/m}^2$ );  $A_s$  : surface area of pile shaft ( $\text{m}^2$ );  $A_{ps}$  : area of plate zone which supported by single pile ( $\text{m}^2$ ). Nailed-slab resting on soft soils should consider the ignored end bearing resistance of pile. Ultimate unit friction resistance of the pile shaft in saturated clay is expressed by

$$f_s = a_d c_u \quad (4)$$

Where  $a_d$  : adhesion factor (non-dimensional);  $c_u$  : undrained cohesion ( $\text{kN/m}^2$ ).

## 3. TESTING INVESTIGATION

### 3.1. Soil and Nailed-slab Models Tests

Soft clay parameters are given in Puri, et.al. [9] and also published test result of one row nailed-slab without a vertical barrier. The nailed-slab model with one row of piles consists of 6 piles, 120 cm × 20 cm × 3 cm slab, 20 cm pile spacing ( $s/d = 5$ ), pile diameter  $d = 4$  cm, and pile length  $L_p = 40$  cm. The spacing between edge pile and the end of slab is a half of pile spacing ( $a=s/2$ ). The loading test set up and models of concrete slab supported by piles are shown in Fig. 2. Slabs and piles are made by reinforced concrete. Slab reinforcement was wire mesh with 3 mm-wire diameters, and 5 cm × 5 cm meshing. Pile models were reinforced by 3mm-aluminium wire diameter. Model scale for geometry was 1 : 5. Piles and slabs were connected monolithically. Other model tests were also conducted by different in pile spacing. Table 1 shows the variations in pile spacing and length including the model test of Puri, et.al [9]. All models are presented as strip section of the rigid pavement.

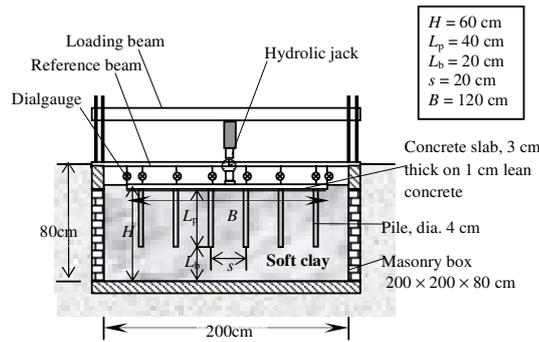


Fig. 2. Schematic set-up of loading test on Nailed-slab System [9].

Puri, et. al. [10] reported that the slabs and piles have the modulus of elasticity  $E_c = 17,000$  MPa. Soft clay has a 15,000 kPa/m modulus of sub grade reaction from plate load test with 30 cm in plate diameter. Lean concrete has a 71,100 kPa/m modulus of sub grade reaction from plate load test with 20 cm in plate diameter. These moduli of sub grade reaction was corrected due to the shape of the slab according to Das [11], and resulted in 16,250 kPa/m and 51,350 kPa/m for soft clay and lean concrete respectively [10]. For homogenous soft clay, correction due to depth of the foundation is not required. The steps of testing were described in Puri, et.al. ([9], [10]). The load was worked on the slab through a circular steel plate with 6.0 cm in diameter and 1.0 cm in thickness. Load positions were on the point A (centric load) and point B (edge load) as shown in Fig. 3a but they worked in different loading time.

Table 1: Variations of pile spacing and length for one-pile row Nailed-Slab models under the 120 cm × 20 cm × 3 cm Slab

Models	Number of Piles	Pile Spacing, $s$ (cm)	$s/d$	Pile Length, $L_p$ (cm)
1	12	10	2.5	40
2#	6	20	5.0	40
3	3	30	7.5	40
4	6	20	5.0	20

# Puri, et.al. [9].

### 3.2. Analysis of Deflections

The theory of beams on elastic foundation (BoEF) can be used to calculate the deflections due to the load acting on plate-supported piles ([4], [5], [8], [9], [10]). The deflection of the finite length of the beam resting on an elastic foundation due to a single concentrated load at any point by Hetenyi [12] was used in the analysis where the  $k$  was replaced by  $k'$  for analysis of nailed-slab system. The small distributed load was simplified by concentrated load. In the 2D finite element analysis (FEM), soft soil model was employed in the study. Likewise, the soil and material properties (model plate and pile) adopted in the model are shown in Table 2 and 3 respectively. Fig 3a shows a used mesh in plain strain FEM analysis and Fig 3b is one of deformed shape output.

Table 2: Soil properties in FEM analysis input

Parameter	Name	Clay	Unit
Material model	Model	Soft soil	-
Material behavior	Type	Undrained	-
Soil behavior under phreatic level	$\gamma$	17.00	kN/m <sup>3</sup>
Young's modulus	$E$	1,870.00	kPa
Poisson's ratio	$\nu$	0.35	-
Cohesion	$c$	21.00	kPa

Friction angle	$\phi$	1.00	°
Dilatancy angle	$\psi$	0.00	°
Initial void ratio	$e_0$	0.92	-
Modified compression index	$\lambda^*$	0.05	-
Modified swelling index	$\kappa^*$	0.01	-
Interface strength ratio	$R$	0.80	-

Table 3: Model slab and pile properties in FEM analysis input

Parameter	Name	Slab			Pile		Unit
					$L_p = 20\text{cm}$	$L_p = 40\text{cm}$	
Material model	Model	Plate			Plate	Plate	-
Material behavior	Type	Elastic			Elastic	Elastic	-
Normal stiffness	$EA$	122,400.00			27,200.00	54,400.00	kN/m
Flexural rigidity	$EI$	9.18			3.63	7.25	kNm <sup>2</sup> /m
Equivalent thickness	$d$	0.03			0.04	0.04	m
Weight	$w$	0.70			0.92	0.92	kNm/m
Poisson's ratio	$\nu$	0.20			0.20	0.20	-

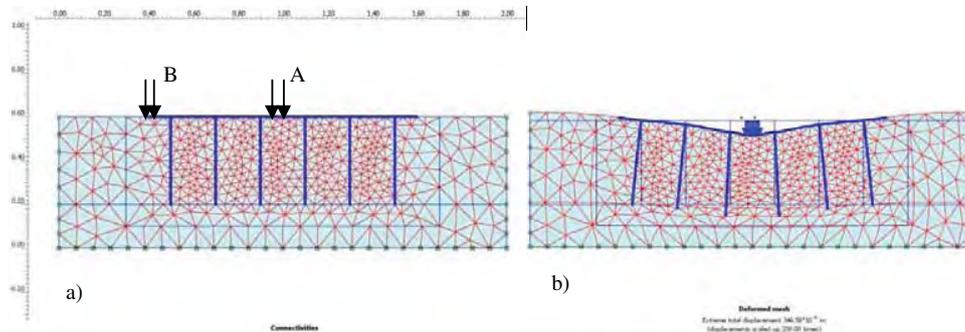


Fig. 3. Used meshes in FEM analysis of plain strain: a). used meshes, b). deformed shape output.

## 4. RESULTS AND DISCUSSION

### 4.1. Loading Test Results

Distribution comparisons of deflection along the slab of a one-pile row nailed-slab system with different pile spacing are shown in Fig. 4. The others loads, the deflections have a similar behavior. The slab surface of Model 3 ( $s=30\text{ cm}$ ) was cracked under edge load  $P = 1.347\text{ kN}$ . The crack of slab surface was occurred over the outer of edge pile. Pile spacing affects the stiffness of the nailed-slab system; more close the pile spacing, stiffer the nailed-slab system and lower the deflections. The slab tends to be critical under edge loading. It is concluded that the deflection of the slab for edge loadings are to be more than 2 times the deflection of the center loadings. Generally, there is no significant uplift of the slab end. It means that the installed piles tend to keep the slab contact with the soil. The capability of the nailed-slab system is higher due to center loading than edge loading.

Distribution comparisons of deflection along the slab of a one-pile row nailed-slab system with different pile length are shown in Fig.5. This is between Model 2 and 4. The other loads, the deflections have a similar behavior. The nailed-slab system with longer pile has lower deflection. It is caused by increase in stiffness of system due to pile installation under the slab coincide with the increase of soil depth which reinforced by piles.

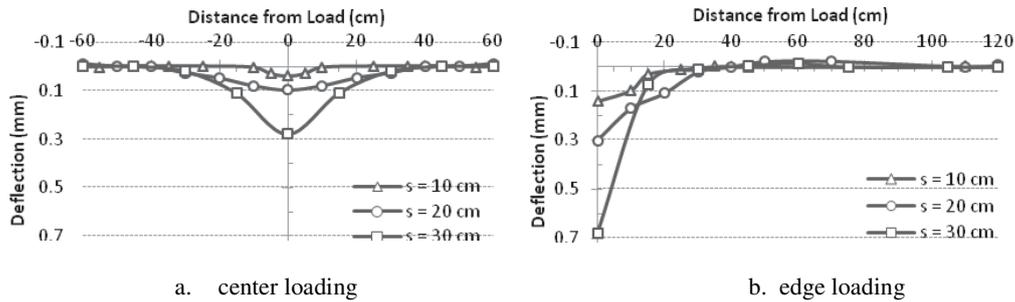


Fig. 4. Distribution of deflection along the slab of nailed-slab system in different pile spacing for  $P = 1.347$  kN.

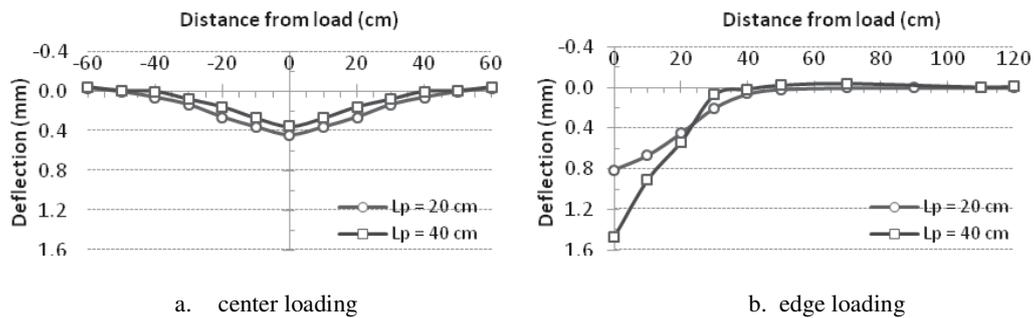


Fig. 5. Distribution of deflection along the slab of nailed-slab system in different pile length for  $P = 2.694$  kN.

#### 4.2. Pile Spacing Effects Due To Additional Modulus of Sub Grade Reaction

Additional and equivalent modulus of sub grade reaction due to pile installation was calculated by (2), and (3) for Hardiyatmo method and Modified Hardiyatmo method respectively, and results are shown in Table 5 and 6. The observed maximum deflections were taken as tolerable settlements ( $\delta_a$ ) in Modified Hardiyatmo method. Modulus of sub grade reaction for lean concrete is 51,350 kPa/m. According to Table 5, it is shown that  $\sigma k$  of Hardiyatmo method relatively constant eventhough the different in loading type. Otherwise, the Modified Hardiyatmo method (Table 6) the  $\sigma k$  decreases by increasing the displacement. These values tend to be lower for edge loadings. Pile spacing affects the  $\sigma k$  for all loading types. The  $\sigma k$  increases by decreasing the pile spacing. This is caused by decreasing the slab zone which supported by single pile, while the pile shaft area remains constant. The  $k'$  values in Table 5 and 6 are used to calculate the nailed-slab deflection by using BoEF. Both tables show also the results of calculated deflection.

Calculation results of deflection are also figured by Fig. 6 and 7 for center loading and edge loading respectively. Good results are obtained in the sense that the calculated settlement is in good agreement with observation. In case of edge loading, calculated settlement tends to be over-estimated at any pile spacing. Puri, et.al. ([9], [10]) and Hardiyatmo [5] also found that the calculated settlement for edge loading tends to be over-estimated. In case of finite element analysis, results show that the deflections tend to be under estimated for higher pile spacing. Finite element results are not in good agreement for edge loadings. Higher pile spacing tends to decrease the stiffness of this system. Hence, higher deflection is occurred.

Table 5: Additional modulus ( $\Delta k$ ) based on Hardiyatmo method and equivalent modulus ( $k'$ ) of sub grade reaction for  $L_p = 40$  cm

A. $s = 10$ cm							
Loading Type	Loads, P (kN)	Observed $\delta$ (mm)	$\delta/\delta_0$	$\Delta k \times 10^3$ (kPa/m)	$k' \times 10^3$ (kPa/m)	Calculated $\delta$ (mm)	Deference of Deflection (%)
Center	2.694	0.1	8.59	93.32	144.67	0.26	159.86
	1.347	0.04	20.71	96.81	148.16	0.13	218.95
	1.010	0.02	40.28	99.53	150.88	0.09	371.70
Edge	2.694	0.62	1.49	86.75	138.10	1.07	72.47
	1.347	0.14	6.22	92.07	143.42	0.25	81.60
	1.010	0.09	9.51	93.72	145.07	0.19	109.47
B. $s = 20$ cm							
Loading	Loads, P	Observed	$\delta/\delta_0$	$\Delta k \times 10^3$	$k' \times 10^3$	Calculated	Deference of

Type	(kN)	$\delta$ (mm)	(kPa/m)	(kPa/m)	$\delta$ (mm)	Deflection (%)	
Center	2.694	0.35	2.58	22.19	73.54	0.44	25.56
	1.347	0.10	8.87	23.36	74.71	0.22	124.44
	1.010	0.07	12.53	23.70	75.05	0.16	140.22
Edge	2.694	1.47	0.65	20.95	72.30	1.74	18.19
	1.347	0.30	2.99	22.33	73.68	0.86	185.49
	1.010	0.20	4.42	22.69	74.04	0.64	219.93

C.		$s = 30 \text{ cm}$					
Loading Type	Loads, P (kN)	Observed $\delta$ (mm)	$\delta/\delta_0$	$\Delta k \times 10^3$ (kPa/m)	$k' \times 10^3$ (kPa/m)	Calculated $\delta$ (mm)	Deference of Deflection (%)
Center	2.694	0.83	1.13	9.53	60.88	0.51	-38.55
	1.347	0.28	3.20	9.95	61.30	0.24	-12.53
	1.010	0.20	4.42	10.09	61.44	0.19	-5.08
Edge	1.347	0.68	1.36	9.60	60.95	0.99	45.22
	1.010	0.37	2.45	9.84	61.19	0.74	99.52

Table 6: Additional modulus ( $\Delta k$ ) based on Modified Hardiyatmo method and equivalent modulus ( $k'$ ) of sub grade reaction for  $L_p = 40$

A. $s = 10 \text{ cm}$							
No.	Loading Type	Loads, P (kN)	Observed $\delta_a$ (mm)	$\Delta k \times 10^3$ (kPa/m)	$k' \times 10^3$ (kPa/m)	Calculated $\delta_a$ (mm)	Deference of Deflection (%)
1	Center	2.694	0.10	320.73	372.08	0.13	27.15
		1.347	0.04	801.83	853.18	0.04	0.00
		1.010	0.02	1,603.66	1,655.01	0.02	0.00
2	Edge	2.694	0.62	51.73	103.08	1.33	114.76
		1.347	0.14	229.09	280.44	0.31	124.49
		1.010	0.09	356.37	407.72	0.18	97.76

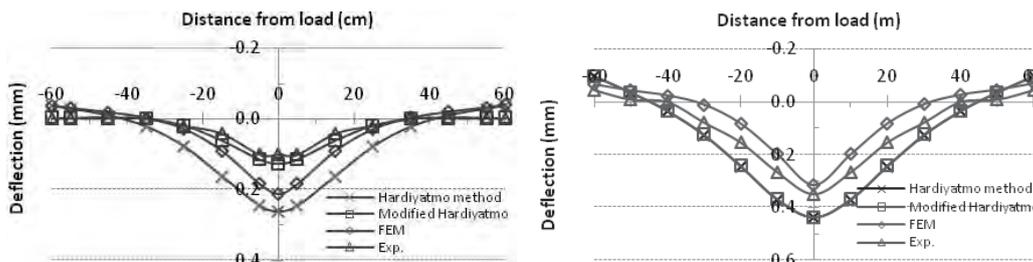
  

B. $s = 20 \text{ cm}$							
No.	Loading Type	Loads, P (kN)	Observed $\delta_a$ (mm)	$\Delta k \times 10^3$ (kPa/m)	$k' \times 10^3$ (kPa/m)	Calculated $\delta_a$ (mm)	Deference of Deflection (%)
1	Center	2.694	0.35	22.91	74.26	0.44	24.61
		1.347	0.10	82.92	134.27	0.14	42.29
		1.010	0.07	118.79	170.14	0.09	27.51
2	Edge	2.694	1.47	5.45	56.80	2.08	41.64
		1.347	0.30	26.73	78.08	0.82	173.34
		1.010	0.20	40.09	91.44	0.55	173.12

C. $s = 30 \text{ cm}$							
No.	Loading Type	Loads, P (kN)	Observed $\delta_a$ (mm)	$\Delta k \times 10^3$ (kPa/m)	$k' \times 10^3$ (kPa/m)	Calculated $\delta_a$ (mm)	Deference of Deflection (%)
1	Center	2.694	0.83	4.29	55.64	0.55	-34.02
		1.347	0.28	12.73	64.08	0.24	-12.53
		1.010	0.20	17.82	69.17	0.17	-13.55
2	Edge	1.347	0.68	5.24	56.59	1.04	53.53
		1.010	0.37	9.63	60.98	0.74	100.04

Analysis results from Modified Hardiyatmo method are better than results from Hardiyatmo method in predicting the nailed-slab deflections. The advantage of the Modified Hardiyatmo method is more practical for designing purposes.



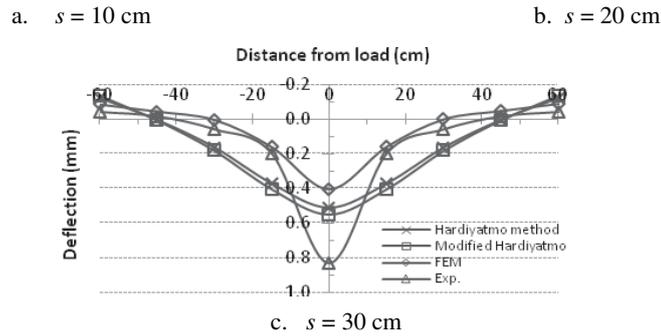


Fig. 6. Distribution of predicted deflection of nailed-slab for center loadings ( $P= 2.694$  kN).

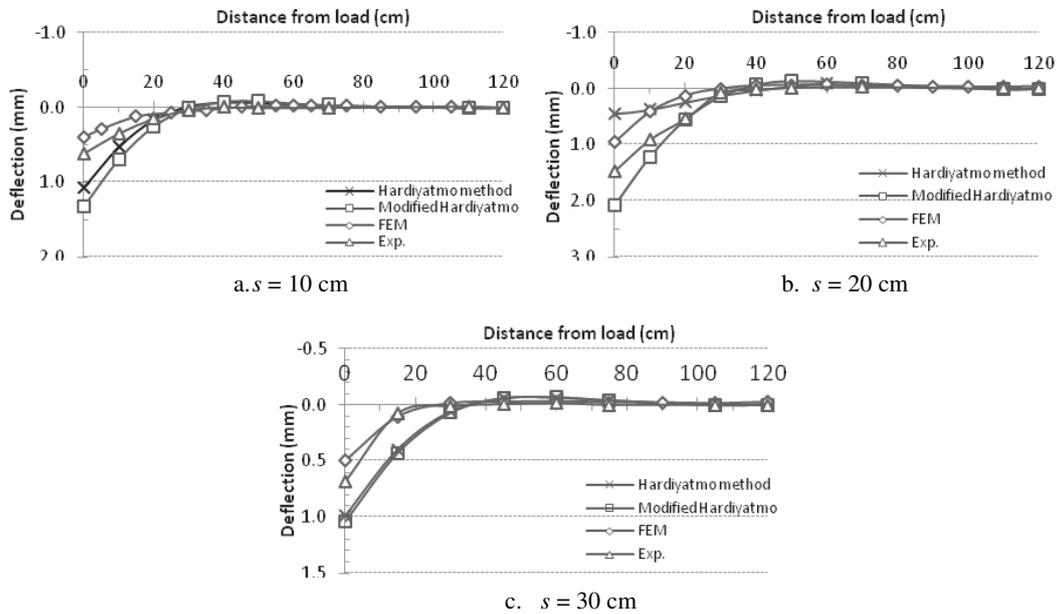


Fig. 7. Distribution of predicted deflection of nailed-slab for edge loadings ( $P= 2.694$  kN, except for  $s = 30$  cm  $P= 1.347$  kN).

### 4.3. Pile Length Effects Due To Additional Modulus of Sub Grade Reaction

Additional and equivalent modulus of sub grade reactions due to 20 cm pile length are shown in Table 7 and 8 including the calculated settlements. It is shown that  $k'$  and  $\sigma k$  relatively constant for Hardiyatmo method and tend to decrease by increasing displacement for Modified Hardiyatmo method. According to results from Modified Hardiyatmo method, these values tend to be lower for edge loading. Good agreement results find between calculated and observed deflections (Fig. 8). While the calculated deflections for edge loadings tend to be over-estimated. The nailed-slab which used longer pile is stiffer then shorter pile. In case of FEM results, the deflections tend also to be under estimated for edge loadings.

Table 7: Additional modulus ( $\Delta k$ ) based on Hardiyatmo method and equivalent modulus ( $k'$ ) of sub grade reaction for  $L_p = 20$  cm;  $s/d = 5$

Loading Type	Loads, P (kN)	Observed $\delta$ (mm)	$\delta/\delta_0$	$\Delta k \times 10^3$ (kPa/m)	$k' \times 10^3$ (kPa/m)	Calculated $\delta$ (mm)	Deference of Deflection (%)
Center	3.367	0.70	1.33	10.79	62.14	0.63	-10.32
	2.694	0.44	2.07	10.99	62.34	0.50	13.77
	1.684	0.22	4.03	11.30	62.65	0.31	41.68
Edge	2.694	0.82	1.14	10.72	62.07	1.95	137.57
	1.684	0.37	2.45	11.07	62.42	1.21	227.73

Table 8: Additional modulus ( $\Delta k$ ) based on Modified Hardiyatmo method and equivalent modulus ( $k'$ ) of sub grade reaction for  $L_p = 20$  cm;  $s/d = 5$

No.	Loading Type	Loads, $P$ (kN)	Observed $\delta_a$ (mm)	$\Delta k \times 10^3$ (kPa/m)	$k' \times 10^3$ (kPa/m)	Calculated $\delta_a$ (mm)	Dereference of Deflection (%)
1	Center	3.37	0.71	5.65	57.00	0.67	-5.33
		2.69	0.44	9.11	60.46	0.51	16.38
		1.68	0.22	18.22	69.57	0.29	30.44
2	Edge	2.69	0.82	4.89	56.24	2.10	155.84
		1.68	0.37	10.84	62.19	1.22	228.68

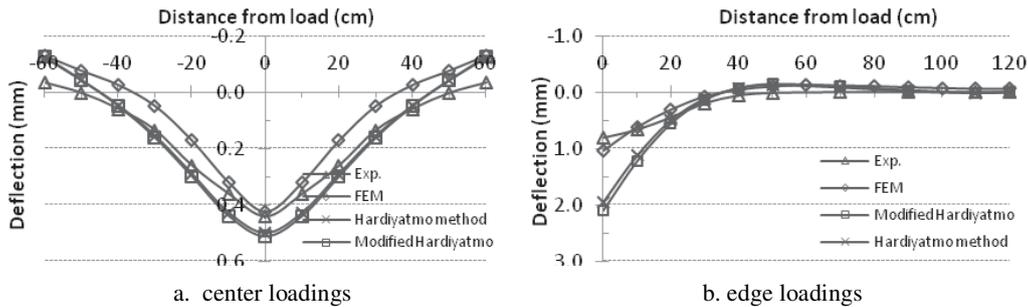


Fig. 8. Predicted distribution of deflection of nailed-slab with  $L_p = 20$  cm ( $P = 2.694$  kN).

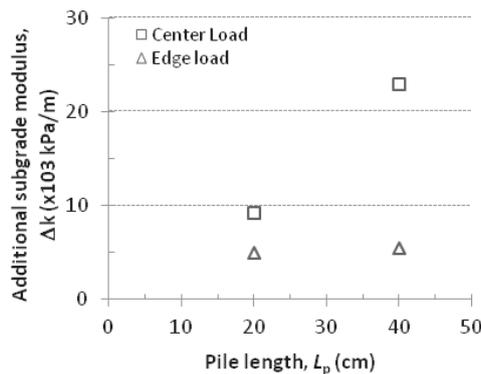


Fig. 9. Pile length effects due to  $\Delta k$  at  $P = 2.694$  kN.

Fig. 9 shows the increasing of  $\sigma k$  due to the increasing of pile length at  $P = 2.694$  kN. The other load intensities have similar trend. The  $\sigma k$  tends to increase by increasing the pile length. Increasing in pile length is affected significantly for center loading. This is caused by increasing the pile shaft areas, while the slab zone supported by single pile remains constant. Yet, increasing in pile length is affected less significant for edge loading. It is caused by the end of slab was acted as a cantilever slab, even though the pile length is increased.

## 5. CONCLUSION

The observations and analysis on the deflection of the Nailed-slab System model have been performed. The effects of pile spacing and pile length to the additional sub grade reaction modulus ( $\Delta k$ ) were analyzed. Pile spacing affects the stiffness of the Nailed-slab System; more close pile spacing, stiffer the Nailed-slab and lower the deflections. The slab tends to be critical under the edge loading. The additional modulus of sub grade reaction tends to increase by decreasing the pile spacing. This is caused by decreasing the slab zone which supported by single pile, while the pile shaft area of the single pile remains constant. Both Hardiyatmo method and Modified Hardiyatmo method can well predict the slab deflections. Good results are obtained in the sense of that the calculated settlement is in good agreement with observation. The Modified Hardiyatmo method is more practical.

Increasing in pile length is affected significantly to reduce the slab deflection under the center loadings, however pile length is affected less significant for edge loading. This paper will contribute to geotechnics research focusing on construction on soft soil.

## ACKNOWLEDGMENT

The author would like to give acknowledgment to all those involved in the project, especially to Prof. N. Yasufuku, and R. Ishikura, Ph.D. for their valuable advice.

## REFERENCES

- [1] Hardiyatmo, H.C., Nailed-slab System for Reinforced Concrete Slab on Rigid Pavement, *Proc. of National Seminar on Appropriate Technology for Handling Infrastructures*, MPSP JTSL FT UGM., Yogyakarta, 2008, pp. M-1—M-7.
- [2] Puri, A., Hardiyatmo, C. H., Suhendro, B., and Rifa'i, A., Experimental Study on Deflection of Slab which Reinforced by Short Friction Piles in Soft Clay, *Proc. of 14<sup>th</sup> Annual Scientific Meeting (PIT) HATTI*, Yogyakarta, 10-11 February, 2011a, pp. 317-321.
- [3] Hardiyatmo, H.C., and Suhendro, B., Pile Foundation with Thin Pile Cap as an Alternative to Solve Problems of Building on Soft Soils, *Report of Competitive Grant Research of Higher Education*, Institute for Research and Community Service, Gadjah Mada University, Yogyakarta, 2003.
- [4] Hardiyatmo, H.C., Method to Analyze the Slab Deflection by Using Equivalent Modulus of Sub Grade Reaction for Flexible Slab Structure, *Dinamika Teknik Sipil*, Vol.9 No.2, 2009, pp. 149-154.
- [5] Hardiyatmo, H.C., Method to Analyze the Deflection of the Nailed Slab System, *IJCEE-IJENS*, Vol 11. No. 4, 2011, pp. 22-28.
- [6] Nasibu, R., Study on Modulus of Sub Grade Reaction Due to Effect of Pile Attached Under Plate (Loading Test on Fullscale), *Master Theses*, Graduate Program of Engineering, Gadjah Mada University, Yogyakarta, 2009.
- [7] Dewi, D.A., Study on Effect of Single Pile Due to the Value of Equivalent Modulus of Sub Grade Reaction from Full-scale Loading Tests, *Master Theses*, Graduate Program of Engineering, Gadjah Mada University, Yogyakarta, 2009.
- [8] Taa, P.D.S., Effects of Installation of Group Pile Due to Slab Uplift of Nailed-slab Resting on Expansive Sub Grade, *Master Theses*, Graduate Program of Engineering, Gadjah Mada University, Yogyakarta, 2010.
- [9] Puri, A., Hardiyatmo, H.C., Suhendro, B., and Rifa'i, A., Contribution of Wall Barrier to Reduce the Deflection of Nailed-Slab System in Soft Clay, *Proc. of 9<sup>th</sup> Indonesian Geotech. Conf. and 15<sup>th</sup> Annual Scientific Meeting (KOGEI IX & PIT XV) HATTI*, Jakarta, 7-8 December, 2011b, pp. 299-306.
- [10] Puri, A., Hardiyatmo, H.C., Suhendro, B., and Rifa'i, A., Determining Additional Modulus of Sub Grade Reaction Based on Tolerable Settlement for the Nailed-slab System Resting on Soft Clay, *IJCEE-IJENS*, Vol. 12 No. 3, 2012, pp. 32-40.
- [11] Das, B.M., *Principles of Foundation Engineering*, 7th ed., Engage Learning, 2011.
- [12] Hetenyi, M., *Beams on Elastic Foundation: Theory with applications in the fields of civil and mechanical engineering*, The University of Michigan Press, Ann Arbor, 1974.

# INFLUENCE OF SAND ADDITION ON EXPANSIVE CLAY TO CBR AND SWELLING POTENTIAL VALUES

Putera Agung, MA<sup>a</sup>, Sutikno<sup>b</sup>

<sup>a</sup>Civil Engineering Department of State Polytechnic of Jakarta (PNJ) – UI Campus, Indonesia  
E-mail: putera\_agung2002@yahoo.com

<sup>b</sup>Civil Engineering Department of State Polytechnic of Jakarta (PNJ) – UI Campus, Indonesia  
E-mail: tsumomihardjo@yahoo.com

## ABSTRACT

*Expansive soil is one of problems of soil mechanic and always found on civil engineering issues since they always destruct on building construction. Expansive soils have a large swelling potential. Expansive soil shows the behavior of extremely stiff soil in dry condition, however particle bonds of soil grain will be decomposed when they submerged by the water. This paper presents the study results performed at laboratory works on expansive soil from Cikarang Estate, Bekasi area with sand fraction of 0%; 10%; 20%; 25%; and 30%. CBR values from standard test can increase caused by sand addition of 25% or more. Generally, swelling potential can decrease with sand addition of 30% or more.*

**Keywords:** expansive soil, sand fraction, CBR, swelling potential

## 1. INTRODUCTION

Expansive soils are found extensively in tropical areas, likes Indonesia. The presence of expansive soils greatly affects the construction activities in many parts of Indonesia, especially around of the big city of Jakarta. More and more expansive soil regions are being discovered each year with an increase in the amount of constructional activities, particularly in the underdeveloped nations. These soils are characterized by the presence of a large proportion of highly active clay minerals of the montmorillonite group which are responsible for the pronounced volume change capability of the soils. The expansive soils are distributed geographically very widely, covering large areas.

Jakarta as the capital city and economic center makes this town becoming increasingly crowded, so that Governor of Jakarta launches a new program that Megapolitan city concept. Integration between government of Jakarta and local government around of this town to solve the existing problems, because of problems in Jakarta is not only from Jakarta but also from the area around Jakarta as urbanization increases. Economic growth is distributed around of the city of Jakarta ((Bogor, Depok, Tangerang, Bekasi and Cianjur or they called as Bodetabekjur area) to reduce urbanization. Good infrastructure is required to encourage the economic growth; however it was not easy to achieve the ideal condition.

Development of economic activity center, such as industrial estate area consists of many factories, real estate for housing and transportation infrastructure at Cikarang – Bekasi area finds some obstacles since soil foundation is expansive clay soil type. Expansive soil is one of the problems in the infrastructure development. Mitigation of the effects of expansive clay on structures built in areas with expansive clays is a major challenge in geotechnical engineering. Expansive clay has a large swelling potential, expansive clays are soils that expand when water is added, and shrink when they dry out. Expansive soil will also exert pressure on the vertical face of a foundation, basement or retaining wall resulting in lateral movement. Shrink-swell soils which have expanded due to high ground moisture experience a loss of soil strength or “capacity” and the resulting instability can result in various forms of foundation problems and slope failure. Expansive soil should always be a suspect when there is evidence of active foundation movement.

Recently, there are a lot of methods used to defend expansive soil problem, these are: chemical stabilization by cement; lime or salt treated, beside the other of mechanical stabilization method. One of methods to prevent expansive soil problem performed by this research is to design soil foundation improvement using addition of sand material. Paper focuses on the effects of mixing sand with some measure of the value of CBR and swelling potential of expansive soil is developed by several tests in laboratory models. Disturbed samples were taken from the area Cikarang Estate, Bekasi area. Compaction testings were performed by using two methods, standard and modified compaction method. Sand addition is expected to reduce the swelling potential at study area. Stabilization effect is focused on CBR value and swelling potential.

## 2. CHARACTERISTICS OF EXPANSIVE CLAY SOILS OF CIKARANG ESTATE, BEKASI AREA

Undisturbed and disturbed samples were taken from Cikarang eastate area (Figure 1). From Figure 1, it can be seen that generally soil type from alluvial to hydromorf, with a little fraction of podsolis and latosol soil types, which colours of soil were dominantly grey; brown; yellow; and red. Characteristics of undisturbed and disturbed samples are shown in Table 1.

Soil classification from USCS identified undisturbed samples from Cikarang Estate, Bekasi area is CH (clay of high plasticity, fat clay). Undisturbed samples condition shows water content of 47.8 % and specific gravity of 2.62. Liquid limit; plastic limit; and plasticity index are 103.3%; 40.9%; and 62.4%, respectively. Clay fraction is more than 40% and activity (A) value is around 2.1. From X-ray diffraction for clay mineralogy is obtained value of 34% fraction of montmorillonite (Table 2). Holtz and Gibbs (1956); Seed & Chan (1959); Seed et al (1962); Woodward & Lundgren (1963) Chen (1975, 1988) show that degree of expansion of undisturbed samples from study area has a very high soil expansivity and swelling values.

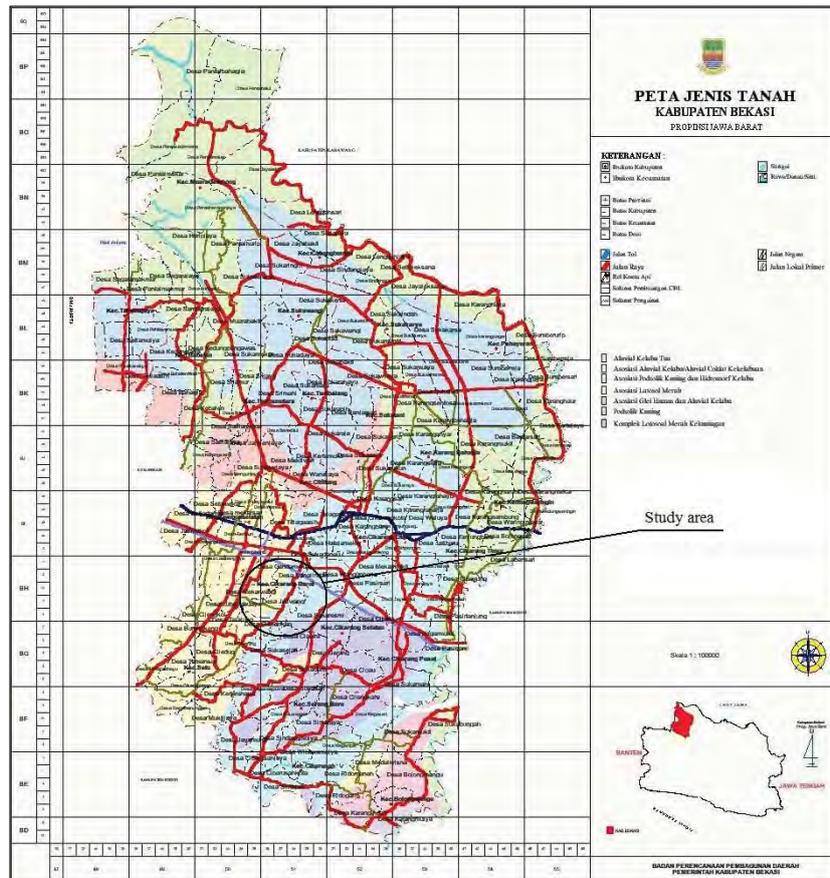


Figure 1. Locations of undisturbed and disturbed samples based on the Peta Jenis Tanah Kabupaten Bekasi (Source: Badan Perencanaan Pembangunan Daerah Kabupaten Bekasi, 2005)

Tabel 1. Summary of soil properties from study area

No.	Soil properties	Results
1.	Water content (w) (%)	47.8 – 48.5
2.	Weight volume ( $\gamma_m$ ) (gr/cm <sup>3</sup> )	1.8 – 1.9
3.	Specific gravity ( $G_s$ )	2.62 – 2.63
4.	Liquid limit (LL) (%)	102.4 – 104.2
5.	Plastic limit (PL) (%)	39.2 – 42.6
6.	Plasticity index (PI) (%)	61.6 – 63.2
7.	Shrinkage limit (SL) (%)	22.2 – 25.9
8.	Sieve analysis (% passed of No. 200)	48.3 – 58.6 (clay)
9.	Hydrometer analysis (% of diameter < 0.002 mm)	58.3 – 78.3 (clay)
10.	Activity (A)	1.6 – 2.0

Table 2. Mineral composition of expansive clay soil

No.	Mineral composition	Content (% of weight)
1.	Monmorillonite	34.03
2.	Halloysite	34.86
3.	Alpha Quartz	25.42
4.	Hematite	5.69

### 3. RESEARCH RESULTS

All tests were performed at Soil Mechanics Laboratory Test of Civil Engineering Department of State Polytechnic of Jakarta and Balai Pusat Pengujian Keramik (*Institution Center for Ceramic Test*), Bandung. Flow chart of research conducted is shown in Figure 2.

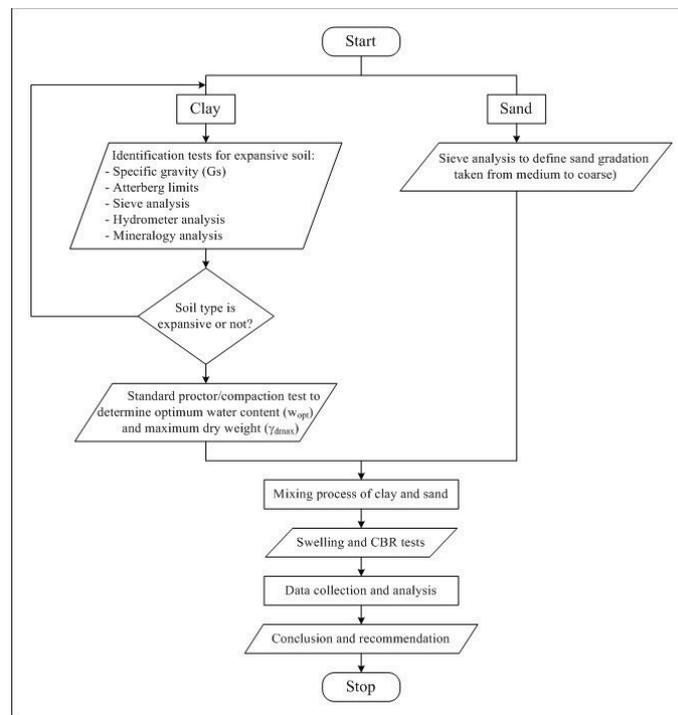


Figure 2. Research flow chart

CBR (*California Bearing Ratio*) test results shows in Figure 3 (a; b; c; and d). Based on Figure 3, it can be concluded that sand addition from 10.0 % to 17.7 %, CBR value of tends expansive clay soil to decrease. So, the sand addition of these ranges cannot contribute to increase soil bearing capacity. However, for sand addition more than 17.7%, CBR value of expansive clay soil can increase, it can be assumed that all sand grain filled pore spaces of expansive clay soil and stabilized clay mineral of montmorillonite, even though these assumptions has to be proven by a micro laboratory works.

From swelling tests, it can be shown that influence of sand contents of 10 and 20% will increase swelling potential values. However, when the sand contents reach 25 and 30%, expansive soil will decrease the swelling potential. It can be concluded that the influence of sand addition will cause decreasing of swelling potential after the optimal values of sand content. In this study, it can be known that to decrease swelling values can be reach if the sand content more than 30% (or > 30 %). So that, influence of sand addition more than 30% will decrease swelling potential and increase CBR values.

### CONCLUSION AND RECOMMENDATION

From laboratory research results, undisturbed and disturbed soil of Cikarang Estate, Bekasi area can be categorized as expansive soil. Influence of sand addition can decrease swelling potential values and increase CBR values after sand contents more than 30%.

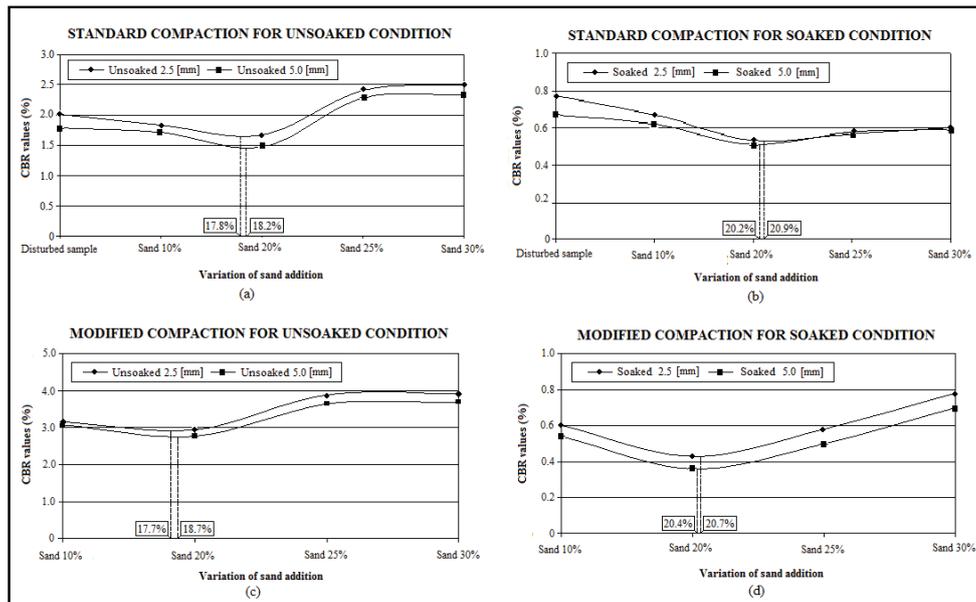


Figure 3. Typical correlation between variation of sand addition and CBR values in soaked & unsoaked conditions

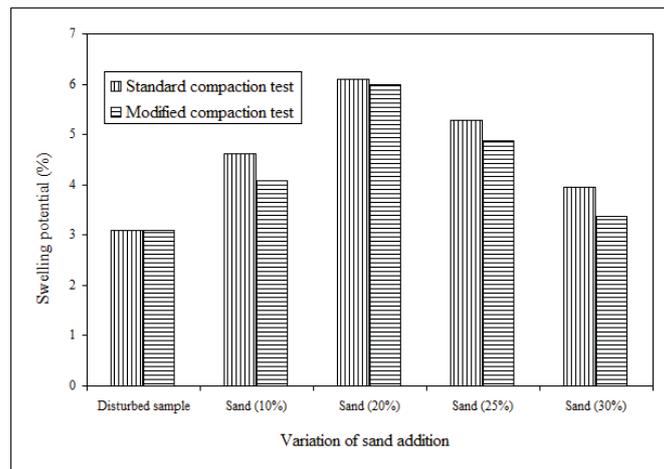


Figure 4. Variation of sand addition and swelling potential based on standard and modified compaction tests

The previously described analysis has clearly indicated that the index properties such as liquid limit, plasticity index and related parameters cannot satisfactorily predict the soil expansivity, as they do not consider the effect of clay mineralogy. The free swell ratio approach, in addition to predicting the soil expansivity more realistically and satisfactorily, gives additional information about the nature of the clay mineralogy of soils. The study should be compared with the stabilizing agents for expansive clay, such as: hydrated lime, portland cement, bitumen, and the others, however the stabilization using agents as mentioned above is quite expensive and requires precision and high accuracy work.

## REFERENCES

- [1] Chen. F.H., *Foundations on Expansive Soils*. Elsevier, 1975, 1988, Amsterdam.
- [2] Holtz.W. G. and Gibbs H. J., "Engineering properties of expansive clays," *Transactions of ASCE*, 1956, 121, pp. 641 – 677.
- [3] Seed, H.B and Chan, C.K., "Structure and Strength Characteristics of Compacted Clays," *ASCE Journal of the Soil Mechanic and Foundations Division*, Vol. 85, No. SM5, 1959.
- [4] See, H.B., Woodward, R.J., and Lundgren, R., "Prediction of swelling potential for compacted clays," *ASCE Journal of the Soil Mechanic and Foundations Division*, Vol. 88, No. SM4, pp. 107 – 131, 1962.
- [5] Seed, H.B., Mitchell, J.K., and Chan, C.K., "Studies of Swell and Swell Pressure Characteristics of Compacted Clays", *Bulletin No. 131, Highway Research Board*, pp. 12 – 39, 1962.

# THE EFFECT OF EXTERNAL DISTURBANCE TO CAR DRIVER AND MOTORCYCLE RIDER BEHAVIOUR

Leksmono Suryo Putranto<sup>a</sup>, Jimmy Kurniawan<sup>b</sup>

<sup>a</sup>Civil Engineering Department, Faculty of Engineering, Tarumanagara University, Jakarta 11440  
E-mail : ls.putranto@ftuntar-id.com

<sup>b</sup>Civil Engineering Department, Faculty of Engineering, Tarumanagara University, Jakarta 11440  
E-mail : jimz\_blueray@yahoo.co.id

## ABSTRACT

*Car driver and motorcycle rider behaviour might be affected by external disturbances. These include the behaviour of other driver/ rider, the behaviour of pedestrian, the road condition, the existence of outdoor advertisement, people activities on road and surroundings, building lighting, etc. There were 100 respondents interviewed consist of university students, lecturers and employees. Both males and females were covered and both car drivers and motorcycle riders were covered. The questionnaire consists of social status (gender, age, marital status, residential status, health), economic status (monthly expenditure, education back ground, employment status), vehicle data (engine size and production year), driving/ riding skill (driving/ riding experience, driving/ riding license possession), driving/ riding habit (helmet/ safety belt use, equipment check), travel characteristics (daily driving/ riding distance/ time, daily departure and arrival time), risky behaviour (exposure to traffic violation/ accident, etc), and 9 other questions regarding external disturbances. Covariance based SEM (Structural Equation Modeling) will be used to analyzed the effect of repondents socio- economic characteristics, driving/ riding skill/habit/risky behaviour, vehicle/ travel characteristics to their attitude towards external disturbance. A free Partial Least Square (PLS) software available on web called Smart-PLS was used.*

## Keywords:

*External Disturbance, Car Driver Behaviour, Motorcycle Rider Behaviour, Structural Equation Modeling, Partial Least Square*

## 1. INTRODUCTION

Driving a car or riding a motorcycle has already been a multitasking activity [1]. Ones needs to concentrate in this kind of activity to ensure safe drive/ ride. Therefore any disturbance both internal or external disturbances should be minimized. Internal disturbance can be defined as disturbance caused by internal activities in the vehicle such as using mobile phone (initiate/ receive call, sending/ replying text, etc) as stated by [2], using other gadgets (observing map through GPS, using smartphone for various tasks, etc), operating audio visual equipments [3], engaged in internal activities with passengers [4], eating and drinking [5], etc. External disturbance can be defined as disturbance caused by activities/ things outside the vehicle such as behaviour of other driver/ rider, the behaviour of pedestrian, the road condition, the existence of outdoor advertisement, people activities on road and surroundings, building lighting, etc. In this paper the the effect of repondents socio economic characteristics, driving/ riding skill/habit/risky behaviour, vehicle/ travel characteristics to their attitude towards external disturbance will be discussed.

## 2. PREVIOUS STUDIES

Reference [6] shows that older motorcycle riders check the equipment before the ride more frequent compare to the younger one. They stated that whealtier rider tend to involve in less traffic rule violation. They aso stated that helmet use was associated with other responsible behaviour such as bring vaid license on ride, involve in less traffic rule violation and low accident exposure.

According to [7] younger rider was more likely to involve in fatal accident. This is confirmed by [8] that stated older riders tend to conduct safe riding.

According to [9] law enforcement might increase helmet use. At the end, this increase will lead to less number of head injuries.

According to [10] higher rider education could increase possession of valid license. It also increase helmet use rate. According to [11] possession of license would improve riding performance.

According to [12] younger rider, lower road class and male rider tend to fall into low helmet use group. Meanwhile according to [13] law enforcement could decrease fatal and non-fatal injuries. Further they said that rider education and lower speed limit would decrease non-fatal injuries.

Reference [14] shows that less riding experience/ riding skills and poor license system would increase accident risk. They also found that female rider tend to have less experience.

Reference [15] shows that younger female drivers with less experience and more speeding and parking offences tend to be more inattentive and more dangerous. Some of these characteristics confirming the finding of [16]. Meanwhile, [17] stated that younger and wealthier drivers with speeding and traffic rule violation history tend to involve in more accident.

Reference [18] shows that street lighting increase car speed, decrease driver concentration and decrease accident rate. Another road condition such as road segment homogeneity might maintain car speed stability [19].

According to [20], driver stress might increase driving error and driving violation. Meanwhile, [21] stated that drivers with dangerous and speeding habit were usually young, wealthy, less likely to use seat belt and involved in more traffic rule violation and accident. They also stated that experienced and well educated drivers tend to be less dangerous although driving in higher speed.

According to [22], less ability in accident probability judgement, less concern, less worry and security and less emotional reactions formed more risky behaviour. Furthermore they stated that risky behaviour was reflected by unsafe driving and social pressure, speeding and traffic rule violation.

Reference [23] shows that driver who rarely use seat belt tend to involve in severe crash and severe injury. Meanwhile, according to [24] unbuckled caucasian drivers tend to involve in red light running.

Reference [25] shows that driver with more risky driving behaviour tend to conduct speeding and violate traffic rule. They also stated that risk perception was reflected by worry and concern.

Provocation by other road users might lead to speed acceleration by the provoked drivers [26]. However, male driver tend to accelerate faster [27].

According to [28] more speed limit violation was done by non seat belt user. Meanwhile, driver risky behaviour was usually stronger in less educated and less wealthy communities [29]. According to [30] drivers with more traffic violation history tend to involve in crashes.

Higher education was related to higher safety belt use rate [31]. Moreover, older driver with higher job level and higher wealth level was related to higher safety belt use rate [32].

Variable message sign would increase driver alertness [33]. However, truck drivers utilized more time to read roadside displays [34].

Street level advertisement was attracting more driver attention compare to raised level advertisement [35]. In general, outside distractions tend to trigger more absence of hand on steering wheel and cause more lane wandering [5].

### 3. METHODOLOGY

There were 100 respondents interviewed consist of 73 university students, 12 university lecturers and 15 university employees. There were 66 males and 34 females. There were 49 car drivers and 51 motorcycle riders were covered.

Based mainly on the literature review with necessary modification, the questionnaire consists of :

- social status (gender, age, marital status, residential status, health)

- economic status (monthly expenditure, education back ground, employment status)
- vehicle data (engine size and production year)
- driving/ riding skill (driving/ riding experience, driving/ riding license possession)
- driving/ riding habit (helmet/ safety belt use, equipment check)
- travel characteristics (daily driving/ riding distance/ time, daily departure and arrival time)
- risky behaviour (exposure to traffic violation/ accident, etc)
- attitude towards external disturbances (include the behaviour of other driver/ rider, the behaviour of pedestrian, the road condition, the existence of outdoor advertisement, people activities on road and surroundings, building lighting, etc.).

Covariance based SEM (Structural Equation Modeling) was used to analyzed the effect of repondents socio- economic characteristics, driving/ riding skill/habit/risky behaviour, vehicle/ travel characteristics to their attitude towards external disturbance. A free Partial Least Square (PLS) software available on web called Smart-PLS was used. Only indicators with standardized loading factor (SLF) equal and above 0.5 were considered.

Car models were separated from motorcycle models. During data inputting, for both models there were two methods, using limited ordinal scale and using widen ordinal scale (for example for data with wide range of values such as responden age, vehicle production year, etc). Therefore four models were produced. In this paper only visual model for widen ordinal scale will be presented due to the limited pages allowed. However the indicators with  $SLF \geq 0.5$  were presented both for limited ordinal scale models and widen ordinal scala models.

#### 4. RESULTS AND DISCUSSIONS

Figure 1 shows the full model for car with widen ordinal scale whilst Figure 2 shows the final model for motorcycle after all indicators with  $SLF < 0.5$  (including negative SLF's) removed. Figure 3 shows the full model for motorcycle with widen ordinal scale whilst Figure 4 shows the final model for motorcycle after all indicators with  $SLF < 0.5$  (including negative SLF's) removed.

Table 1 shows the summay of all indicators with  $SLF \geq 0.5$  both in car and motorcycle models. The models consist of limited ordinal scale models and widen ordinal scale models. It can be seen that in car models all indicators reflect economic characteristics latent (education attainment, monthly expenses and job level), whilst in motorcycle model only job level was significant.

Marital status was a significant indicator forming social status in car and motorcycle widen ordinal scale models. In car and motorcycle limited ordinal scale models, age was the only significant indicator forming social status.

Except for car model with limited ordinal scale, in all other models, production year was the only indicator significantly forming vehicle characteristic latent. For all models, driving/ riding experience was the only significant indicator reflecting driving/ riding skill latent.

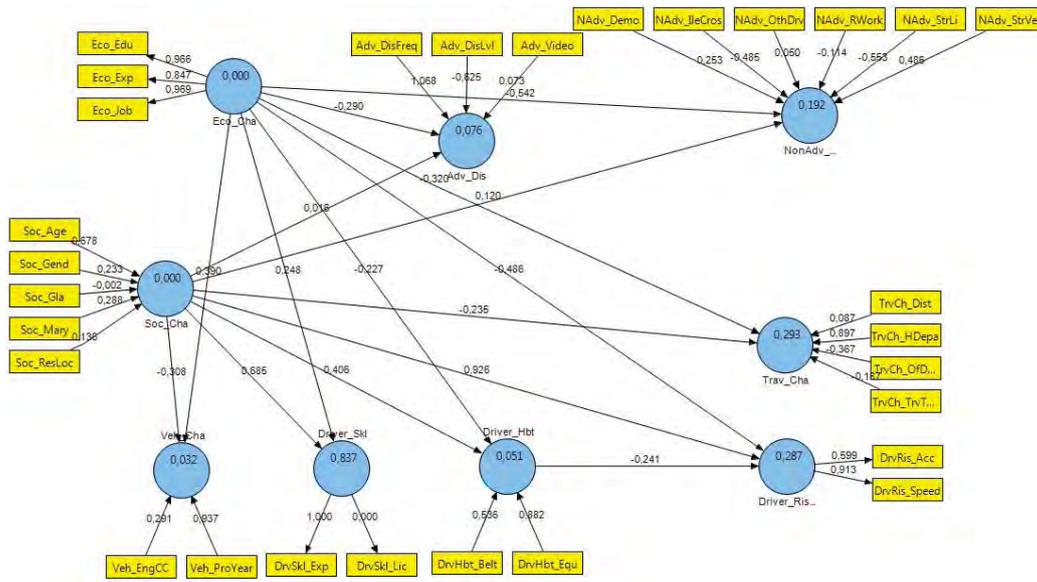


Figure 1: Full Model for Car-Widen Ordinal Scale

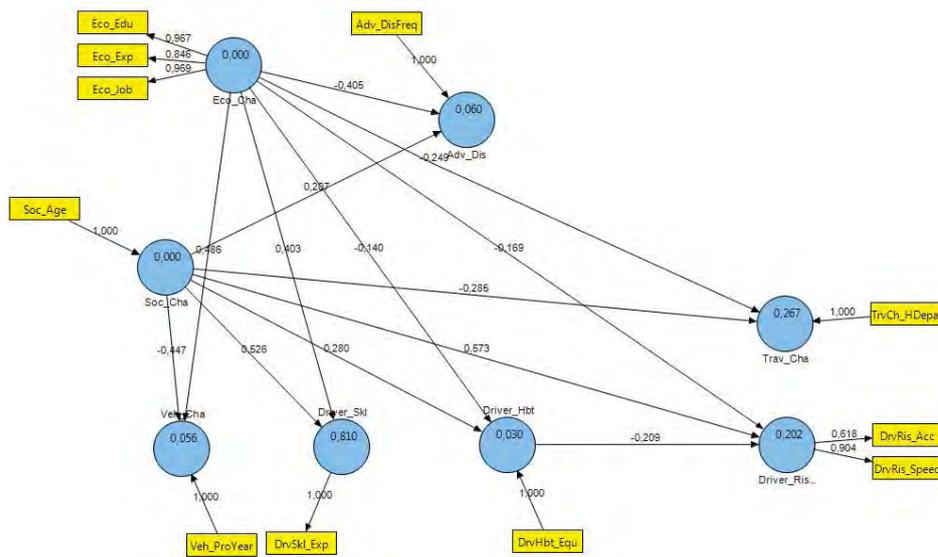


Figure 2: Final Model for Car-Widen Ordinal Scale

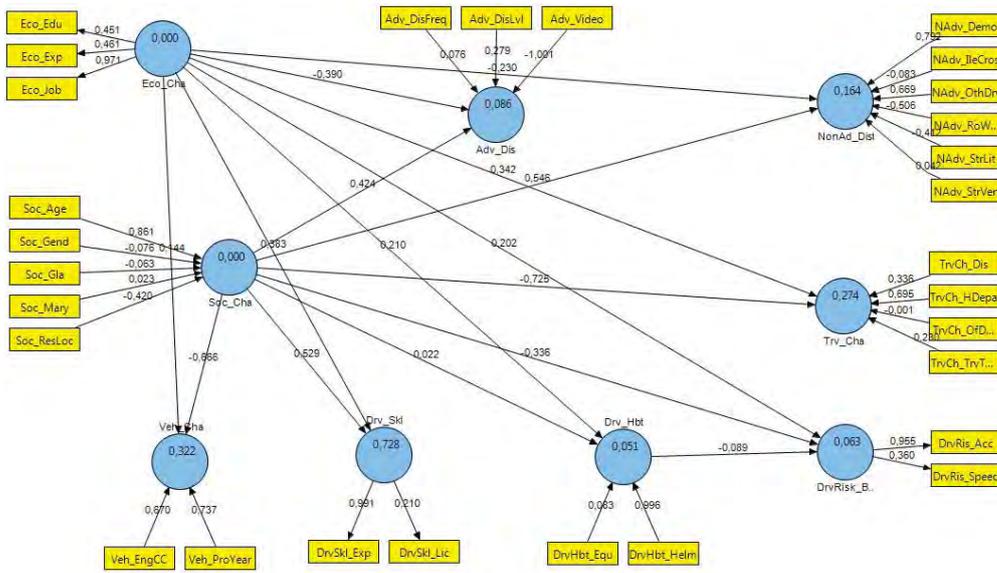


Figure 3: Full Motorcycle Model-Widen Ordinal Scale

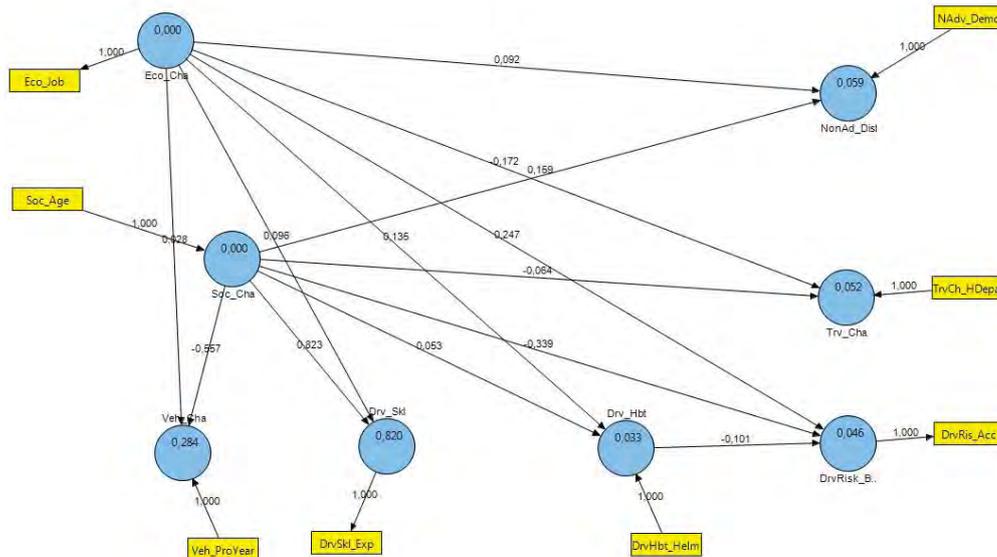


Figure 3: Final Motorcycle Model-Widen Ordinal Scale

For all car models, equipment check before driving was the only indicator significantly forming driving habit latent. For all motorcycle models, helmet use was the only indicator significantly forming driving habit latent.

For all widen ordinal scale models, accident involvement history was a significant indicator reflecting driver/ rider risky behaviour latent. However in car model, driving in a speed more than 100 km/hour was another significant indicator. Driving in a speed more than 100 km/hour was the only significant indicator reflecting car limited ordinal scale model.

For all models, departure time was the only significant indicator forming travel characteristic latent. For all car models, advertisement disturbance frequency was the only significant indicator forming advertisement external disturbance latent (there were no significant indicator for motorcycle models for this latent). For all motorcycle models, demonstration disturbance was the only significant indicator forming non-advertisement latent ((there were no significant indicator for car models for this latent).

In general, economic characteristic latent influence social characteristics, vehicle characteristics, driving skill, driving habit, driver/ rider risky behaviour, travel characteristics, advertisement disturbance and non-advertisement disturbance latents. Social characteristic latent influence all other latents except economic characteristics. Driving habit latent influence driver/ rider risky behaviours.

Table 1: Summary of Indicator with  $SLF \geq 0.5$

Latent Variable	Car-Limited Ordinal Scale	Car-Widen Ordinal Scale	Motorcycle-Limited Ordinal Scale	Motorcycle-Widen Ordinal Scale
<b>Economics Characteristics</b>	Education Expenses Job	Education Expenses Job	Job	Job
<b>Social Characteristics</b>	Marital Status	Age	Marital Status	Age
<b>Vehicle Characteristics</b>	- <sup>1)</sup>	Production Year	Production Year	Production Year
<b>Driving Skill</b>	Experience	Experience	Experience	Experience
<b>Driving Habit</b>	Equipments Check	Equipments Check	Helmet Use	Helmet Use
<b>Driver/ Rider Risky Behaviour</b>	Speeding	Speeding Accident Involvement	- <sup>1)</sup>	Accident Involvement
<b>Travel Characteristics</b>	Departure Time	Departure Time	Departure Time	Departure Time
<b>Advertisement Disturbance</b>	Frequency of Disturbance	Frequency of Disturbance	- <sup>1)</sup>	- <sup>1)</sup>
<b>Non-Advertisement Disturbance</b>	- <sup>1)</sup>	- <sup>1)</sup>	Demonstration	Demonstration

1) SLF for all of the indicators in this latent are negative or below 0.5

## 7. CONCLUSION AND RECOMMENDATION

It can be concluded that except for economic characteristics latent and driver risky behaviour latent, all other latents have only single valid indicator to form or to reflect each of them. One of the possible cause was the use of non-standard questionnaire without statistical validation test. In further research this statistical validation test should be carried out.

## REFERENCES

- [1] J. Fofanova, M. Vollrath, "Distraction while driving: The case of older drivers", *Transportation Research Part F* Vol. 14, pp. 638–648, 2011.
- [2] D.D. Salvucci, K L. Macuga, "Predicting the effects of cellular-phone dialing on driver performance", *Cognitive Systems Research*, Vol 3, pp. 95–102, 2002.
- [3] T. Horberry, J. Anderson, M.A. Regan, T.J. Triggs, J. Brown, "Driver distraction: The effects of concurrent in vehicle tasks, road environment complexity and age on driving performance", *Accident Analysis and Prevention*, Vol. 38, pp. 185–191, 2006.
- [4] S. Koppel, J. Charlton, C. Kopinathan, D. Taranto, "Are child occupants a significant source of driving distraction", *Accident Analysis and Prevention*, Vol. 43, pp. 1236–1244, 2011.
- [5] J. Stutts, J. Feaganes, D. Reinfurt, E. Rodgman, C. Hamlett, K. Gish, L. Staplin, "Driver's exposure to distractions in their natural driving environment", *Accident Analysis and Prevention*, Vol. 37, pp. 1093–1101, 2005.
- [6] L.S. Putranto, A. Pramana, H. Kurniawan, "Relationship between Motorcyclist Behaviour in Various Traffic Condition with Driver, Vehicle and Trip Characteristics" (in Bahasa), *Jurnal Transportasi Forum Studi Transportasi antar Perguruan Tinggi*, Vol. 6, No. 1, pp 63-69, 2006.
- [7] M.M.A. Manan, A. Varhelyi, "Motorcycle Fatalities in Malaysia", *International Association of Traffic and Safety Sciences Research* (article in press), 2012.

- [8] J.T. Wong, Y.S. Chung, S.H. Huang, "Determinants Behind Young Motorcyclist' Risky Riding Behaviour", *Accident Analysis and Prevention*, Vol. 42, pp 275-281, 2010.
- [9] W.T. Chiu, C.Y. Kuo, C.C. Hung, M. Chen, "The Effect of the Taiwan Motorcycle Helmet Use Law on Head Injuries", *American Journal of Public Health*, Vol. 90, No. 5, pp 793-796, 2000.
- [10] W. Swadhiwudhipong, C. Boonmak, P. Nguntra, P. Mahasakpan, "Effect of Motorcycle Rider Education on Changes in Risk Behaviours and Motorcycle-Related Injuries in Rural Thailand", *Tropical Medicine and International Health*, Vol. 3, No. 10, pp. 767-770, 1998.
- [11] T. Rosenbloom, A. Perlman, A. Pereg, "Hazard Perception of Motorcyclist and Car Drivers", *Accident Analysis and Prevention*, Vol.43, pp. 601-604, 2011.
- [12] L.P. Li, G.L. Li, Q.E. Cai, A.L. Zhang, S.K. Lo, "Improper Motorcycle Helmet Use in Provincial Areas of a Developing Country", *Accident Analysis and Prevention*, Vol. 40, pp. 1937-1942, 2008
- [13] M.T. French, G. Gumus, J.F. Homer, "Public Policies and Motorcycle Safety", *Journal of Health Economics*, Vol. 28, pp. 831-838, 2009
- [14] H.L. Chang, T.H. Yeh, "Motorcyclist Accident Involvement by Age, Gender and Risky Behaviour in Taipei, Taiwan", *Science Direct Transportation Research Part F*, No.10, pp. 109-122, 2007.
- [15] J. Harveya, S.Heslop, N. Thorpeb, "The categorisation of drivers in relation to boredom", *Transportation Planning and Technology*, Vol. 34, No. 1, pp. 51-69, February 2011.
- [16] D.T. Levy, "Youth and Traffic Safety: The Effects of Driving Age, Experience, and Education", *Accident Analysis & Prevention*, Vol. 22, No. 4, pp. 327-334, 1990.
- [17] F.H. Norris, B.A. Matthews, J.K. Riad, "Characterological, situational, and behavioral risk factors for motor vehicle accidents: a prospective examination", *Accident Analysis and Prevention*, Vol. 32, pp. 505-515, 2000
- [18] F. Jørgensen, P.A. Pedersen, "Drivers' response to the installation of road lighting: An economic interpretation", *Accident Analysis and Prevention*, Vol. 34, pp. 601-608, 2002.
- [19] M. Haglund, L. Aberg, "Stability in drivers' speed choice", *Transportation Research Part F*, Vol. 5, pp. 177-188, 2002.
- [20] S.J. Westerman, D. Haigney, "Individual differences in driver stress, error and violation", *Personality and Individual Differences*, Vol. 29, pp. 981-998, 2000.
- [21] M.G. Karlaftis, I. Kotzampassakis, G. Kanellaidis, "An empirical investigation of European drivers' self-assessment", *Journal of Safety Research*, Vol. 34, pp. 207-213, 2003.
- [22] T. Rundmo, H. Iversen, "Risk perception and driving behaviour among adolescents in two Norwegian counties before and after a traffic safety campaign", *Safety Science*, Vol. 42, pp. 1-21, 2004.
- [23] K. Kim, L. Nitz, J.Richardson, L. Li, "Personal and Behavioral Predictors of Automobile Crash and Injury Severity", *Accident Analysis and Prevention*, Vol. 27, No. 4, pp. 469-481, 1995.
- [24] B.E. Porter, K.J. England, "Predicting Red-Light Running Behavior: A Traffic Safety Study in Three Urban Settings", *Journal of Safety Research*, Vol. 31, No. 1, pp. 1-8, 2000.
- [25] P. Ulleberg, T. Rundmo, "Personality, attitudes and risk perception as predictors of risky driving behaviour among young drivers", *Safety Science*, Vol. 41, pp. 427-443, 2003.
- [26] A.R. McGarva, M. Steiner, "Provoked driver aggression and status: a field study", *Transportation Research Part F*, Vol. 3, pp. 167-179, 2000.
- [27] E. Ericsson, "Variability in urban driving patterns", *Transportation Research Part D*, Vol. 5, pp. 337-354, 2000.
- [28] A. Steptoe, J. Wardle, R. Fuller, S. Davidsdottir, B. Davou, J. Justo, "Seatbelt Use, Attitudes, and Changes in Legislation: An International Study", *American Journal of Preventive Medicine*, Vol. 23, no. 4, pp. 254-259, 2002.
- [29] E. Petridou, X. Zavitsanos, N. Dessypris, C. Frangakis, M. Mandyla, S Doxiadis, D. Trichopoulos, "Adolescents in High-Risk Trajectory: Clustering of Risky Behavior and the Origins of Socioeconomic Health Differentials", *Preventive Medicine*, Vol. 26, pp. 215-219, 1997.
- [30] M.J.M. Sullman, M.L. Meadows, K.B. Pajo, "Aberrant driving behaviours amongst New Zealand truck drivers", *Transportation Research Part F*, Vol. 5, pp. 217-232, 2002.
- [31] J. Russell, M. Kresnow, R Brackbill, "The Effect Of Adult Belt Laws And Other Factors On Restraint Use For Children Under Age 11", *Accident Analysis and Prevention*, Vol. 26, No. 3, pp. 287-295, 1994.
- [32] D. Shinar, "Demographic And Socioeconomic Correlates Of Safety Belt Use", *Accident Analysis and Prevention*, Vol. 25, No. 6, pp. 745-755, 1993
- [33] J. Luoma, P. Rama, M. Penttinen, V. Anttila, "Effects of variable message signs for slippery road conditions on reported driver behavior", *Transportation Research Part F*, Vol. 3, 75-84, 2000.
- [34] M. Iwao, A. Horiguchi, M. Kobayashi, "Study on behavior of cab-over truckdriver looking at a display while driving", *JSAE Review*, Vol. 23, pp. 489-494, 2002
- [35] D. Crundall, E. Van Loon, G. Underwood, "Attraction and distraction of attention with roadside advertisements", *Accident Analysis and Prevention*, Vol. 38, pp. 671-677, 2006

# Traffic Control of Road Closure on Saturated Two Way Two Lane Roads

**Endang Widjajanti**

Civil Engineering Department-Faculty of Engineering and Planning,  
 Institut Sains & Teknologi Nasional  
 Jl. M.Kahfi II, Jagakarsa Jakarta 12620, Indonesia  
 Tel/Fax: +62-21-7270092  
 E-mail: wiwin62@gmail.com

## ABSTRACT

The objective of the study is to develop a signal-control strategy and its application for road closure area on two way two lanes roads which is treated as an isolated intersection during severe over saturation. The study developed a method which introduces a ratio between cumulative departure and cumulative arrival ( $R$ ). With the same arrival and saturation flow data, the method introducing in this study has a better performance results comparing amongst the Discrete Minimal Delay Model and the Maximum Throughput Model. The simulation results show that the optimum arrival detection period is 240 seconds and the optimum cycle time is 240 seconds. The study indicates the percentage of increasing total delay, decreasing of average throughput and decreasing of over saturation period if there is a change of cycle time from 240 seconds to less than 240 seconds and the maximum road closure length that can be accommodated by signalized traffic control in over saturation traffic condition based on total Degree of Saturation ( $DS$ ), average speed on lane closure area ( $S_w$ ).

## Keywords

signalized traffic control, road closure areas, oversaturated.

## 1. INTRODUCTION

Road activity which requires the closure of one of the two ways two lane roads need a special effort to maximize the capacity of bottleneck areas, especially on over saturation traffic condition. To overcome the problem arises on an oversaturated two way two lane road closure areas, this study developed a two steps of green time planning method which is introducing a ratio between cumulative departure and cumulative arrival ( $R$ ) on its signalized traffic control strategy.

## 2. RESEARCH OBJECTIVE

The objective of the research is to evaluate the application of a ratio of vehicle's cumulative departure to cumulative arrival ( $R$ ) value as a switch over point parameter on oversaturated two way two lane road closure areas (RCA) as a signalized traffic control strategy with the speeds on RCA are 20 km/h and 30 km/h.

## 3. ROAD CLOSURE AREA (RCA) TRAFFIC CONTROL

Portable traffic signals use of the red clearance interval, or "all red" period to allow vehicles that have entered a RCA under a green or yellow indication to safely pass through and exit the one-lane RCA. The factor that determines duration of the red clearance interval is the speeds at which motorists will drive through the one lane RCA. The lay out of signalized traffic control on two way two lane RCA installation is shown on Figure 1, whereas Figure 2 displays the time needed in both directions to clear the road closure areas.

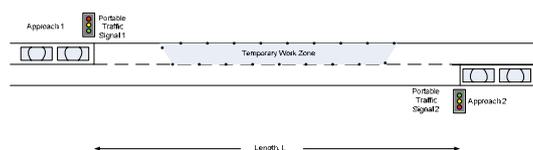


Figure 1: Portable Traffic Signal Installation for Road Closure Area Control

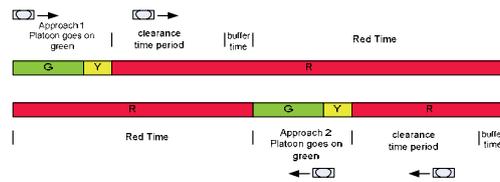


Figure 2: Complete Signal Cycle for Portable Traffic Signal Installation

$$\text{Maximum Wait Time (each direction)} = 2Y + 2R + 2B + G_{\max} \quad (2)$$

where

- $Y$  = yellow clearance time (applies to both directions), seconds
- $R$  = red clearance time (applies to both directions), seconds
- $B$  = buffer time (applies to both directions), seconds
- $G_{\max}$  = maximum green time in the opposing direction, seconds

Ginger et al [3] indicates that the maximum wait time (i.e., before driver confusion and possible violation) is approximately four minutes.

#### 4. SIGNALIZED TRAFFIC CONTROL ON OVERSATURATED TRAFFIC FLOW

##### 4.1. Previous Studies

The previous studies of signalized traffic control on oversaturated traffic flow were conducted by Chang and Lin [1] and Talmor and Mahalel D [6] which is summarized on Table 1.

Table 1: The Previous Studies Of Signalized Traffic Control On Oversaturated Traffic Flow

	Chang TH and Lin JT (2000).	Talmor I and Mahalel D, (2007),
Objective	minimize the total delay on the intersection during the oversaturated period by deriving a basic discrete minimal delay model and a performance index model	to maximize the average throughput of the intersection during the oversaturated period
uniqueness	Appication of bang-bang like control, by which signals are operated alternatively and sequentially, with minimal maximal green time, significantly outperforms conventional equal timesharing dispersion control; and not all provided cycle lengths are applicable to oversaturation control, since some may fail to meet the warrant of simultaneous dispersion indicated by Gazis	Application of discharge-flow functions instead of saturation-flow functions. Maximum throughput is achieved, based on the best balance between the decrease in discharge flows and the saving in lost time.
conclusions	The discrete type performance index model, which results in bang-bang like control, is quite appropriate for oversaturation control. The performance of this model is rather robust even when the input data appear to be slightly biased. The proposed model can also determine the optimal cycle length and the optimal assigned green time.	Control based on the maximization of throughput enables an optimization of traffic operations as long as congestion persists, without the need for any further knowledge of existing or future demand. This capability is important and significant, since congestion is often random and may occur without any prior information of its existence or duration.

##### 4.2. Demand and Service Approach

The traffic signal service equation is describing the service rate from the beginning until the end of the oversaturated period. The curve of cumulative arrival of vehicle and service of traffic signal control at oversaturated period presented at Figure 3. Beginning of oversaturated period happened at the time of  $T=0$  and oversaturated period end at the time of  $T=n.c.$  ( $n$ =total number of cycle time and  $c$ = cycle time).

At  $T = n.c.$ ,  $Q = G$

$$-(a_1 + a_2).t^2 + (b_1 + b_2).t = (\gamma_1 + \gamma_2)t$$

$t = n.c.$ , then

$$-(a_1 + a_2).(n.c)^2 + (b_1 + b_2).(n.c) = (\gamma_1 + \gamma_2).(n.c) \quad (5)$$

$$\begin{aligned} \gamma_1 &= \frac{g_1 s_1}{c}, \quad \gamma_2 = \frac{g_2 s_2}{c} \quad \text{and} \quad g_1 + g_2 = c \\ \gamma_1 &= \frac{(c - g_2) s_1}{c} \\ -(a_1 + a_2) \cdot (n \cdot c)^2 + (b_1 + b_2) \cdot (n \cdot c) &= \frac{(c - g_2) s_1 + g_2 s_2}{c} \cdot (n \cdot c) \\ -(a_1 + a_2) n \cdot c + (b_1 + b_2) &= \frac{(c - g_2) s_1 + g_2 s_2}{c} \end{aligned} \tag{6}$$

where

- $G$  = Total Cumulative service function, pcu
- $G_{1,2}$  Total Cumulative service function of movement 1 and 2, respectively, pcu
- $\gamma_{1,2}$  = Service rate (throughput) of movement 1 and 2 respectively, pcu/hour
- $a_{1,2}, b_{1,2}$  = Constants of the polynomial functions

$C$  is an input value, whereas the value of  $a_1, a_2, b_1, b_2, s_1, s_2$  is determined based on field data. If the equation fulfill the equation  $g_1 + g_2 = c$ , the value of  $n, T$  and  $\gamma$  can be calculated. Based on the assumption that that both approaches disperse the queues at the same cycle, hence the value of  $\gamma_1, \gamma_2, g_1$  and  $g_2$  also can be calculated.

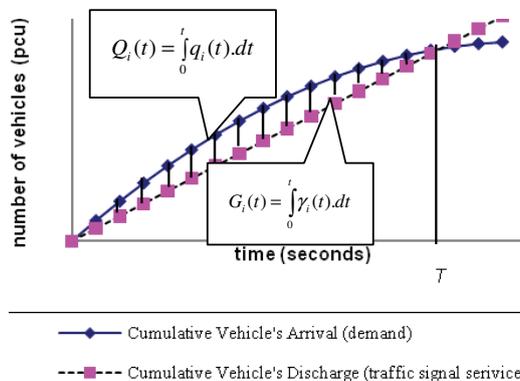
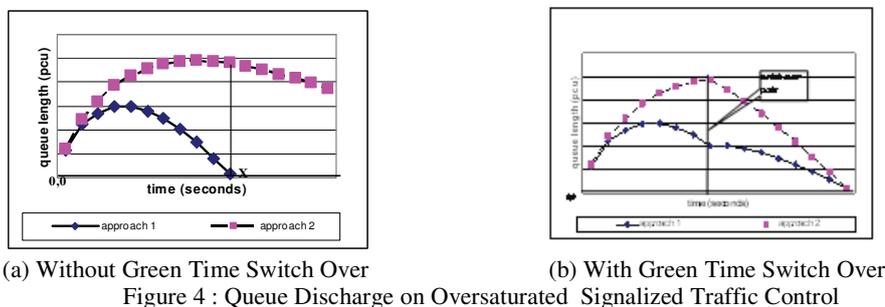


Figure 3: Vehicle's Cumulative Arrival and Cumulative Service of Traffic Signal Control at Oversaturated Period  
**5. SWITCH OVER POINT APPROACH**

Figure 4 show the queue length in an intersection with 2 phase signalized traffic control along the oversaturated period. The first phase serves the movement from the left of RCA (will be termed as first movement) and the second phase serves the movement from the right of road closure area (will be termed as second movement). As shown on Figure 4a, the traffic signal control on oversaturated period with single green time often cannot disperse the queue at both approaches concurrently. It can be seen that at  $T=X$ , the all queue at 1<sup>st</sup> movement has been discharged, but at the 2<sup>nd</sup> movement the queues still exist. To overcome this, the two step green time method with switching of green time at certain point has been developed. This point is called as switch over point (Figure 4b).



**5.1. Ratio Of Cumulative Vehicle Arrivals to Cumulative Vehicle Discharge**

As already mentioned above, the study developed a parameter to determine the switch over point named  $R$ , which is defined as ratio of cumulative vehicle arrivals to cumulative vehicle discharge.

Performance parameter calculated at any cycle time (iteration) is :

1. Vehicle discharge on the  $i$ th of green and  $j$ th iteration ( $VD_{i,j}$ )

$$VD_{i,j} = \frac{s_m}{3600} \times G_i(m) \quad m = 1,2 \quad (7)$$

where

- $VD_{i,j}$  = Vehicle discharge on the  $i$ th of green and  $j$ th iteration  $j$ , pcu
- $s_m$   $m = 1,2$  = Saturation flow of approach 1,2 pcu/hour
- $G_i(m)$  = Green time of approach  $m$  on the  $i$ th green time,  $i = 1,2$  (1 for before switching and 2 for after switching)

2. Queue length on the  $i$ th of green time and  $j$ th iteration ( $Q_{i,j}$ )

$$Q_{i,j} = CA_{ij} - CA_{i,j-1} + Q_{i,j-1} - VD_{i,j} \quad (8)$$

3. Ratio of cumulative vehicle arrivals to cumulative vehicle discharge on the  $i$ th of green time and  $j$ th iteration ( $R_{i,j}(m)$ )

$$R_{i,j}(m) = \frac{CD_{i,j}}{CA_{i,j}} \quad (9)$$

where

- $Q_{i,j}$  = queue length on the  $i$ th of green time and  $j$ th iteration, pcu
- $CA_{i,j}$  = cumulative vehicle arrivals on the  $i$ th of green time and  $j$ th iteration, pcu
- $CD_{i,j}$  = cumulative vehicle discharge on the  $i$ th of green time and  $j$ th iteration, pcu

Switch over point will be done if the value of  $R_{i,j}(m)$  at one of the two approaches has already achieved the determined value of  $R_{i,j}(m)$ . Which its value is in the range of zero to one ( $0 < R_{i,j}(m) < 1$ )

## 5.2. Simulation Scenario

### 5.2.1. R Value

The simulation was done on the various value of  $R_{i,j}(m)$  as follows:

$$R_{i,j}(m) \geq 0,1; 0,4; 0,5; 0,65; 0,75; 0,85; 0,9; 0,95; 0,97$$

The example of Chang and Lin [1] and Talmor and Mahalel D [8] is applied in the simulation as shown on Table 2. The example assumed an intersection of two one way streets with a two-phase signal control. One street is denoted as approach 1, and the other street as approach 2. No left turn is considered. Approach 1 has a saturation flow of 1400 vehicle/hour and approach 2 has a saturation flow 1000 vehicle/hour. In this study the saturation flow was converted into 1400 pcu/hour and 1000 pcu/hour, respectively. The cycle time is 150 seconds. In order to compare with the other model, the simulation was done with the value of zero in the length of RCA.

Table 2: Input Data

Cumulative time period (second)	Cumulative vehicle arrival (pcu)	Arrival flow (pcu/hour)	Saturation flow (pcu/hour)	Degree of Saturation	Cumulative vehicle arrival (pcu)	Arrival flow (pcu/hour)	Saturation flow (pcu/hour)	Degree of Saturation
	Approach 1				Approach 2			
300	121	1452	1400	1.04	86	1032	1000	1.03
600	205	1008	1400	0.72	147	732	1000	0.73
900	268	756	1400	0.54	192	540	1000	0.54
1200	318	600	1400	0.43	227	420	1000	0.42
1500	359	492	1400	0.35	257	360	1000	0.36
1800	396	444	1400	0.32	283	312	1000	0.31
2100	430	408	1400	0.29	307	288	1000	0.29
2400	462	384	1400	0.27	330	276	1000	0.28
2700	492	360	1400	0.26	352	264	1000	0.26
3000	523	372	1400	0.27	373	252	1000	0.25
3300	552	348	1400	0.25	394	252	1000	0.25
3600	582	360	1400	0.26	415	252	1000	0.25
3900	611	348	1400	0.25	436	252	1000	0.25
4200	640	348	1400	0.25	457	252	1000	0.25

Source : [1] & [8]

### 5.2.2. Simulation on RCA

To accommodate various variation of lane width, this study applied the total Degree of Saturation (DS) value to substitute the values of saturation flow and passenger car equivalent of each vehicle type. DS is sum of ratio of arrival flow to saturation flow on each movement or each approach. Therefore, the research's simulation scenario is as follows:

- a. Variation of vehicle arrival is represented by total Degree of Saturation and the Degree of Saturation (DS) of each approach.
- b. The observation time of the vehicle's arrival is 1 hour (3600 seconds) and the over saturation period is assumed happen on the first 300 seconds. The vehicle's arrival after the first 300 seconds is assumed as unsaturated flow, with the value of total Degree of Saturation is 0.71.
- c. The variation of DS on the first 300 seconds are as follows:
  - $1 < DS < 1.5$  (represents by DS=1.44)
  - $1.5 < DS < 2$  (represents by DS=1.86)
  - $2 < DS < 2.5$  (represents by DS=2.26)
  - $DS > 2.5$  (represents by DS=2.76)
- d. The simulation applies at various length of RCA, speed at RCA and cycle time as follows:
  - Length of RCA : 10, 15, 25, 50, 75, 100, 125, 150, 175, 200 meter
  - Speed at RCA: 20 km/tour
  - Cycle time: 120, 150, 180, 210, 240 seconds
  - Vehicle's Detection Period : 120, 180, 240, 300 seconds

## 6. PERFORMANCE INDICATOR AND R VALUE

The simulation results on Table 3 and Figure 4 show that the various of R do not give a significant trend of both average throughput and total delay. The simulation results also show that although average throughput has a maximum value on the value of  $R \geq 0.95$ , but the difference is very small. The two performance indicators, those are average throughput and total delay, do not have any special trend in result regarding with the difference of the R value. The first simulation results show that green time determination has a significant difference if be chosen based on the minimum total delay value. The minimum total delay was happened on the value of  $R \geq 0.95$ .

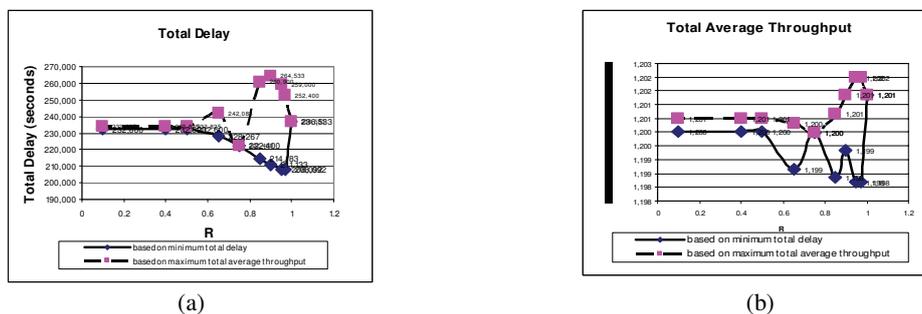


Figure 4: Total Delay and Total Average Throughput of Various R Values

Table 3 shows the performance results of the study and the two other methods, i.e. Discrete Minimal Delay Model [1] and Maximum Throughput Model [6] based on the same input data. The results then compared to the based result, which is Minimal Delay Model [1]. The difference in percentage to the based result was done also presented in this Table.

Comparing with Discrete Minimal Delay Model [1], this study has improved some of performance indicators of signalized traffic control, those are 5,88% better in length of over saturation period, 1,46% in average throughput, 13,57% in number of vehicles in the queue and 12,80% in total delay. This performance also better than Maximum Throughput Model [6]

Table 3: Performance Results

Performance Indicator	Discrete Minimal Delay Model	Maximum Throughput Model	Research, R=0,95
Over saturation period (second)	2550.00	2434.80	2400.00
throughput (pcu/hour)	1181	1195	1198
Number of vehicles in the queue (pcu)	1609	1566	1391
total delay (second)	238,625	233,035	208,092
Comparison to Discrete Minimal Delay Model			
Over saturation period (second)	-	4.52%	5.88%
throughput (pcu/hour)	-	1.16%	1.16%
Number of vehicles in the queue (pcu)	-	2.69%	13.57%
total delay (second)	-	2.34%	12.80%

Source : Talmor I & Mahalel D [8] & Result of the Study (2009)

Evaluations of the first simulation are as follows:

- Green time determination has a significant difference if be chosen based on the minimum total delay value.
- The minimum total delay was happened on the value of  $R \geq 0.95$ .
- The ratio of vehicle's cumulative departure to cumulative arrival (R) value as a switch over point parameter could be applied on a two phase oversaturated signalized traffic control strategy.
- The research method, which was applied a ratio of vehicle's cumulative departure to cumulative arrival (R) value of 0.95, has improved the performance of the previous methods, i.e. the Discrete Minimal Delay Model and the Maximum Throughput Model.
- The research method could be applied to oversaturated two way two lane road closure areas signalized traffic control strategy by inputting the length of road closure area and the average journey speed in the road closure area.

### 6.1. Optimum Detection Period

The simulation results show that minimum total delay is achieved when the detection period is more than 240 seconds. When  $DS < 2$  the minimum total delay is 300 seconds, but at  $DS > 2$  the minimum total delay of 240 seconds and 300 seconds vehicle's detection period has the same value of minimum total delay. The percentage of increasing total delay comparing to 240 seconds of detection period at cycle time 240 seconds is shown on Table 4.

Table 4 Total Delay on Various Detection Periods Comparing to Detection Period of 240 seconds= 240 Seconds

DS	Lw	Total Delay (seconds)				oversaturated period	average throughput	% comparing to detection period of 240 seconds			
		detection period (seconds)						detection period (seconds)			
		meter	120	180	240			300	seconds	pcu/hr	120
1<DS<1.5	10	47,675	35,835	27,995	27,803	960	1626	70%	28%	0%	-1%
	25	52,200	40,360	32,520	32,328	960	1591	61%	24%	0%	-1%
	50	61,740	49,900	42,060	41,868	1,200	1,527	47%	19%	0%	0%
	75	76,225	64,385	56,545	56,353	1,440	1,464	35%	14%	0%	0%
	100	99,667	87,827	79,795	79,795	1,920	1,400	25%	10%	0%	0%
	125	144,802	132,962	125,122	124,930	2,880	1,336	16%	6%	0%	0%
1.5<DS<2	10	111,468	95,788	85,548	85,836	1,440	1,626	30%	12%	0%	0%
	25	120,353	104,673	94,433	94,721	1,680	1,591	27%	11%	0%	0%
	50	145,382	129,702	119,462	119,750	1,920	1,527	22%	9%	0%	0%
	75	180,750	165,070	154,830	155,118	2,400	1,464	17%	7%	0%	0%
	100	239,326	223,646	213,406	213,694	3,120	1,400	12%	5%	0%	0%
2<DS<2.5	10	197,899	179,019	167,179	167,179	1,920	1,626	18%	7%	0%	0%
	25	215,633	196,753	184,913	184,913	2,160	1,591	17%	6%	0%	0%
	50	257,734	238,854	227,014	227,014	2,640	1,527	14%	5%	0%	0%
	75	323,688	304,808	292,968	292,968	3,120	1,464	10%	4%	0%	0%
2.5<DS<3	10	341,670	318,310	304,230	304,230	2,640	1,626	12%	5%	0%	0%
	25	373,560	350,200	336,120	336,120	2,880	1,591	11%	4%	0%	0%
	50	449,914	426,554	412,474	412,474	3,360	1,527	9%	3%	0%	0%

### 6.2. Optimum Cycle Time

The simulation results of cycle time variation, are as follows:

- Cycle time of 240 seconds resulting the smallest total delay at most of variations, except on the following scenarios, which the smallest total delay occurred on cycle time of 210 seconds:
  - Length of RCA 10 meter and 25 meter on  $1 \leq DS \leq 1.5$
  - Length of RCA 25 meter on  $1 \leq DS \leq 1.5$  and  $2 \leq DS \leq 2.5$ .

- b. Cycle time of 240 seconds resulting the largest total average throughput at all variations.
- c. Cycle time of 240 seconds resulting the smallest oversaturated period at all variations.

Based on the simulation results mentioned above, the cycle time of 240 second is chosen as the optimal cycle time. Total delay, total average throughput and oversaturated period on Various Cycle Time Comparing to Cycle Time of 120 seconds is shown on Table 5.

*Table 5: Total Delay, Total Average Throughput and Oversaturated Period on Various Cycle Time Comparing to Cycle Time of 120 Seconds*

Length of RCA	Cycle time	Total Delay	average throughput	Length of RCA	Cycle time	Total Delay	average throughput	Length of RCA	Cycle time	Total Delay	average throughput
meter	second	second	pcu/hour	meter	second	second	pcu/hour	meter	second	second	pcu/hour
10	120	37,436	1555.38	50	120	106,240	1357.60	100	120	-	-
	150	32,270	1583.87		150	67,584	1425.48		150	-	-
	180	28,539	1602.72		180	53,249	1470.73		180	-	-
	210	27,096	1616.19		210	45,841	1503.06		210	105,605	1357.60
	240	27,995	1626.29		240	42,060	1527.30		240	79,795	1400.03
	120	100%	100%		120	100%	100%		120	-	-
	150	86%	102%		150	64%	105%		150	-	-
	180	76%	103%		180	50%	108%		180	-	-
	210	72%	104%		210	43%	111%		210	100%	100%
	240	75%	105%		240	40%	113%		240	76%	103%
25	120	51,060	1484.88	75	120	-	-	125	120	-	-
	150	41,190	1527.30		150	139,031	1323.66		150	-	-
	180	36,176	1555.58		180	85,648	1385.88		180	-	-
	210	33,283	1575.79		210	66,056	1430.33		210	-	-
	240	32,520	1590.94		240	56,545	1463.66		240	125,122	1336.39
	120	100%	100%		120	-	-		120	-	-
	150	81%	103%		150	100%	100%		150	-	-
	180	71%	105%		180	62%	105%		180	-	-
	210	65%	106%		210	48%	108%		210	-	-
	240	64%	107%		240	41%	111%		240	100%	100%

### 6.3. Prediction Of Delay, Throughput And Oversaturation Period

The simulation results show that the length of RCA (Lw) that could be accommodated by a signalized traffic control on two way two lane RCA at oversaturated period is limited and depend on the value of the total Degree of Saturation (DS) of the two approach. The approaching model of total delay and length of RCA relationship is an exponential equation, while for the total average throughput and length of RCA relationship is a linear equation.

The equations to predict the total delay and average throughput based on the value of DS and the length of RCA on observation period 240 seconds and cycle time 240 seconds are shown on Table 6. The value of oversaturated period is presented on Table 7.

*Table 6 Equation of Total Delay and Average Throughput Prediction*

DS	equation		Lw can be accommodated
	total delay	throughput	
	second	pcu/hour	meter
$1 \leq DS \leq 1.5$	$y = 23286 e^{0.0128 x}$	$y = -2.523 x + 1653$	$Lw \leq 125$
$1.5 \leq DS \leq 2$	$y = 74325 e^{0.0102 x}$	$y = -2.523 x + 1653$	$Lw \leq 100$
$2 \leq DS \leq 2.5$	$y = 150682 e^{0.0068 x}$	$y = -2.511 x + 1653$	$Lw \leq 75$
$2.5 \leq DS \leq 3$	$y = 280113 e^{0.0077 x}$	$y = -2.482 x + 1652$	$Lw \leq 50$

*Table 7: Oversaturated Period Based on the Length of RCA, DS and Sw on Observation Period 240 Seconds and Cycle Time 240 Seconds*

Length of RCA meter	over-saturated period (seconds)			
	$1 \leq DS \leq 1.5$	$1.5 < DS \leq 2$	$2 < DS \leq 2.5$	$2.5 < DS \leq 3$
10	960	1,440	1920	1920
25	960	1,680	2160	2160
50	1,200	1,920	2640	2640
75	1,440	2,400	3120	3120
100	1,920	3,120	-	-
125	2,880	-	-	-

## 7. CONCLUDING REMARKS

A signal-control strategy for road closure area on two way two lanes roads which is treated as an isolated intersection during severe over saturation was developed using ratio of vehicle's cumulative departure to cumulative arrival (R) value as a switch over point parameter could be applied on a two phase oversaturated signalized traffic control strategy.

With the same arrival and saturation flow data, the switching method introduced in this study has a better performance results comparing with the Discrete Minimal Delay Model and the Maximum Throughput Model. The application of a ratio of vehicle's cumulative departure to cumulative arrival (R) value of 0.95, has improved the performance comparing with the two previous methods.

The switching method could be applied to signalized traffic control strategy on oversaturated two way two lane road closure areas by inputting the length of road closure area and the average journey speed in the road closure area.

The results of simulation to the various lengths of road closure area and the average journey speed in the road closure area are that minimum total delay is achieved when the detection period is more than 240 seconds and the optimal cycle time is 240 seconds

The length of Road Closure Area (Lw) could be accommodated by a signalized traffic control on two way two lane RCA at oversaturated period is limited and depend on the value of the total Degree of Saturation (DS) of the two approach. The approaching model of total delay and length of RCA relationship is an exponentials equation, while for the total average throughput and length of RCA relationship is a linier equation.

## REFERENCES

- [1] Chang TH and Lin JT, "Optimal Signal Timing For An Oversaturated Intersection". Journal of Transportation, Res 34B:471-491, 2000.
- [2] Daniels Ginger et al, "Feasibility of Portable Traffic Signals to Replace Flaggers in Maintenance Operation", Texas Transportation Institute, 2000.
- [3] Daniels Ginger et al, "Guidelines For The Use Of Portable Traffic Signals In Rural Two-Lane Maintenance Operations", Texas Transportation Institute, 2000.
- [4] Green, D.H., "The Simulation of Some Simple Control Policies for a Signalized Intersection", Operational Research Vol. 17, No. 3 (Sep., 1966), pp. 263-277, 1966
- [5] Green, D.H., "Control of Oversaturated Intersections", Operational Research Quarterly 18 (2), 161-173, 1968
- [6] Talmor I and Mahalel D, "Signal Design For An Isolated Intersection During Congestion", Journal of the Operational Research Society 58, 454-466, 2007.
- [7] Widjajanti E et al, Traffic Control on Two Way Two Lane Roads Work Zones: A Case Study In Indonesia, Proceedings of the Eastern Asia Society for Transportation Studies, Vol.6, 2007
- [8] Widjajanti E et al, "Traffic Control on Saturated Two Way Two Lane Roads Work Zones", Eastern Asia Society for Transportation Studies (EASTS) Conference, Surabaya, 2009
- [9] Widjajanti E, "Signalized Traffic Control on Oversaturated Two Way Two Lane Road Closure Area", Dissertation, University-of Indonesia, Jakarta, Indonesia, 2009

# Modeling Risk Guarantee on Highway Infrastructure Development Using Real Option Approach

Susanty Handayani<sup>b</sup>, R. Jachrizal Soemabrata<sup>a</sup>, Sigit Pranowo H<sup>c</sup> and Yusuf Latief<sup>d</sup>

Faculty of Engineering, Universitas Indonesia, Depok, Indonesia 16424

Tel : (021) 7270011 ext 51. Fax : (021) 7270077

<sup>a</sup>rjs@eng.ui.ac.id, <sup>b</sup>susanhandayani@yahoo.com, <sup>c</sup>sigit@eng.ui.ac.id, <sup>d</sup>latief73@eng.ui.ac.id

## ABSTRACT

*It is crucial to applied risk guarantee to infrastructure projects for the reason that assurance in the handling of various risks is vital in infrastructure development especially in a scheme of public-private partnerships. Government attract private sector participation as a scheme of policy solutions to budgetary limitations by incentives such as debt guarantees, Minimum Revenue Guarantee (MRG), or direct cash support. The incentive system is an important factor in determining the success of infrastructure projects but still not lucrative in the bidding process due to the failure of traditional capital budgeting theory such as Net Present Value (NPV) analysis in evaluating the value of collateral. This is because the NPV analysis can not reflect the characteristics of a contingent guarantee agreement. This study is to develop a model of risks guarantees of highway infrastructure with binomial real options to evaluated the value of MRG by considering the asset uncertainty , and using detailed level of volatility with a monte carlo simulation approach. Finally, real options models appear to offer a practical and theoretical framework in evaluate MRG agreement and assist governments establish policy of public-private partnership and provision the right bidding strategy in the investment.*

**Keywords :** risk guarantees, minimum revenue guarantee, real options.

## 1. Introduction

Availability of reliable and adequate infrastructure has a very substantial role, sometimes even decisive, for productivity and economic development of a country and the quality of life [1]. [2] estimates that a 1% increase in infrastructure investment associated with 1% increase in Gross Domestic Product (GDP). Similarly, governments in developing countries and industrialized countries in the rest of the world, the Indonesian government also recognizes the importance of infrastructure for national economic growth. GDP growth in the 2004-2009 period, on average, expected to reach 6.6%. To achieve these targets, the required infrastructure investments worth approximately Rp. 1300 trillion [3]. Meanwhile, the fiscal capacity of the Government and other domestic financing from banking institutions, insurance companies, pension funds, and mutual funds can only cover respectively about 17% and 21% resulting in a gap of approximately 62% of total funding needs. The private sector is expected to cover most of the gap in order to achieve the investment target.

Infrastructure development projects, involving the private sector often foundered on the risks difficult to overcome by the respective parties. Thus, in its development needs assurance from the government directly or involve a third party. Assurance government itself set up infrastructure projects in the two existing legal framework. In order to accelerate the development of infrastructure deemed necessary to support the government (government support) to encourage the participation of enterprises and increasing investment in infrastructure provision. Furthermore, government support is financial compensation or other compensation given by the government to businesses through risk sharing scheme for the implementation of joint infrastructure projects.

Guarantee risk is very important, because without the certainty of handling the risks mentioned above as well as the provision of the parties will bear those risks, it would be difficult to convince the private sector, or potential investors and the fund provider (financier) to invest or finance the project or participate in infrastructure projects. It is quite urgent applied to infrastructure projects, especially in Indonesia, the risks perceived by investors are still relatively high. The purpose of this study was to develop a model of risk assurance highway infrastructure with binomial option for evaluating the value of assets MRG by considering uncertainty, and use a more granular level of volatility with monte carlo simulation approach. Finally, based on the results and analysis, real options model developed seems to provide a practical and theoretical framework to

evaluate the quantitative MRG agreement and help the government build public-private partnership policy better and help make the right bidding strategy in the investment.

## 2. Toll Road Infrastructure in Indonesia

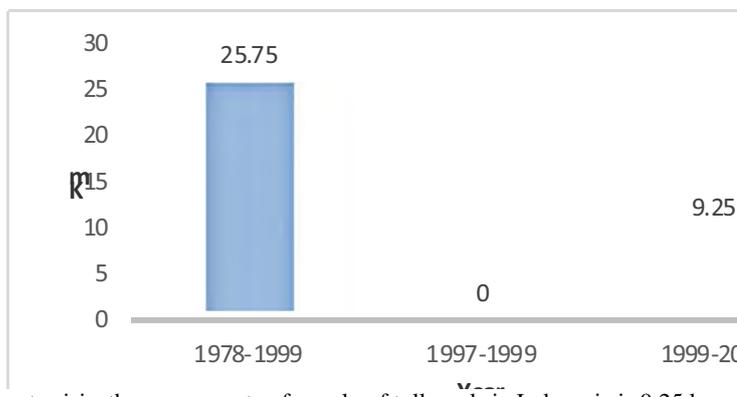
Due to the financial crisis in July 1997 which resulted in the government should suspend highway construction program with the issuance of Presidential Decree. 39/1997. Due to delay construction of toll roads in Indonesia stagnant, as evidenced by the establishment of only 13.30 km of highways in the period 1997-2001. In 1998 the government issued Presidential Decree No.7/1998 on Public-Private Partnership in the provision of infrastructure. Furthermore, in 2002 the government issued Presidential Decree. 15/2002 concerning forwarding infrastructure projects. The government also evaluated and forwarded to the exploitation of toll road projects were delayed. From 2001 to 2004 awakened 4 roads with a total length of 41.80 km. In 2004 issued Law No.38 of 2004 on the road instead of the establishment BPJT regulator role that had been held by PT Jasa Marga.

The process of re-entering the highway construction acceleration phase began in 2005. On June 29, 2005 established the Toll Road Regulatory Agency as a regulator of toll roads in Indonesia. Continuation of the 19 toll road construction projects postponed in 1997 took place. In the future the government will fund the construction of toll roads using three approaches, namely full financing by the private sector, public-private partnership program (Public Private Partnership / PPP) and the financing of the construction of the Government and by private-maintenance operation. Phase development of toll roads in Indonesia brief seraca can be seen in Table 2.1 below.

Table 1 History of Toll Roads in Indonesia

Phase	Period	Specification
I	1978 – 1983	Toll facility entirely funded through the government budget
II	1983 – 1987	Toll facilities financed using a combination of public funds and bonds Jasa Marga
III	1987 – 1994	Toll road market open to domestic private investors
IV	1996 – current	Toll road market was opened to foreign investors of private sector land acquisition

The pace of construction of toll roads in Indonesia can be distinguished in the condition as shown in Figure 2.1, the pre-crisis (1978-1998), during the crisis (1998-1999) and post-crisis (1999-present). In the pre-crisis levels, the average rate of supply of the highway is at 25.75 km per year, during the supply crisis relatively highway so that growth is the growth rate equal to zero.



While the post-crisis, the average rate of supply of toll roads in Indonesia is 9.25 km per year

Figure 1 Growth in toll roads per year

### 3. Government Guarantee Assessment Project Financial Analysis with Real Option

#### 3.1 Analysis of Net Present Value (NPV) and Internal Rate of Return Analysis (IRR)

Traditional analysis Discounted Cash Flow (DCF), NPV analysis works well when the risk of the assets remained stable over time. Traditional assessment methods are sufficient for the investment decisions regarding the assets in place if the operation ensures a relatively stable cash flow [4,5]. NPV analysis also works well for a typical engineering investment as replacement equipment if the main benefit is cost reduction. However, sometimes the project creates the possibility of a contingency such as delay, abandon or expand the project by changes in management decisions. And, changes in future cash flows as a result of development or new information is received. In this case, the NPV analysis have either underestimate or ignore the value of this management flexibility [6,7,8,5]. After starting role in the investment risk, the NPV analysis can accommodate risk attitudes using risk-adjusted discount rate for discounting the expected cash flows. In the real world, in general, many companies classify different risk categories of the project and set the price of each of the different categories to reflect the risks involved [7] or using different discount rates in different periods to reflect changes in interest rates nominal [9]. Even as the NPV analysis has been widely used in almost every industry as an effective method of project appraisal, there was also some criticism that can be leveled against it.

Along with the analysis of NPV, Internal Rate of Return (IRR) is a popular approach to the analysis of capital budgeting as intuitive as with rate of return. Generally, the NPV decreases with increasing discount rate. At some value of the discount rate, the NPV of a certain cash flow stream is zero. This is the discount rate that makes NPV equal to zero is called IRR. That is, the IRR is the rate of return on investment of the project is reflected in a set of future cash flows [9,10]. If the IRR is higher than the required rate of return, then the project is considered acceptable. In general, the required rate of return earned by the cost of borrowing for similar projects plus a few percentage points higher than the cost of borrowing to compensate for the risk, time, and the problems associated with investment [11]. Unlike NPV analysis, this approach can help to eliminate the problem of selecting the appropriate discount rate but still produces more questions in a way to determine a reasonable hurdle rate to be used as a standard to estimate if the IRR is high enough to agree to the project.

#### 3.2 Monte Carlo simulation approach

Monte Carlo simulation approach, as one of the extensions of the NPV analysis, is to explain the uncertainty [12,7] and was originally proposed by [13]. The simulation procedure is used to identify the key variables that determine the cash flow of the project and then simulate the variables to obtain the distribution of the cash flow generated or NPV. It is an analytical approach that relies on repeated random sampling from the probability distribution of the main variables underlying cash flows of the project to arrive at a risk profile, which is a distribution of cash flows or NPV [14]. This simulation reflects real-world setting decisions using mathematical models to capture the essential characteristics of the project as it progressed through time and encounter various random events. As a common type of simulation approach, Monte Carlo simulations generally follow the following process [14,7]. The first is to identify all the variables of uncertainty in project cash flow setup, noting the interdependencies between different variables and any serial dependence. In the second process, for each variable is uncertain, it defines the possible values of with probability distribution. Here, the type of distribution is selected based on the nature of the uncertainty of that particular variable. The third, and then selected a random value for each variable bound by a probability distribution to calculate the net cash flow for each period and then the NPV. Eventually, this process will be repeated for a number of iterations, which produces a probability distribution for the project NPV.

#### 3.3 Assessment of Real Option Analysis

Option Pricing theory, designed in financial assets by [15] and [16], are the building blocks of the concept of Real Option Theory to figure out the interaction between the behavior of option holders maximize profit "Theory of Option real." , An asset uncertainty, and market discipline. Financial concept imported to evaluate the real assets of physical investment, which was then called "options." So, the real option theory is the application of financial option pricing theory as a management tool to evaluate investment real assets [6]. Real option analysis, in many respects, be considered as an effective tool to evaluate embedded options and flexibility in projects such as oil and gas, pharmaceutical, manufacturing, aviation, mining, real estate, and other industries. In financial assets such as stocks, bonds, currencies and so on, the choice is right, but not the obligation, to perform certain actions in the face of uncertainty. Likewise, in tangible assets, tangible, like a project or a business relative to financial assets [17], real option is the right, but not the obligation, to take some specific action. This is referred to as "management flexibility" as delay, abandon, or expand a fee for a certain time [18].

Real options theory provides a framework for analyzing strategic capital investment by identifying the flexibility of management to be handled as a valuable opportunity [19] so that decision makers can keep the investment options open in the face of uncertainty and is done after finishing with a time of uncertainty or further information [20]. When the present value of the cost of decision making changes during construction or operation outweigh the additional cost to design flexibility into the investment opportunities in the beginning [21], the options actually available.

The main difference between real option analysis and NPV analysis comes from some of the effects of different variables to the model. For example, the higher the uncertainty, the greater the interest rate, or more time before doing a project does not necessarily make the investment opportunities are less valuable in the analysis of options, as well as the NPV analysis [7]. That is, although each of these factors have a negative effect on the NPV of the investment opportunities, these factors may increase the value of the choices made by the managerial flexibility.

#### 4. Qualitative Risk Assessment

A qualitative risk assessment (qualitative risk assessment or QRA) consists of several stages, ranging from risk identification and risk analysis qualitatively. QRA approach is taken to facilitate the respondents, especially those from the industry, in an opinion which is very valuable to get the global information about the risks of toll roads.

Of the 27 (twenty seven) types of risks identified can be drawn perspective possible, land acquisition delays risk factors (R3) be a risk factor ranks highest, followed by the risk of late payment (R4), and the risk of cost escalation (R10). Meanwhile, the risk of low traffic volume only sorted on the 11th although this risk is often a major concern for prospective investors considering the difficulty of prediction of traffic volume carried, not only for the long term but in the short term. Meanwhile, the impact of the dimensions of the event, delay in land acquisition risk factors (R3) again ranked top, followed by the risk of the claim (R6), which has ranked second level in terms probability and risk financing (R1) was third. This survey shows that the two main risk factors in the toll road business is a risk and the risk of higher land acquisition costs. Furthermore, the trend of the probability and impact is calculated based on the arithmetic average of each factor for subsequent mapping (mapping) that terdiri four groups: a) high-probability high impact, b) low-probability high-impact, c) low-probability high-impact high, and d) low-impact low probability. This mapping is useful to determine what mitigation measures are most appropriate. For example, if a risk factor known to have a high risk of impact despite having a low probability, risk transfer to third parties, for example, is one of the mitigation options that could be considered. The results obtained can be seen in Figure 2.

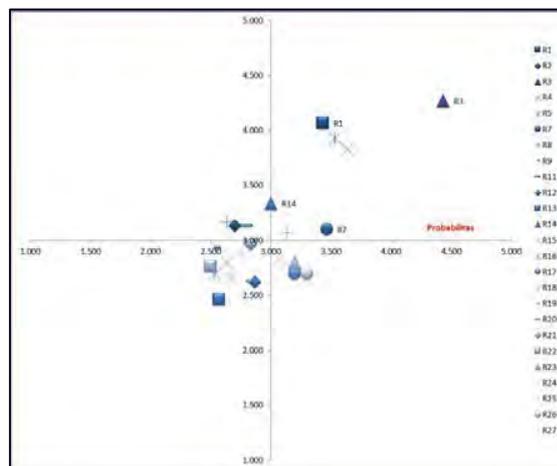


Figure 2 Diagram Risk Probability and Impact Factor

#### 5. Model Government Guarantee

Government guarantee on infrastructure projects set in two existing legal framework. First is PP67/2005 Article 17 and PMK 38/2006. Article 17 of Presidential Decree No. 67/2005 states the government can provide fiscal support to the PPP project by

asserting that such support should follow the principles of risk management and its mitigation and within the framework of the state budget or the budget. This task should be done by the Minister of Finance, or the Head of Unit in the Region.

Meanwhile, PMK 38/2006 states that in order to accelerate the development of infrastructure deemed necessary to support the government (government support) to encourage the participation of enterprises and increasing investment in infrastructure provision in Indonesia. Furthermore, PMK 38/2006 states that government support is financial compensation / or other compensation given by the government to businesses through risk sharing scheme for the implementation of joint infrastructure projects (article 1). As for the types of risk that needs to be risk sharing schemes between government and business entities in the provision of infrastructure is the political risk, the risk of project performance, and demand risk. The risk of project performance by PMK 38/2006 is the location of risk and operational risk. While the demand risk are: 1) if actual revenues is lower than the minimum revenues. 2) the realization of revenue is higher than the minimum acceptance.

Given the nature of the conditional payment, warranty or guarantee of characteristics that are similar to a derivative financial instrument option (option). Options are contracts that give the right, but not the obligation, to the holder (holder) to buy (call) or sell (put) a particular asset (the underlying asset) at a specified price, known as the exercise price at a specific time or:

$$Q_c = \begin{cases} Q_{\min} - Q & \text{bila } Q < Q_{\min} \\ 0 & \text{bila } Q \geq Q_{\min} \end{cases} \quad (1)$$

Since Q in Equation 1 is uncertain (stochastic), the amount of Qc is also stochastic. Because of this contingent liability insurance is often called "conditional on some future event."

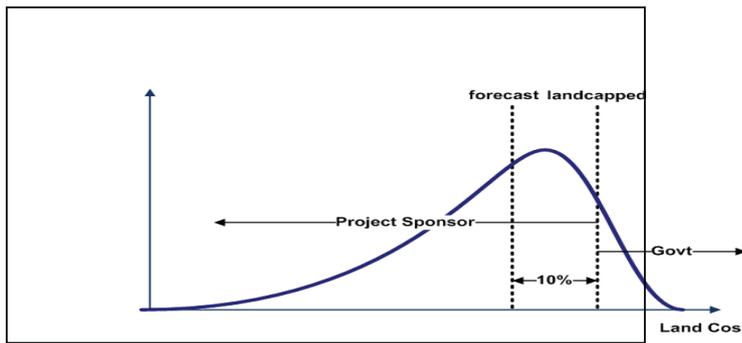


Figure 3 Risks Sharing the Land Acquisition Costs

For example, cases in this study used the Project Cileunyi-Tanjung Sari-Sumedang with basic assumptions used remained the same or if duplicated here:

Table 2 Probability Function Assumption of Risk Factors

Risk	distribution	Parameter
inflation rate	Lognormal	Mean=8,8%, standar deviasi=3,4%
Interest rate (BI rate)	Lognormal	Mean =9,8% dan standar deviasi =1,7%
Accuracy construction costs	Triangular	Minimum=5%, most likely=0%, maximum=15%
Escalating cost of land acquisition	Uniform	Minimum=20%, maximum=70%
volume of traffic	Triangular	Minimum=nilai pesimistik, most likely=nilai moderat, maximum=nilai optimistik

In the simulation, the government intends to use the numbers to guarantee minimum traffic volume 80% of moderate value for all of the concessions and give landcapping Rp. 75,000 per m<sup>2</sup> (these values are preliminary estimates before adjusting with escalating expectations of 45%). Table 3 shows the differences in the major statistical indicators before and after guarantee eligibility. As can be seen, the average IRR increased slightly from 12.12% to 12.37% IRR atan will be in the interval between 8.49% (percentile 5) and 17.28% (percentile 95) (see Table 4.3). When used MARR of 10%, the level of confidence only increased from the previous 75% to 79%. In the model used, the provision of guarantees to the value of the fixed course for business entities, the project still has a negative value which meant that the project remains viable despite there landcapping and minimum traffic guarantee as mentioned.

Table 3 Summary Statistics Difference Simulation (1000 iterations)

Statistics	Before Guarantee		After Guarantee	
	NPV	IRR	NPV	IRR
Trials	1000	1000	1000	1000
Mean	-243.049	12,12%	-220.823	12,37%
Median	-242.215	11,86%	-219.053	12,07%
Mode	---	---	---	---
Standard Deviation	19.691	2,82%	18.668	2,81%
Variance	387.729.715	0,08%	348.511.752	0,08%
Skewness	-0,2887	0,9180	-0,3301	0,9035
Kurtosis	2,68	4,63	2,76	4,57
Coeff. of Variability	-0,0810	0,2325	-0,0845	0,2274
Minimum	-304.541	6,14%	-281.220	6,44%
Maximum	-200.898	27,62%	-174.686	27,76%
Range Width	103.643	21,48%	106.534	21,31%
Mean Std. Error	623	0,09%	590	0,09%

## 6. Conclusion

Finally, with real option models that use the IRR, NPV adjusted with the Indonesian Government policy can be used to measure security against the risk of the development of the necessary infrastructure highway.

## References

- [1] Mody, A. and D. Patro. 1995. *Methods of Loan Guarantee Valuation and Accounting CSF Discussion*, Paper No. 116, Washington, DC: World Bank
- [2] World Bank. 1994 Timothy C. Irwin, *Government Guarantees : Allocating and Valuing Risk in Privately Financed Infrastructure Projects*, Project Finance and Guarantee Department, Washington, DC.

- [3] Giriana, M., 2005, "A Road Map for Infrastructure Financing", Prosiding Seminar 25 Tahun Pendidikan Manajemen dan Rekayasa Konstruksi di Indonesia 18-19 Agustus 2005 di Departemen Teknik Sipil, Institut Teknologi Bandung, Bandung.
- [4] Luehrman, T. 1998. "Investment Opportunities as Real Options: Getting Started On the Numbers". Harvard Business Review July-August 1998. Boston, Massachusetts.
- [5] Myers, S.C. 1984. *Using Simulation for Risk Analysis*, Journal of Finance, 39: 575-592
- [6] Amram, M. and N. Kulatilaka. 1999. *Real Options: Managing Strategic Investment in an Uncertain World*. Cambridge, MA: Harvard Business School Press.
- [7] Trigeorgis, L. 1999. *Real Options: Managerial Flexibility and Strategy in Resource Allocation*. Cambridge, MA: The MIT Press.
- [8] Dixit, A.K. and R.S. Pindyck. 1995. The Option Approach to Capital Investment. *Harvard Business Review*, June: 105-115.
- [9] Aggarwal, R. 1993. *Capital Budgeting under Uncertainty: New and Advanced Perspectives*. Englewood Cliffs, NJ: Prentice Hall
- [10] Herbst, A.F. 1982. *Capital Budgeting: Theory, Quantitative Methods and Applications*. New York: Harper & Row Publishers, Inc.
- [11] Butler, J.S. and B. Schachter. 1989. The Investment Decision: Estimation Risk and Risk Adjusted Discount Rates. *Financial Management*, 18(Winter): 13-22.
- [12] Razgaitis, R. 2003. *Dealmaking: Using Real Options and Monte Carlo Analysis*. Hoboken, NJ: John Wiley & Sons, Inc.
- [13] Hertz, D.B. 1964. *Risk Analysis in Capital Investment*. Harvard Business Review, 42(1): 95-106.
- [14] Evans, J. R. and D.L. Olson. 1998. *Introduction to Simulation and Risk Analysis*. Construction Management and Economics, 20: 143-156
- [15] Black, F. and M. Scholes. 1973. *The Pricing of Options and Corporate Liabilities*. Journal of Political Economy, 81: 637-54.
- [16] Merton, R.C. 1973. *Theory of Rational Option Pricing*. Bell Journal of Economics and Management Science, 4: 141-83
- [17] Copeland, T.E. and V. Antikarov. 2001. *Real Options: A Practitioner's Guide*, New York: Texere LLC.
- [18] Reiss, A. 1998. *Investment in Innovations and Competitions: An Option Pricing Approach*. The Quarterly Review of Economics and Finance, Special Issue, 38: 635-650
- [19] Dixit, A.K. and R.S. Pindyck. 1995. *The Option Approach to Capital Investment*. Harvard Business Review, May-June: 105-115.
- [20] Trigeorgis, L. 1993a. *Real Options and Interactions with Financial Flexibility*. Financial Management, 22(3): 202-224.
- [21] Lander, D. M. and G.E. Pinches. 1998. *Challenges to the Practical Implementation of Modeling and Valuing Real Options*. Quarterly Review of Economics and Finance, Special Issue, 38: 537-567.

## Development of Indonesian Airport Infrastructure “Is the PPPs Solution?”

Bambang Susantono<sup>a</sup>, Sigit P. Hadiwardoyo<sup>b</sup>, Eny Yuliawati<sup>c</sup>

<sup>a</sup>Department of Civil Engineering, Faculty of Engineering, Univerisity of Indonesia  
 Kampus Baru UI Depok 16242  
 Phone : (021) 7270029 – Fax. (021) 7270028  
 Email: bsantono@gmail.com

<sup>b</sup>Department of Civil Engineering, Faculty of Engineering, Univerisity of Indonesia  
 Kampus Baru UI Depok 16242  
 Phone : (021) 7270029 – Fax. (021) 7270028  
 Email : sigit@eng.ui.ac.id

<sup>c</sup>Department of Civil Engineering, Faculty of Engineering, Univerisity of Indonesia  
 Kampus Baru UI Depok 16242  
 Phone : (021) 7270029 – Fax. (021) 7270028  
 Email : enjulia\_2005@yahoo.co.id

### ABSTRACT

Indonesia is one country that the growth of passenger air transport is very fast in the world, with the domestic air passengers grew on average 12,8 % and international air passengers 15,7 % per year the airport infrastructure would be necessary. However, the allocation of state budget for the transportation sector is still limited, budgeting for airport infrastructure only Rp. 19,5 trillion meanwhile the need for the development of 233 airports in Indonesia during 5 periods amount Rp. 54 trillion, it means there is the financing gap Rp. 34.5 trillion or more than 63% of the funds needed are not covered.

The purpose of this paper to explore the funding gap on development the airport infrastructure in Indonesia and discuss the problems of any obstacles on involving the private sector on Indonesian airport infrastructure development with considering the characteristics of the Indonesian airport

Therefore it required to think how the important efforts of the Indonesian Government could be conceived to create a more conducive climate to stimulate the private sector to invest in the Indonesian airport infrastructures.

#### Keywords:

Airport infrastructure, Funding Gap, PPP, Indonesian Airports.

### 1. INTRODUCTION

Infrastructure development is an important and vital aspect for the economic development of a country. It plays also an important role for the driving of the economic growth. The economic growth of a country can not be separated from the availability of infrastructures such as transportation, telecommunications, sanitation, and energy. Therefore the development of this sector is a key dimension to push further the economic development.

The 1997-1998 economic crisis that south-east asiatic countries faced yielded many consequences, especially concerning the funding of infrastructure in Indonesia. The infrastructure projects funded by both the private and the state budget were reduced drastically. The state budget for this sector has declined by approximately 80% compared with the situation before the crisis. In 1994, the central government spends nearly 14 billion U.S. dollars for construction, 57% were for infrastructure. In 2002 the development expenditure reached only roughly 5 billion U.S. dollars and only 30% of the previous amount for infrastructure. Infrastructure development has provided the foundation for supporting the economic and socio-cultural life of society. Nevertheless there are still many challenges in Indonesia, especially when the infrastructure is not functioning properly because there are still many the isolated regions.

This paper deals with the airport infrastructure needs in Indonesia, and especially it investigates the possibility of finding a solution to fund them. Section 2 shows how the airport infrastructures are important in Indonesia: they are the conditions of the economic growth of the country. They are also a source of growth for many economic sectors.

Section 3 presents the financial needs of Indonesia concerning transport infrastructure. In fact, Indonesia faces a financial gap. The private sector could be a solution, but there are some important institutional constraints to take into consideration. Section 4 deals with the current situation of airport infrastructures in Indonesia, which could be seen as a kind of puzzle, but has to be conceived as a network. The sector of airport infrastructure knows a dynamic growth for its activity. The last section is

concerned with the PPP solution. It develops the institutional framework and details the different involve parties and their functions.

## 2. The Current Situation for the Airport Infrastructure in Indonesia

The system of air transportation infrastructure consists of the airport, which have a function of node and the air space that have a function of an organized air traffic space. In Indonesia, the airports were differentiated by function, utilization, classification, status, management and the activities. Based on the hierarchy of functions, the airports are grouped into the hub airport category (distribution centers) and the spoke airport category (non distribution center). The hub airport is divided on the service scale of primary, secondary and tertiary, depending on the importance of traffic, while the spoke airports play the role of collectors and one of the support infrastructures in servicing the local activities. The criteria hub and spoke airports based on the number of passengers (hub airports = 5 Million passengers >X ≥500 thousand passengers per year and spoke airport = >500 thousand passengers/year).

Another categorization is possible when the type of utilization is considered as a criterion. Airports can be grouped into two different categories the international airport and the domestic airport. The international airport is the airport which serves the domestic and the international flights and the domestic airport is the airport which serves only the domestic flights. If the status is considered, the airport can be categorized on the public airport and the special airport. The public airport is the airport which is opened for the public interest and the special airport is the airport that owned for the private interest for example only used for the operational of company (the oil company, manufacturing company, etc)

Based on Ministry Regulation No. 11 of 2010 on the National Airport System, followed the data of airports of 2010 on the categories function and utilization by the big island in Indonesia. (Table 1).

Table 1: The Number of Airport in Indonesia by Function and Utilization

No	Island on Indonesia	Domestic		International	
		Hub	Spoke	Hub	Spoke
1.	Sumatera	7	27	8	2
2.	Jawa	3	7	6	1
3.	Bali-Nusa Tenggara	5	11	4	0
4.	Kalimantan	12	19	4	0
5.	Sulawesi-Malut	7	24	2	0
6.	Papua-Maluku	7	73	4	0
Total		233			

Source: Ministry Regulation No. 11 of 2010, 2010.

It can be drawn many highlights from the table 1. First, there is a high number of airports in Indonesia. Few of them can be considered as a national hub or a node of connections for the country. The most of part of them play a role of connection (a frontier spot inside the web of airport infrastructures in Indonesian. and the second the degree of openness towards outside countries concerns only a minor of them. The majority of airports are oriented towards domestic considerations. We have to conclude that airport situation is hugely segmented with some implications in terms of traffic, connexions with outside countries, and their role of node. Obviously this high diversity means consequences concerning the business of each category of airport infrastructures, but also the interest of the private sector in investing in such a project. Some implications for the institutional framework have to be into consideration.

The second important fact concerns the importance of the number of passengers. In 2009, almost one hundred million of passengers used the airport transport infrastructure. Roughly 83% of the total concerns domestic transportation (table 2 and table 3). Over the period 2005-2009 domestic air transportation increased by 42,58 %. This increase was superior to 42,63 % for international air transportation. It emphasizes the existence of huge opportunities for the private sector.

Table 2: Development of Domestic Air Transportation Passengers in 2005-2009

Airport Operator	2005	2006	2007	2008	2009	% growth fifth annual
DGCA	3.282.812	7.878.049	6.276.658	9.363.021	9.468.693	188,43%
SOE I	23.620.739	25.146.501	26.485.137	27.955.926	32.536.219	37,74 %
SOE II	31.126.276	34.310.728	36.548.878	35.928.628	40.731.734	30,86 %
Total	58.029.827	67.335.278	69.310.673	73.247.575	82.736.646	42, 58 %

Source: Statistic of Ministry of Transportation, 2009.

Table 3: Development of International Air Transportation Passengers in 2005-2009

Airport Operator	2005	2006	2007	2008	2009	% growth fifth annual
DGCA	32.551	25.656	10.476	18.891	33.112	58,02 %
SOE I	4.292.904	3.995.520	4.980.058	5.771.360	6.643.884	1,83 %
SOE II	6.959.800	7.315.848	8.059.377	8.549.403	9.419.545	2,83 %
Total	11.285.255	11.337.024	13.049.911	14.339.654	16.096.541	42,63 %

Source: Statistic of Ministry of Transportation, 2009.

The current situation of the market for airport infrastructures is characterized by a complex system of airports linked through different connections and by different categories of airports. They are not homogeneous, meaning without doubt the existence of high variability of economic activities, and the existence of markets. Second, these markets know a very level of expansion. Third, each market are not independent, they belong by a network embedded in pregnant institutional framework.

### 3. Airport facilities and services as a bundle of revenues a self-funding source

In the long term perspectives of growth in air transport industry represent an important reason for the private sector to be present and to be interested in airport business. When comparing within air transport industry, airport have significantly better results in operating margin ratio than airlines (Graham, 2008). Moreover airport infrastructures represent complex entities providing a wide range of business activities. They can provide a bundle of goods and services. These goods and services can be categorized in core (or aeronautical) as well as non-core (or commercial) ones (Akintoye, A & Beck, M, 2009). Most airports provide retail shops and parking facilities not only for airline passengers and their visitors but also to residents of the area. They are also retail outlets and airport free zones which are bonded areas, adjacent to the airport premises which, as the name suggests, are duty free areas promoting industry and other commercial activity. For example, at Heathrow International Airport London as the Mega Mall in the world class, so that someone who wants to buy clothes of the famous French products not needed to be to Paris. Indonesia of course can imitate these things mainly can be developed in the big cities and tourist destinations in Indonesia which is of course needed the integrated planning between the actor of businesses and relevant agencies (Dikun, 2007)

Marketing all these provisions of goods and services permit for airports to optimize their revenue and to exceed all direct and indirect operating costs, including general administration etc, and so provide for reasonable return on assets (before tax and cost of capital) to contribute toward necessary capital improvements (PPP Model of Indian Airports). The International Civil Aviation Organization (ICAO) recognizes the continuing importance for airports of deriving income from such sources as concessions, rental of premises and "free zones" (ICAO, 2001). ICAO encourages also a policy of autonomy for airports by marketing such activities and becoming independent from the public realm. However it is quite uncertain that the marketing of goods and services will be enough to cover the current financial needs.

### 4. The Private Public Partnership Scheme as a Solution?

According the report of the ICAO the overall passenger growth was 5.7 % over the period 1999-2000 and after 6 % per year, it is almost uncontrollable growth in demand for air transport services has prompted countries across the world, from Australia to Zimbabwe, to consider seriously the selling of their airports to private entrepreneurs. It is distinctly possible that, in keeping with this trend, hundreds of airports may be sold over the next few years. Indonesia faces huge financial needs to complete the investment program for developing airport infrastructures.

The vision of the regulation of planning national airport in Indonesia rests upon a vision of airport as a reliable, integrated, efficient infrastructure. It has to support global competitiveness by promoting regional and national development of the Indonesian archipelago (DGCA Ministry of Transportation Indonesia, 2010). With the review of the regulation planning of national airports, the Indonesian government plan to distinguish the different air traffic services concerning the activities of airport services/ single Air Traffic Service Provider (DGCA Ministry of Transportation Indonesia, 2010). It is expected that the private sector could help in completing the financial gap the authorities face.

However, although the participation of private capital could be very helpful in funding the investments and could be involved in the management of airport infrastructure, such involvement has to be aligned with the lines of development defined by the government. Consequently, the private operation of airport infrastructure and the participation of private capital holder would be constrained by a strong institutional framework, which would influence the contracting dimension with the private sector. Indeed the Indonesian government still has some doubts to involve fully the private sector in managing the airport because the government through the state owned enterprise (SOE/BUMN) privileged this way to operate the commercial airport for obtaining income and Technical implementing units (UPT) of the Directorate General of Civil Aviation for operating the non commercial airport. Consequently, the current main source of funding for the transport infrastructure development is derived from the government budget (APBN). However public transport infrastructure investments have a tendency to involve large amounts of money with a very low rate of return. It does not help in solving the financial gap previously described. It explains why some other policies are followed and that some of them encourage the participation of private sector, the community and

the local government in developing and operating infrastructure and transportation facilities. However they have to maintain and keep paying attention to aspects of public services which represents an important duty for the government. Nevertheless the Aviation Act No. 1/ 2009 stated that the government will let an important role to the private sector related to the transfer of management and ownership. It implies also to limit the public sector investment, to free the access to commercial markets, to circumscribe the government control, and have competitiveness on airport business (Indonesia Aviation Act, 2009). It is expected such openness to the private sector could help in answering the requirements related to the development of airport infrastructure and services while being in conformity with the political constraints defined by the government. However, the pattern and how the financing scheme that will be used in accordance with the characteristics of airports in Indonesia is not currently defined. It implies the pattern for the private sector's role and the contracting dimensions of such intervention have to be defined and negotiated. It implies also to find an appropriate pattern for associating successfully government and the private sector and defining the financial scheme (Yescombe, 2002). Moreover public private partnerships scheme can be considered as being a specific channel through which transnationalization of airport business become possible for Indonesian airports and put them as global airport players (Tomova, 2009). In this sense, the Indonesian airports would benefit from a new dimension with a private provision.

## 5. CONCLUSION

Indonesia as the biggest archipelago country in the world with more than 17,000 islands makes the infrastructure a key factor for economic development and for regional development purposes. Infrastructure, especially transport and connectivity, are crucial for regional cooperation and integration. At present, the conditions in Indonesia in terms of transportation infrastructure, especially concerning its funding could not support the growth of transportation sector meanwhile transportation is one of a network chain in the distribution of goods and passenger movement. Therefore the inadequate transportation infrastructure and facilities has important consequences for economy (reduced economic competitiveness of exports, constraint on GDP/GRDP), for operation of airports (increased costs of operations), the quality of services (queuing, availability, capacity, etc), and the performance of airports (increased delays, lower safety, reduced comfort, etc). The private funding is an unavoidable solution.

## REFERENCES

- [1] Akintoye, A. & Beck, M. (Eds.), (2009) *Policy, Finance & Management for Public-Private Partnerships*. Blackwell Publishing Ltd, Oxford.
- [2] Dikun, S. (2010), *Indonesia Infrastructure Initiative*, Indonesia, Jakarta.
- [3] Dikun, S., (2003), *Infrastruktur Indonesia, National Development Planning Agency of Indonesia*, Jakarta.
- [4] Edkins, A.J., Smyth, H.J., 2006. Contractual management in PPP projects: evaluation of legal versus relational contracting for service delivery. *Journal of Professional Issues in Engineering Education and Practice* 132 (1), 82–93.
- [5] Graham, A. (2008), *Managing Airports: An International Perspective*. Butterworth-Heinemann.
- [6] Grimsey, D. and M.K. Lewis (2000), *The Risk of Public Private Partnerships for Infrastructure Projects*, International Journal of Project Management, Australia.,
- [7] Indonesia, Aviation Act No: 1 of 2009 on Civil Aviation, Ministry of Transportation Indonesia.
- [8] ICAO, 2001. Doc 9082/6 ICAO's Policies on Charges for Airports and Air Navigation Services.
- [9] Ministry Regulation No: 11 of 2010 on the National Airport System, Ministry of Transportation Indonesia.
- [10] Rajan T., Shared S. and S. Sinha (2009), "PPP in Greenfield Airport Development: A Case Study of Cochin International Airport Limited", in Akintoye, A. & Beck, M. (Eds.), *Policy, Finance & Management for Public-Private Partnerships*. Blackwell Publishing Ltd, Oxford.
- [11] Susantono, B. (2010), *Attracting Investment in The Transportation Sectors Recent Measures and Opportunities*, Indonesia Day, Asia Pacific Ministerial Conference UNESCAP.
- [12] *Transportation Statistic (2009)*, Ministry of Transportation Indonesia, Jakarta.
- [13] Tomova A., (2009), *PPP Projects and Airports: Experience and State in world Regions*, Department of Air Transport University of Zilina, The Slovak Republic.

[14] Yescombe, E.R. (2002), *Principles of Project Finance*. Academic Press Publisher, London.

# The Orientation Angles Rating of the Simple Model Construction In Residential Region Closed to the Airport

Erni Setyowati<sup>a</sup>, Anggana Fitri Sadwikasari<sup>b</sup>

<sup>a</sup>Faculty of Engineering, University of Diponegoro, Semarang 50275  
E-mail : ernisyahdu@gmail.com

<sup>b</sup>Faculty of Engineering Islamic University of Indonesia, Yogyakarta  
E-mail : anggana\_fitri@gmail.com

## ABSTRACT

Many cities in Indonesia have an airport located near the downtown area. Those airports certainly propagate noise disturbance to the environment included the residential areas. Housing units were built without silencer elements gain considerable noise emissions. Ahmad Yani Airport in Semarang city changed its status from National Airport to International Airport. As a result, housings surrounding the airport are increasingly disturbed by the noise, because the flight intensity is increase. Based on the flight schedule issued by PT. Angkasa Pura, there were about 68 scheduled flights a day. This study is a modeling research that measure values of noise reduction on the building model created in the field with the certain value of Sound Transmission Loss (STL). Analyses of the research were obtained by using Completed Randomized Design (CRD) or Compare Means Sample. With these methods, it established the rating result that the angle rotations of simple building models could significantly reduce the noise level received by inhabitants in the housings.

**Keywords:** Simple model constructions, STL, Compare Means, Angle orientation Rating

## 1. INTRODUCTION AND BACKGROUND OF STUDY

This environmental acoustic research had been done in 2011. Based on preliminary observations, it was found out that the housing near the airport had been disturbed by the noise generated by airport activity at the time when the air plane landed and took off. The research carried out at the time showed results that the difference in orientation of buildings to the runway would have any differences in the sound level received by inhabitants in buildings. Building materials become the other variables that affect the level of noise.<sup>1,2</sup>

Due to the existing house has limited variety of angles to the runway orientation, hence researchers then made building models that have a value of STL (Sound Transmission Loss) similar to houses on the real conditions. These models could be rotated on their axes so that the varying orientation angles could be observed accurately. This full paper will discussed in detail the methodology of research conducted by the researchers, starting from the description of graha padma residence, the housing near the noisy airport as an object sample, and concluded with the output rankings of angle building orientations based on the Compare Means Sample method that was found through this experimental research.<sup>3,4</sup>

## 2. NOISY HOUSING NEAR THE AIRPORT AND RESEARCH AIM

Noisy Housing taken as a sample in this study was Graha Padma Residence, because this Residence is getting the highest sound level than other housings around Achmad Yani Airport in Semarang. Graha Padma has several clusters; one of them is Avonia cluster that is very close to the airport runway. The cluster is just about 310 meters from the runway. Noise level received by inhabitants in the Cluster is between 80-90 dB.<sup>1,2</sup>

According to the Minister of Environment Decree No. 48/MENLH/11/1996, it is about the Ambient of Noise Level Standard, noise level standards for the housing function area is 55 dB.<sup>5</sup> Based on field measurements, the highest Sound Transmission Loss (STL) value of the existing housing units is ranged to about 29-30 dB, so that the sound level received in the building is still high for about 50-60 dB. This value is still above the noise limit allowed under the Decree No. 48/MENLH/1996. Below is the location of the cluster Avonia toward the airport runway:

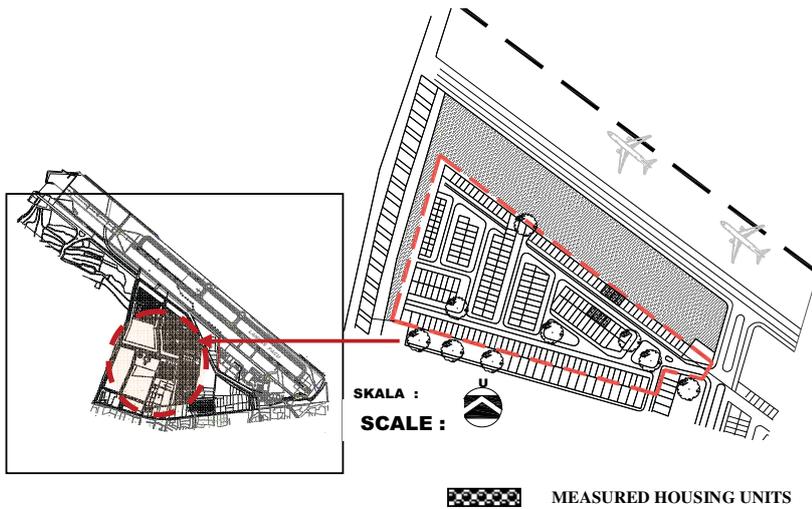


Figure 1: Avonia Cluster Site Plan at Graha Padma Residence

In the figure 1 above, it is only a few angle of the housing orientations can be observed, they are:  $0\sigma$  ,  $180\sigma$  and  $66\sigma$  . This limitation would greatly complicate the analysis because it can only produce a very few number of the data output. In this case, researchers must create building models that have similar value of STL (Sound Transmission Loss) to the actual buildings in the cluster. In order to get the same value with the real STL belong to cluster housings, then the material of the models use the same type of material with the housings material in the real condition. Researchers made the models with the aim of observing the various angle of orientations easily. Therefore, building models should be able to rotate on their axes. Shortly, this study is aimed to find the rating of the orientation angles of housing towards the runway, as an effort to reduce the noise level emitted by the aircraft in both take off and landing.

### 3. RESEARCH METHODS

#### 3.1. Research Limitations

The study draws on the acoustic grand theory, The Inverse Square Law, where the sound level will be inversely proportional to the square of the distance between the sound source and sound receiver.<sup>6,7</sup>

The grand theory contains the understanding that the greater the distance to the sound source, the smaller the sound level received by recipient. And, the smaller the distance to the sound source, the greater the level of sound received by recipient. In the understanding of the theory, and in relation to the distance aspects within the sound source and the building, so the housings close to the airport will have various effective distances to the noise source depend on the angle of orientation and configuration of the building blocks toward the airport runway. The housings as the object of noise will be closely linked with the theory above. Aircraft moving on the airport runway is assumed as the moving sound source. The sound level is considered as the equivalent sound level ( $L_{eq}$ ) in certain period of measurements. Doppler Effect accompanying the movement speed and change of the aircraft position during the period of measurements, is considered negligible.<sup>7</sup>

Meanwhile, the climatic conditions in tropical areas with considerable wind movement will result in changing the behavior of sound in air. The winds that move would lead to changes in the composition and structure of the particles and the air density. The difference in air density will result changes in the rate of sound waves in the air.<sup>8</sup>

#### 3.2. The Real Condition of Housing Type in the Cluster



mission Loss) of about  
 buses:<sup>1</sup>

Figure 2: Housing Types in Graha Padma Residence's Cluster

Follows are the Sound Transmission Loss (STL) of Clivia: <sup>2</sup>

Table 1: Sound Transmission Loss (STL) of Clivia Type in Graha Padma Residence

PERIODS	TYPE OF CLIVIA		DISTANCE FROM RUNWAY (M)	STL (dB)
	INDOOR (dB)	OUTDOOR (dB)		
I	55,25	83,21	373	27,96
II	54,11	83,84	373	29,74
			Σ STL	57,90
			STL mean	28,95

### 3.3. The Replica of Building Models

The Replica Models were mocked based on the observations demand of the sound level in a variety of building orientation angle toward the runway. Researchers made four models, and then divided them into two groups. The first group, as a single model, was considered as a model of control, while the second group was a united- three models represented building blocks as it was in an actual condition. Here is a detail picture of building model created by researchers: <sup>2</sup>



Figure 3: Model Delivery process to the research field

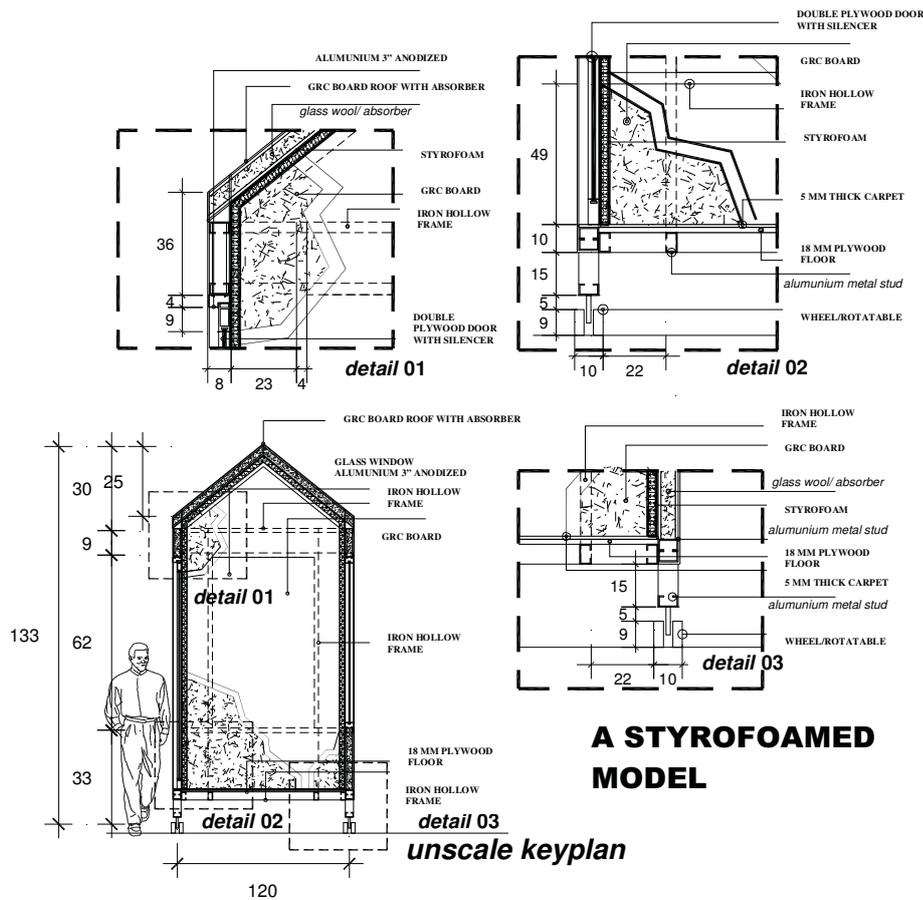


Figure 4: The Detail of Model imitating the real housing<sup>2</sup>

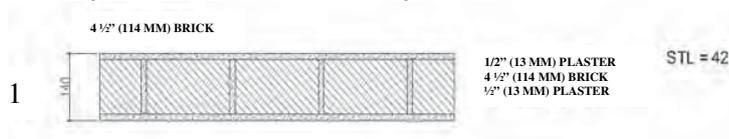
### 3.4. Research Instruments

The research instruments used in this study are :

- a. *Manual Dry – Wet Thermometer.*
- b. *Sound Level Meter* ex Lutron SL-4001 4 units, that are calibrated by KIM-LIPI Laboratory.
- c. *Thermo Anemometer* Ex EXTECH – CFM/CMM serial product: AN – 100
- d. *Camera Digital* that can recorded the movement of airplane.
- e. *Hot wire Anemometer* Ex Extech
- f. *Dry Wet Thermo – Hygrometer* Ex Krisbon

### 3.5. Sound Transmission Loss (STL)

According to L. Doelle, STL values are indicated on each wall construction states the average value, and derived from test results reported by leading experts working in the field of research and testing acoustic.<sup>9</sup> The information shown in the reference table is issued by: A Guide to Air-borne, Impact, and Structure-borne Noise Control in Multi-family Dwellings, National Bureau of Standards, Washington, D.C,1967, and the National Research Council of Canada, Ottawa, in the note of Building Research entitled: Transmission Loss of Plasterboard Walls, 1968. While according to S. Kurra, Selma and N. Tarner that in determining the design of the insulation there are 3 things that need to be addressed: the type of the sound source, the sound level on the facade, as well as the function space.<sup>10</sup> Here are a comparison between some of the materials for this study which are relevant to this study:



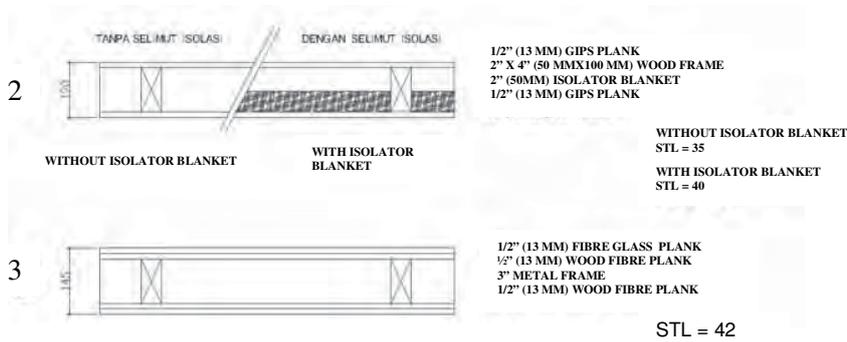


Figure 5: Sound Transmission Loss (STL) Value of models materials<sup>8</sup>

Then the model and then coupled with absorber layer. Absorber used to enhance the value of STL is Styrofoam sheet.

Table 2: Sound Transmission Loss (STL) of Styrofoamed Model

PERIODS	HOUSING MODEL		DISTANCE (M)	STL (dB)
	INSIDE (dB)	OUTSIDE (dB)		
I	52,21	81,45	1	29,24
II	51,66	80,56	1	28,90
III	51,00	80,54	1	29,54
IV	53,72	81,25	1	27,53
V	52,45	81,98	1	29,53
			Σ STL	144,74
			STL MEAN	28,95

This result compares favorably with the values obtained before the models get additional layers styrofoam. With this result, it can be concluded that the model can reduce the sound of 28.685 dB of noise level received at the outer surface of the wall model. These results indicate significant considerable value. As the comparison, it is represented the value of STL on the Clivia (see Table 1).

### 3.6. Relative Value (R<sub>v</sub>)

In order to determine the ranking of the orientation angle of the models, then the models must be able to rotate on their axes. The formula used to determine how much value is the effectiveness of the model in response to the sound level is the Relative Value (R<sub>v</sub>). The Relative value (R<sub>v</sub>) changes due to the velocity of sound is obtained by comparing the value of the sound level model to the sound level value of un-rotated model (control factor).

$$R_v = \frac{L_\alpha}{L_0} \dots\dots\dots(1)$$

- R<sub>v</sub> : Relative Value
- L<sub>α</sub> : Noise Level of model having an orientation angle of α° in deci Bell
- L<sub>0</sub> : Noise Level of model having an orientation angle of 0° in deci Bell

$$\bar{R}_v = \frac{\sum R_v}{\sum x} \dots\dots\dots(2)$$

- R<sub>v</sub> : Relative Value
- $\bar{R}_v$  : Means Relative value
- x : The amount of measurement data

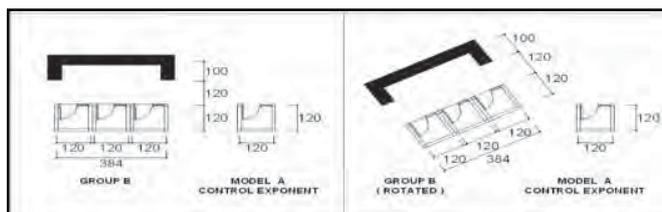


Figure 6: Rotation of the united-model and a control model  
 Equipped with the wall in front of it<sup>2</sup>

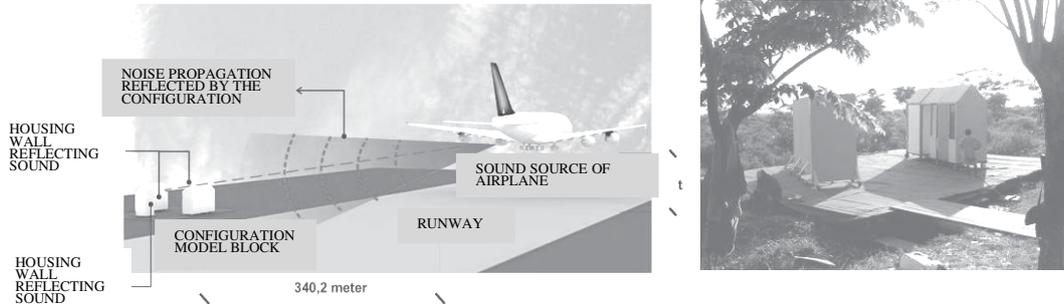


Figure 7: Model position toward the airport runway

Rating the relative values was analyzed using the comparative method of Compare Means Samples (Compare Means). In the field of statistical science, this method is commonly used in the analysis of experimental research. The method is applied measurement data and compares them with a group of control variables.<sup>11, 12</sup>

#### 4. THE RATING OF ORIENTATION ANGLES

The rating of the orientation angles have been established either at the time of takeoff or landing. To give a brief overview but does not reduce the flow of the discussion; the researchers will present the rating results of orientation angles at the time of take off.

Table 3: Rating of the orientation angles outside the models when the airplane take-off

Tukey HSD(a)	KONFIGU	N	Subset for alpha = .05					
	1		2	3	4	5	1	
135	40	40	0.834					
120	40	40	0.844					
150	40	40	0.854	0.854				
90	40	40	0.855	0.855				
210	40	40	0.861	0.861				
45	40	40	0.861	0.861				
240	40	40	0.862	0.862				
30	40	40	0.883	0.883	0.883			
300	40	40	0.898	0.898				
60	40	40	0.900	0.900				
0	40	40		0.922	0.922			
225	40	40		0.928	0.928			
180	40	40			0.950			
315	40	40			0.954			
330	40	40			0.961			
270	40	40						1.041
Sig.			0.050	0.087	0.104	0.344		1

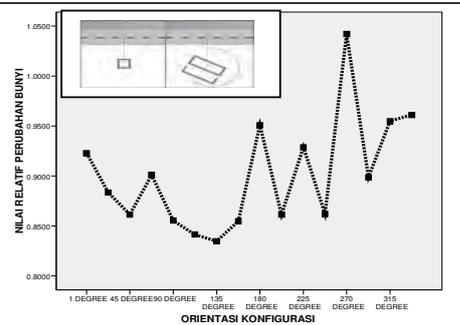


Figure 8: Rating of the orientation angles outside the models when the airplane take-off

Table 4: Rating of the orientation angles inside the models when the airplane take-off

KONFIGURASI	N	Subset for alpha = .05									
		1	2	3	4	5	6	7	8	1	
135	40	0.703									
90	40	0.740	0.740								
150	40	0.746	0.746	0.746							
210	40	0.750	0.750	0.750	0.750						
240	40	0.751	0.751	0.751	0.751						
45	40	0.751	0.751	0.751	0.751						
30	40		0.793	0.793	0.793	0.793					
300	40		0.827	0.827	0.827	0.827	0.827				
60	40			0.828	0.828	0.828					
0	40					0.861	0.861	0.861			
120	40						0.877	0.877			
225	40						0.878	0.878			
180	40							0.916			
315	40							0.922			
330	40							0.930			
270	40										1.076
Sig.		0.824	0.658	0.053	0.077	0.228	0.710	0.226			1

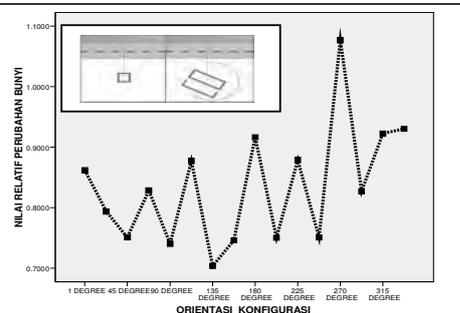


Figure 9: Rating of the orientation angles inside the models when the airplane take-off

Table 5: Rating of the orientation angles in the opened-window conditions when the airplane take-off

	KONF	N	Subset for alpha = .05		
			1	2	3
Tukey HSD(a)	180	40	0.918		
	150	40	0.935	0.935	
	120	40	0.936	0.936	
	225	40	0.939	0.939	
	135	40	0.940	0.940	0.940
	240	40	0.952	0.952	
	30	40	0.953	0.953	
	0	40	0.954	0.954	
	90	40	0.956	0.956	
	210	40	0.962	0.962	
	60	40	0.963	0.963	
	270	40	0.967	0.967	
	45	40	0.967	0.967	
	300	40	0.967	0.967	
	315	40	0.967	0.967	
	330	40	0.972	0.972	
	Sig.		0.721	0.066	0.058

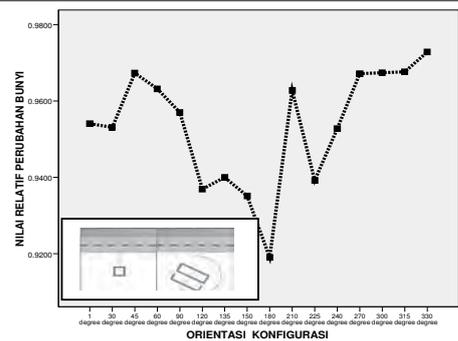


Figure 10: Rating of the orientation angles in the opened-window conditions when the airplane take-off

Table 4 illustrates the relative value ratings changes sound, with the lowest value at 135° angle with the value of  $R_v$  0.835 and the highest value at 270° angle with  $R_v$  value of 1.042. This suggests that the orientation of the runway 135° very effective in reducing the level of noise received on the building. Angle of 45° have a high enough value for its position facing perpendicular to the airplane's position at the top of the sound experience, the position of the plane when it takes off. Table 5 illustrates the relative value ratings changes sound, with the lowest value at 135° angle with the value of  $R_v$  0.703 and the highest value at 270° angle with  $R_v$  value of 1.076. The angle of 30° and 45° lies in the relatively position perpendicular to the sound source. So the value of  $R_v$  average angle is quite high, namely 0.751 to 0.790. The value  $R_v$  300° angle high, because of its position perpendicular to the sound source. Table 6 illustrates the relative value ratings changes sound, with the lowest value at 180° angles with the value of  $R_v$  0.919 and the highest value at 330° angle with  $R_v$  value of 0.973. 330° angle that the conditions outside and inside the building have low  $R_v$ , on the condition of an open window reaches the highest average  $R_v$ . This is caused by the reflection factor of the open window.

That the lowest orientation angle of 135° on the outside and inside the building, and the opposite to the runway orientation (180°) has a Relative Value sound with a significant change in the condition of an opened window, while the other orientation, which forms various angles to the runway has various relative values.

## 5. WIND AND SOLAR DIRECTION REVIEW

Since this is a research study of noise in the airport, then according to the results of the preliminary study on the effects of solar orientation of the noise is not significant, because the pattern of the sound level is influenced by the orientation of the sound source, not the orientation of the sun. On the other hand, that the wind is an aspect that significantly affect the level of sound received by the residents of the housing. Housing and airport locations in this study is located on the north coast city of Semarang, and apply the phenomena as follows:

1. At takeoff, the sound level is influenced by the wind direction of 69.5%. Sound level increases when the sea breeze moves in the opposite direction at the rate of the plane.
2. At the time of landing the sound level is influenced by the wind direction of 67.5%. Sound level will increase if the wind direction at the rate of the plane landed.

## 6. CONCLUSION

From the description of the study, the researchers concluded the following:

That the lowest orientation angle of 135° on the outside and inside the building, and the opposite to the runway orientation (180°) has a Relative Value sound with a significant change in the condition of an opened window, while the other orientation, which forms various angles to the runway has various Relative values.

## ACKNOWLEDGMENT

The authors would like to thank the creating of the models by the contractors with the materials of Glass Reinforced Cements (Gresik cements plastered board) and glass wool sound-proof inside the models. The opinion and analysis presented in this paper are those of the authors.

## REFERENCES

- [1] E. Setyowati, S. Soetomo, W. Setia Budi, Wahyu; E. Prianto, *Housing Orientation and Transportation Noise in Residential Area Near The Airport*, Journal of Dinamika, Civil Department, Engineering Faculty, University of Muhammadiyah Surakarta, Indonesia, Vol.10, No :3- September 2010, National Accredited Journal, BAN DIKTI: 110/DIKTI/Kep/2009 (2010).
- [2] E. Setyowati, S. Soetomo, W. Setia Budi, E. Prianto, *Konstruksi Model Sederhana dengan Nilai Sound Transmission Loss (STL) yang Optimal pada Kawasan Rawan Kebisingan*, Journal of Dinamika, Civil Department, Engineering Faculty, University of Muhammadiyah Surakarta, Indonesia, Vol.10, No :3-September 2010, National Accredited Journal, BAN DIKTI:110/DIKTI/Kep/2009 (2010).
- [3] J. Newman dan C.R. Benz, *Qualitative – Quantitative Research Methodology : Exploring the Interactive Continuum*, ISBN 0-8093-2150-5, Southern Illinois University Press, USA (1998)
- [4] J.C. Snyder, *Architectural Research – Environmental Design Series*, Volume 6, ISBN 0-442-28211-7, Van Nostrand Reinhold, Melbourne , Australia (1984)
- [5] The Decree of Indonesian Ministry of Environment No. 48/MENLH/11/1996 theme: The ambience level of Environmental Noise.
- [6] C.M. Harris, *Handbook of Noise Control, Second Edition*, Mc Graw – Hill Book Company, New York, St. Louis, San Fransisco (1979).
- [7] [www.search.com](http://www.search.com) reference, accessed on 20th June 2011.
- [8] S.V. Szokolay, *Environmental Science Handbook for Architects and Builders*, The Construction Press, Lancaster London New York (1980).
- [9] S.V. Szokolay, *Environmental Science Handbook for Architects and Builders*, The Construction Press, Lancaster London New York (1980).
- [10] S. Kurra dan N. Turner, 1993, *Rating Criteria for Facade Insulation Against Transportation Noise Source*, J. Applied Acoustics, vol. 40, Issue 3 halaman 213-237.
- [11] G. Casella, *Statistical Design*, Springer, New York, USA, ISBN: 978-0387-759654 (2008).
- [12] H. Sanoff, *Visual Research Methods in Design*, Van Nostrand Reinhold, ISBN 0-4442-23827-4, New York (1991).

# A Neural Network Approach for Conceptual Cost Estimation of Building Construction Projects

Yusuf Latief<sup>a</sup>, Wisnu Isvara<sup>b</sup>, Ludya Kesturi<sup>c</sup>

<sup>a</sup>Department of Civil Engineering, Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel : (021) 7270029, Fax : (021) 7270028  
E-mail : latief73@eng.ui.ac.id

<sup>b</sup>Department of Civil Engineering, Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel : (021) 7270029, Fax : (021) 7270028  
E-mail : wisnu.isvara@gmail.com

<sup>c</sup>Department of Civil Engineering, Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel : (021) 7270029, Fax : (021) 7270028  
E-mail : ludya.kesturi@gmail.com

## ABSTRACT

*Conceptual cost estimates as the basis of project evaluation, engineering design, and cost management, play an important role in project decision at the beginning of design phase of construction project, under a limited definition of scope and constraints in available information and time, and the presence of uncertainties. Conventional tools such as regression analysis have been widely used to tackle the problems. However, recent statistical studies show that errors in cost estimation have not decreased significantly. This paper proposes the utility of an artificial intelligence approach, the neural network model to improve cost estimation accuracy in early phases of building design process. A total of 9 input variables were identified and datasets of 18 office building constructed from 2006 to 2012 in Indonesia were used in estimating the construction cost. Several neural network models were developed using various combination of the number hidden layer and neurons, and the best neural network model with an accuracy of 92.21% was achieved. The predictive behaviour of the model was visualized by sensitivity analysis to reveal how the model capture the impact of variables on the construction cost.*

## Keywords

*Conceptual cost estimates, building construction project, neural network, accuracy*

## 1. INTRODUCTION

The accuracy of conceptual cost estimate is a critical factor in the success of the construction project [1]. During the preliminary or conceptual phase, minimal information is available which makes these estimates less accurate. However conceptual cost estimates are important to project feasibility studies and impact upon final project success. Such estimates provide significant information that can be used in project evaluations, engineering designs, cost budgeting and cost management [2]. According to Holm et al [3] the expected accuracy range of conceptual estimate is  $\pm 10-20\%$ , while AACE 18R-97 [4] states that the accuracy range of budget estimate is  $\pm 10-30\%$ . Abundant studies to improve the accuracy of early cost estimates have been done. Statistical methods have traditionally been used to develop cost estimating models, while regression analysis represents a common alternative. Regression analysis is a very powerful statistical tool that can be used as both an analytical and predictive technique, although it is not appropriate when describing non-linear relationship, which are multidimensional, consisting of a multiple input and output problem [5].

Neural network as an alternative branch of artificial intelligence, has appeared as a viable alternative for estimating construction cost during the 1990s. Neural network is distributed information processing system in which modeling is viewed as a mapping from one multivariate space of information (input variables) to another (output variables). Neural network provide excellent facilities for approximating data, learning knowledge from data, capturing non linear and complex interactions, approximating reason, and parallel processing. In order to develop of high quality neural network models is difficult. Several design factors including selection of input variables, architecture of the network and quantity of training data, significantly impact the accuracy of neural network prediction. The main problem is that there are no fixed rules for

determining the appropriate architecture of its parameter values [6]. This forces the model developer to try different networks configuration to find an optimal setup. The adequacy of relations suggested by the models must be determined by the predictive behaviour of the models. The Predictive behaviour of model is crucial particularly as the model has the potential to present unnecessary complex relations, especially when they are trained with sparse data [7]. For cost estimating, user always wants to know the most sensitive variables affecting the construction cost. Such information is very valuable for designer in developing cost-effective designs [8].

The purpose of this paper is to demonstrate the use of neural network model to improve conceptual cost estimation accuracy. In this study the trial-and-error process was adapted for determining networks parameters and several neural network models were developed using various combination of the number hidden layers and the neurons in hidden layers to achieve the best model. After determining the best model, the predictive behaviour of the model was visualized by sensitivity analysis to reveal how the model capture the impact of variables on the construction cost.

## 2. NEURAL NETWORK

Neural network is a massively parallel distributed processor made up of simple processing units, which has a natural propensity for storing experiential knowledge and making it available for use [9]. Neural network is a computer system that simulates the learning process of human brain and it consist of a large set of interconnected neurons. These neurons are arranged in many layers and interact with each other through weighed connections. NN are trained by the presentation of a set examples of associated input and output as target values. The hidden and output layer neurons process their inputs by multiplying each of their inputs by the corresponding weights, summing the product and then processing the sum using non linear transfer function to produce the result. The S-shaped sigmoid function is commonly used as a transfer function. The neural network learns by adjusting the weights between the neurons in response to the errors between actual output values and target output values.

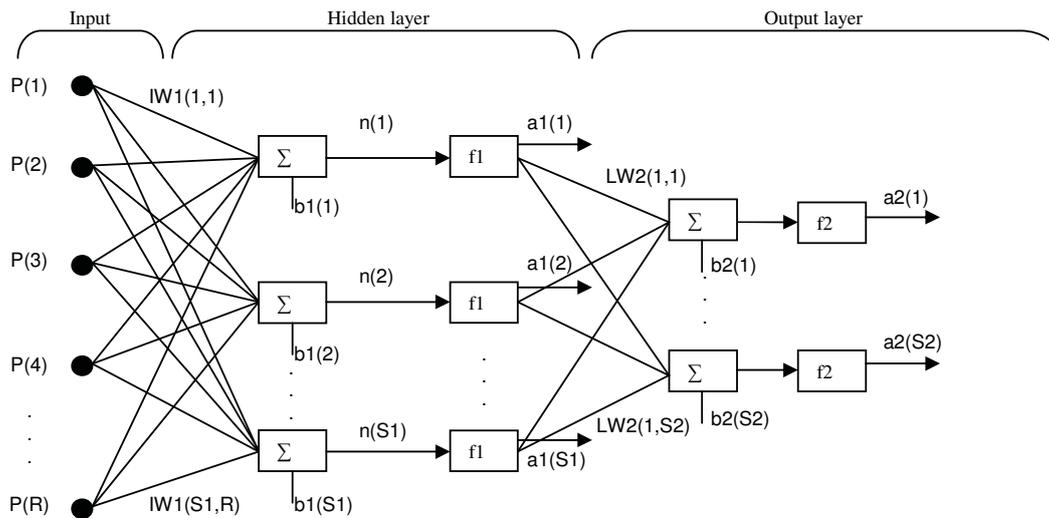


Figure 1 : Architecture configuration of neural network

A typical artificial neural network is shown in Figure 1. The network shown above has R inputs (R neurons in the input layer), S1 neurons in the hidden layer, and S2 neurons in the output layer. The number of hidden layers can be varied based on the application. A network can have several layers. The outputs of each intermediate layer are the inputs to the following layer. Each layer has a weight matrix W, a bias vector b, and an output vector a. Each element of the input vector p is connected to each neuron input through the weight matrix W. The *i*th neuron has a summer that gathers its weighted inputs and bias to form its own scalar output *n*(*i*). The various *n*(*i*) taken together form an S-element vector *n*. Finally, the neuron layer outputs form a column vector *a*. The column vector *a*1 as the input of layer 2 can be determined by equation (1):

$$a1 = f1(IW1*P+b1) \quad (1)$$

And the vector *a*2 as the output layer can be determined by formulation given in equation (2):

$$a2 = f2(LW2*a1+b2) = f2(LW2*(f1(IW1*P+b1))+b2) = Y \quad (2)$$

The layers of a multilayer network play different roles. The layer that produces the network output is called an output layer. The layer that gets the inputs is called input layer. All other layers are called hidden layers. It is common for the number of inputs to a layer be different from the number of neurons.

There are two main phases in the operation of a neural network : learning and training. Learning is the process of adapting the connection weights in response to a number of examples being presented at the input layer and optionally at the output layer. The task is to arrive at a unique set of weights that are capable of correctly associating all example patterns used in learning, with their desired output patterns. The most common neural network model is the multilayer perceptron or known as a supervised network because the network is presented with some input examples and their desired responses. The desired outputs are used in this case to teach the network the correct responses. The multilayer perceptron learns using backpropagation algorithm. This algorithm incorporates a learning algorithm called generalized delta rule, which is responsible for training the network and uses a gradient descent method to determined a unique set of network weights that enables the network to produce outputs that are very close to the the desired outputs associated with a number of training examples. The backpropagation usually incorporates a non-linear sigmoid transfer function to calculate the output of each neuron except for the input neurons. For the training refers to the process that repeatedly applies input vectors to the network and calculates errors with respect to the target vectors and then finds new weights and biases with the learning rule. It repeats this cycle until the sum-squared error falls beneath an error goal, or a maximum number of cycles/epochs have occurred. At the end of this training phase, the neural network represents a model, which should be able to predict a target value given the input value.

### 3. MODEL APPLICATION

A total of 18 office building construction projects developed by a contractor company in Indonesia specially in the city of Jakarta, Tangerang, Bekasi and Bandung, during 2006 to 2012 were taken as case studies [10]. The datasets were divided into two parts by random sampling. The first group of data (16 datasets) as data training were used to develop the model and the second group (2 datasets) as data testing that were used to test the model. And a total of 9 input variables were identified whereas the output variable is the contractual construction costs (in IDR), (See Table 1).

Table 1: Variables description

Variables	Description	Range
P1	Location	1 = Jakarta, 2 = Tangerang, 3 = Bekasi, 4 = Bandung
P2	Type of foundation	1 = bored pile, 2 = driven pile, 3 = mat foundation
P3	Gross floor area	1752 - 111489 m <sup>2</sup>
P4	Number of storey	3 - 42
P5	Number of basement	0 - 5
P6	Type of roof construction	1 = Concrete, 2 = Steel Structure
P7	Finishing grade	1 = Average, 2 = Good, 3 = Luxury
P8	Year of construction	2006 to 2012
P9	Duration of construction	3 - 21 months
Y (Output)	Contractual construction cost (IDR x 1000)	7513241 – 248050000

In order to develop neural network model Matlab R2009a software was chosen for its ease of use, speed of training and host of neural network architectures, including backpropagation with flexible user selection of training parameters. A total of 18 variants were developed using the neural network method based on the variations of the number of hidden layers and the neurons in hidden layers. In this study the experiments run should set parameters such as architecture configuration, learning and training parameters as described in Table 2.

Table 2 : Neural network parameter settings

Parameters	Values	Description
Architecture configuration parameter:		
No of input neurons	9	Number of input variables
No of output neuron	1	Number of output variable
No of hidden layers	1 and 2 hidden layers	
No of neurons in hidden layers	Min 2 and max 12	
Learning parameter:		
Learning algorithm	Backpropagation	
Activation function	Sigmoid bipolar	
Learning function	Gradien Descent Momentum	
Learning rate	0.5	
Training parameter:		
Maximun epoch	5000	
Goal (min MSE)	10 <sup>-3</sup>	

#### 4. RESULT AND DISCUSSION

The accuracy performance of all models using data testing is based on Mean Absolute Percent Error (MAPE), given in equation (3):

$$MAPE = \frac{1}{n} \sum \frac{|actual\ cost - predicted\ cost|}{actual\ cost} \times 100\% \quad (3)$$

The result from MAPE 16 data training and 2 data testing are summarized in Table 3.

Table 3 : Comparisons of MAPE for all models

No	Architecture of configuration	MAPE of 16 Data Training	MAPE of 2 Data Testing
1	9 - 2 - 1	14.02%	26.24%
2	9 - 3 - 1	7.45%	123.02%
3	9 - 4 - 1	11.57%	7.79%
4	9 - 5 - 1	11.79%	119.99%
5	9 - 6 - 1	13.67%	76.40%
6	9 - 7 - 1	15.81%	102.13%
7	9 - 8 - 1	12.27%	36.07%
8	9 - 9 - 1	8.31%	24.11%
9	9 - 12 - 1	6.49%	72.20%
10	9 - 2 - 1 - 1	14.02%	32.96%
11	9 - 3 - 2 - 1	13.21%	34.42%
12	9 - 4 - 3 - 1	11.57%	33.93%
13	9 - 5 - 4 - 1	11.79%	32.72%
14	9 - 6 - 5 - 1	13.67%	32.55%
15	9 - 7 - 6 - 1	15.81%	33.82%
16	9 - 8 - 7 - 1	12.27%	33.70%
17	9 - 10 - 9 - 1	8.31%	34.53%
18	9 - 12 - 11 - 1	6.49%	33.55%

In this study 18 neural network models were implemented to compare the estimation error rates using various combination of parameters including number of hidden layers and number of neurons in hidden layers. The best configuration of the neural network model was determined to be 9-4-1 model configuration which means that there were 9 neurons in input, 1 hidden layer with 4 neurons in hidden layer and 1 neuron in output as shown in Figure 2. This result appropriate to Hegazy et al [11] that one hidden layer is sufficient to generate an arbitrary mapping between inputs and outputs. Out of 18 models, the result of the 9-4-1 model gave the best performance with 7.79% for MAPE data testing, it means that this model has an accuracy of 92.21%, although the amount of data training was limited. According to Holm et al [3] the expected accuracy range of conceptual estimate is ±10-20%, while AACE 18R-97 [4] states that the accuracy range of budget estimate is ±10-30%. Comparing with these references, the proposed model has performed very well.

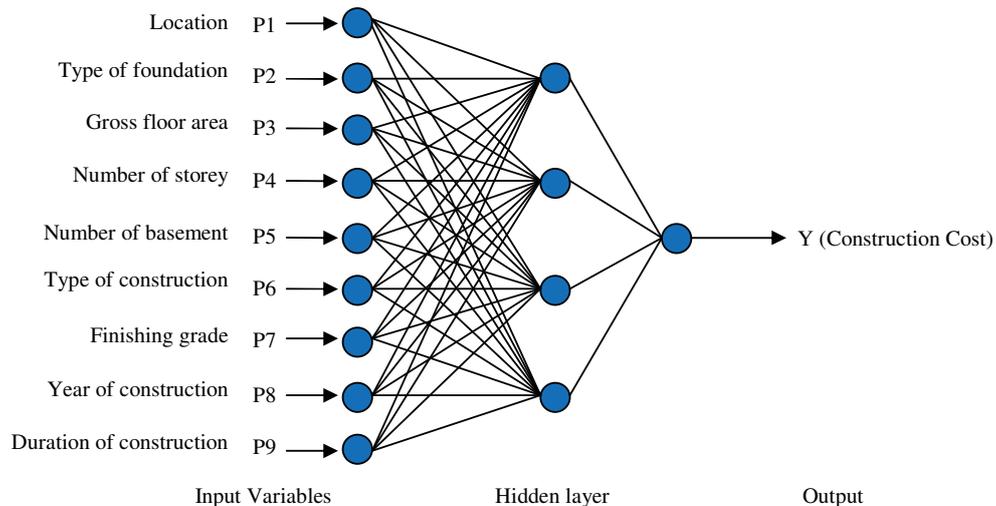


Figure 2 : Neural network model with 9-4-1 configuration

Finally the predictive behaviour of the best model (9-4-1 configuration) was visualized by sensitivity analysis to reveal how the model capture the impact of variables on the construction cost. Sensitivity analysis of model as described in Figure 3, was performed by plotting the outputs of the model against varying levels of several variables, such as (a) number of basement, (b) gross floor area, (c) finishing grade and (d) number of storey.

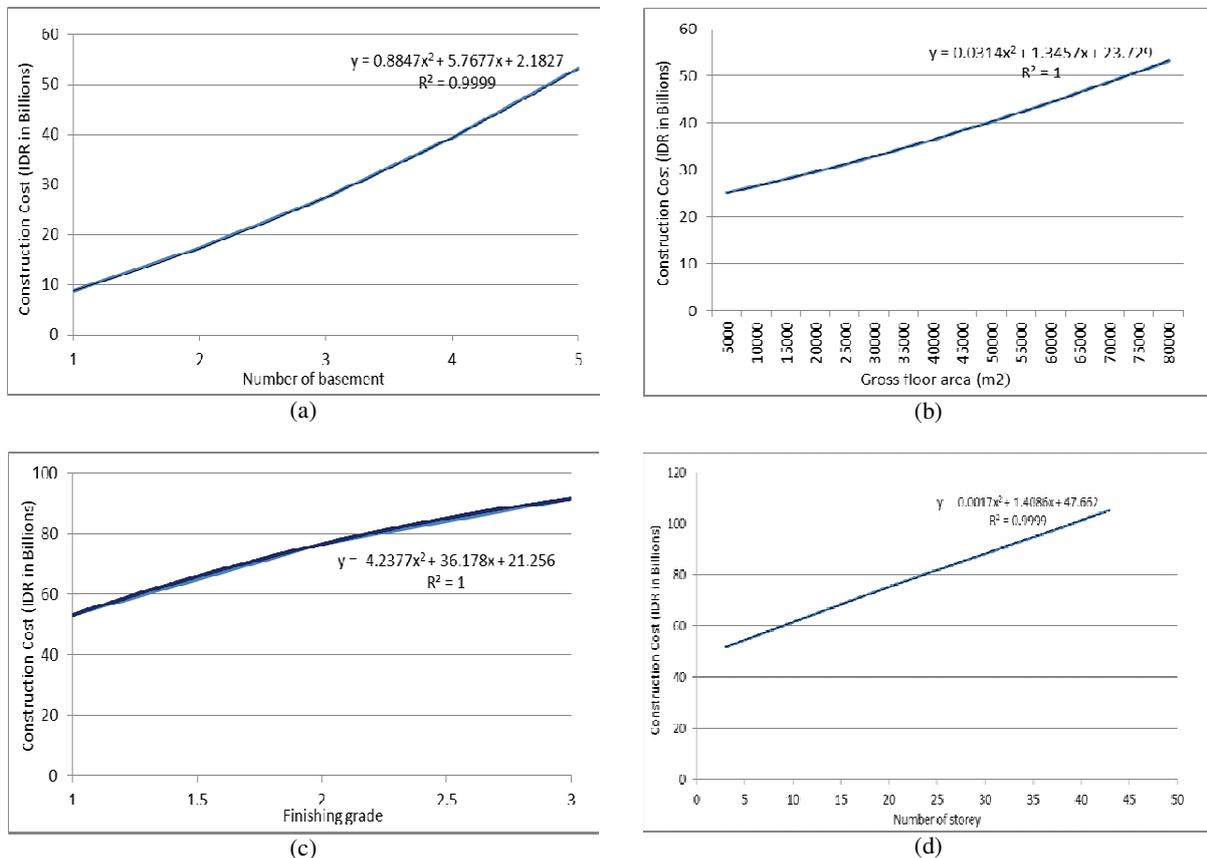


Figure 3 : Sensitivity analysis of model

In general, the plots of the model illustrate non linear relationship between the input variables and the output variable (construction cost). The sensitivity of each variable to the construction cost as shown in Figure 3 provides the useful information for a building designer to identify cost sensitive attributes. With such information, the design process can be guided with the directions to achieve cost-effective designs, rather than to be conducted with an inefficient blind search process.

#### 4. CONCLUSION

The neural networks have the capability of capturing the relations between input variables and output variables. The neural networks require the historical data of cost and data of variables influencing the cost. The neural network is trained with the historical data of past projects so that it can capture the relations between variables and the cost. One of the important decisions about neural network is related with the network architecture. Designing the network architecture is not a straightforward approach, it actually requires some trial and error. One method for determination of the neural network model architecture is training several networks with different architectures and then selecting the neural network with the best prediction performance.

In this study, a neural network model was developed to estimate construction cost of the office building using only information typically available at conceptual design phase. The model could be used to estimate early project cost when detailed construction drawings are not available and detailed cost estimates cannot be performed. A comprehensive set of variables

influencing to the cost of construction such as location, type of foundation, gross floor area, number of storey, number of basement, type of roof, finishing grade, year and duration of construction were included in the model formulation. For the study, data of 18 office building construction projects developed by a contractor company in Indonesia during 2006 to 2012 were taken. The model configuration with one hidden layer and four neurons in hidden layer presented the best performance with 7.79% for MAPE data testing. Predictive behaviour of the neural network model had been visualized by sensitivity analysis and the result was that the model demonstrated adequate relationship between the input variables and construction cost.

## 5. REFERENCES

- [1] Kim, G.H., Seo, D.S., Kang, K.I. "Hybrid Models of Neural Networks and Genetic Algorithms for Predicting Preliminary Cost Estimates," *Journal of Computing in Civil Engineering*, ASCE, Vol. 19, No. 2, pp. 208-211, April 2005.
- [2] Cheng, M.Y., Tsai, H.C., Sudjono, E. "Conceptual Cost Estimates Using Evolutionary Fuzzy Hybrid Neural Network for Projects in Construction Industry," *Journal of Expert Systems With Applications*, Vol. 37, pp. 4224-4231, 2010.
- [3] Holm, L., Schaufelberger, J.E., Griffin, D., Cole, T. "Construction Cost Estimating Process and Practices," Pearson Education, Inc., Upper Saddle River, New Jersey, 2005.
- [4] AACE, Association for the Advancement of Cost Engineering, International Recommended Practice No. 18R-97, (2005). Cost Estimate Classification System – As Applied In Engineering, Procurement, And Construction For The Process Industries, TCM Framework: 7.3 – Cost Estimating and Budgeting, AACE, Inc
- [5] Kim, G.H., An, S.H., Kang, K.I. "Comparison of construction cost estimating models based on regression analysis, neural networks and case-based reasoning," *Journal of Building and Environment*, Vol 39, pp. 1235-1242, February 2004.
- [6] Setyawati, B.R., Creese, R.C., Sahirman, S. "Neural Network for Cost Estimation (Part 2)." AACE International Transaction, ABI/INFORM Global, pg. EST.14.1-14.10, 2003
- [7] Sonmez, R., Ontepeli, B. "Predesign Cost Estimation of Urban Railway Projects with Parametric Modeling," *Journal of Civil Engineering and Management*, Vol. 15(4), pp. 405-409, July 2009.
- [8] Yu, W., Skibniewski, M.J. "Integrating Neurofuzzy System with Conceptual Cost Estimation to Discover Cost Related Knowledge from residential Construction Projects," *Journal of Computing in Civil Engineering*, ASCE, Vol. 24, No. 1, pp. 35-44, January 2010.
- [9] Haykin, S. "Neural Networks - A Comprehensive Foundation," 2nd Edition, Pearson Education, Inc., Pearson Prentice Hall, 1999.
- [10] Kesturi, L. "Conceptual Cost Estimation of Office Building Construction Using Artificial Neural Network Method," Undergraduate Thesis, Department of Civil Engineering, Faculty of Engineering University of Indonesia, June 2012.
- [11] Hegazy, T., Ayed, A. "A Neural Network Model for Parametric Cost Estimation of Highway Projects. *Journal of Construction Engineering and Management*, ASCE, Vol. 24 No.3, pp. 210-218. 1998

## Contribution of Short Coco Fiber on Skid Resistance Pavement Performance

Sigit Pranowo Hadiwardoyo, R Jachrizal Sumabrata, Puspita Jayanti

Departmen of Civil Engineering, Faculty of Engineering, University of Indonesia  
Kampus Baru UI, 16242

Phone: (021) 7270029 - Fax: (021) 7270028

Email :[sigit@eng.ui.ac.id](mailto:sigit@eng.ui.ac.id), [rjs@eng.ui.ac.id](mailto:rjs@eng.ui.ac.id)

### ABSTRACT

*The use of synthetic fibers and natural fibers as composite materials have been proven to increase strength and save the basic material needs of the building. Research has previously stated that the fiber has a high tensile strength and has the potential to increase the cohesive and tensile strength of the asphalt mixture. Previous research suggests that the value of Skid Resistance is influenced by changes in asphalt penetration. The addition of coconut fiber used in this study was short decorticated fibers/pulp fibers. Short Coco fiber measuring 0.5-1.25 cm mixed with asphalt pen 60/70 on the fiber content of 0%, 0.75% and 1.5%. Fibrous asphalt is mixed with aggregate specification of Asphalt Concrete Wearing Coarse. Asphalt concrete mixture is molded and compacted with a compactor Wheel Tracking at 8.16 tons vehicle standard axle loads. Specimens were then tested with a British Pendulum Tester at a temperature of 26 °C, 30 °C, 35°C, 40 °C, 45 °C, 50 °C. Skid resistance value will decrease when an increase in temperature on the surface of the pavement. The addition of 0.75% coconut fiber on the asphalt mixture can improve the skid resistance value but does not increase the resistance to increased temperature on the road surface.*

### Keywords

*Skid resistance, coco-fiber, temperature, pavement.*

**This Paper is Published in Advanced Material Research**

# Study of Compressive Strength of Mortar Containing Rice Husk Ash (RHA) and Concrete Sludge Waste (CSW) with composition 1 Cement : 2 Fine Aggregate

Essy Arijoeni<sup>a</sup>, Madsuri<sup>b</sup>, Farah Dini<sup>c</sup>

Faculty of Engineering, University of Indonesia, Depok 16424  
 E-mail : [Essy@eng.ui.ac.id](mailto:Essy@eng.ui.ac.id), [madsuri@eng.ui.ac.id](mailto:madsuri@eng.ui.ac.id), [farah.dinis@gmail.com](mailto:farah.dinis@gmail.com)

## ABSTRACT

Concrete become one of alternative construction materials that often used. The use of concrete as construction materials makes waste nemed Concrete Sludge Waste (CSW). There is a lot of CSW that produced by use of concrete. The huge amount of CSW in order to not to pollute the environment, so we have to reuse CSW to become something useful. Nowadays a lot of construction is using high quality concrete. CSW from this high quality concrete can reused to produce medium or low quality concrete. CSW will added in mortar as substitute of fine aggregate. Beside CSW we can also reuse Rice Husk Ash (RHA). RHA is product that produced by burning of rice husk. As agricultural country, Indonesia can produce lots of rice husk that produced from rice milling. All this time, rice husk was used as cleansing ashes. RHA will added in mortar as substitute of cement, so we can reduce the use of cement. Physical and mechanical properties of mortar that will tested are compressive strength, absorption, shrinkage and density. Based from the result of this research, mortar with composition 92% cement, 8% RHA, 30% CSW and 70% fine aggregate, is the best mortar composition. The compressive strength that produced from this mortar is 17,052 Mpa at 28th day. For absorption test, this mortar could absorb 134 gram/100cm<sup>2</sup>. Moreover this mortar have the least of shrinkage, 0,126%. And from the result of density test, the density of this mortar is 1,869 g/cm<sup>3</sup>. From this research, based on SNI for non-structural concrete, mortar with composition 92% cement, 8% RHA, 30% CSW and 70% fine aggregate can produce non-structural materials such as paving block.

## Keywords

Rice Husk Ash, Concrete Sludge Waste, compressive strength, Absorption, shrinkage, density.

## 1. INTRODUCTION

The high rate of construction is causing high rite of concrete usage. And the high rate of concrete usegae is also causing high rate of concrete sludge waste (CSW) that wasted in every concrete plans. This is causing problems, because if we don not manage the disposal, this waste will pollute the environment. Waste management is become a problem for concrete plan's owner. All this time, waste management is not optimal yet. CSW was used to close the hole in broken road or thrown away. Waste management that can applied are mixing concrete by the use of return (Reuse) material that is proper to use, and reprocessing (Recycle) are the remaining material. In this research we use CSW as fine aggregate substitute. Beside CSW, we also use rice husk ash (RHA) as cement substitute. Rice husk ash is product of rice husk burning that has useful elements to increase the quality of concrete. Because RHA is a pozzolanic materials and containing the large amount of silika. If silika mixed with cement, will producing higher strength.

This research aims to know physical and mechanical properties of mortar that containing CSW and RHA and to meet the optimum mix design

## 2. MATERIAL and METHODS

The research was conducted at the Department of Civil Materials Testing Laboratory, University of Indonesia. Methods The study was conducted by laboratory testing in accordance with the data from the literature study both SK SNI Standard Indonesia and foreign standards such as ASTM.

### 2.1 Materials And Methods

#### 2.1.1 Cement

Type-I Portland cement (PCC) was used, which was manufactured by tiga roda. and its physical and chemical properties met the ASTM C150 specification.

#### 2.1.2 Fine Aggregate

The sand was obtained from the Cimangkok, West Java.

*Table 1. Fine Aggregate Test*

No.	Physis and Mechanics	Result Test	Spec
1	Specific Gravity	2,090	-
2	Specific Gravity (SSD)	2,179	-
3	Water Absorption (%)	4,280	3
4	Bulk Density( $\text{gr}/\text{cm}^3$ )	1,422	Min 1,2
5	Loose Bulk Density ( $\text{gr}/\text{cm}^3$ )	1,304	Min 1,2
6	Voids (%)	34,64	-
7	Water Content (%)	13,64	-
8	Silt Content (%)	3,30	Max 5%
9	Fineness Modulus (%)	2,66	Zone 2

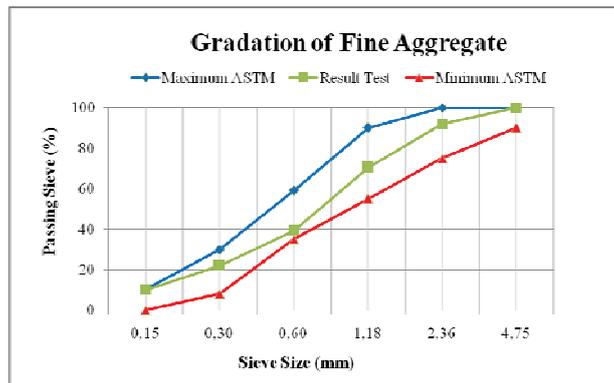


Figure 1. Gradation of Fine Aggregate

### 2.1.3 Rice Husk Ash (RHA)

Rice husk ash is product of rice husk burning that has useful elements to increase the quality of concrete. Because RHA is a pozzolanic materials and containing the large amount of silika. If silika mixed with cement, will producing higher strength. Though there are in the rice husk  $\text{SiO}_2$  reactive element that can be used as an ingredient made Pozolan concrete quality improvement (Priyosulistyo, 2001). ashes that was done burning, then crushed again to escape kesaringan 200-400 Mesh. As a whole from the ashes in the can of rice alone was only 5% or about 20% of the burning husks. Chemical analysis performed on the combustion of rice husk ash content of silica oxide showed a fairly high, as shown in the following table.

Table 2. Composition of Chemical Compounds RHA

Chemical Compounds	Amount (% Weight)
$\text{SiO}_2$	93.4408
$\text{Al}_2\text{O}_3$	0.1031
$\text{P}_2\text{O}_5$	1.0129
S	0.2227
$\text{K}_2\text{O}$	3.4808
CaO	0.7193
$\text{TiO}_2$	0.0946
$\text{MnO}_2$	0.2285
$\text{Fe}_2\text{O}_3$	0.6800
ZnO	0.0173

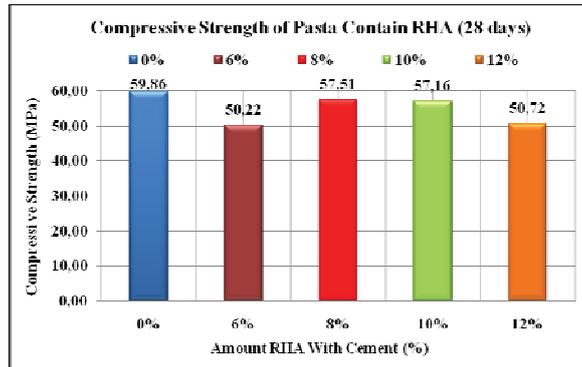


Figure 2. Histogram charts Strong Preliminary Research Findings Press CRHA (a mixture of cement + RHA) at 28th day.

Based on preliminary research results graph CRHA compressive strength that containing RHA, the CRHA compressive strength obtained at 28th day with the most optimal composition of 92% cement and 8% is 57.51 MPa. From the results of this preliminary study we used the optimal composition of RHA 8% of cement content for concrete mixtures containing RHA and CSW.

### 2.1.4 Concrete Sludge Waste (CSW)

Concrete Sludge Waste or CSW is the waste generated from washing truck mixer at the batching plant after producing and sending mixed concrete to construction sites. At the time of washing, the CSW to be like sludge which will then harden to form lumps. CSW is used in this research as fine aggregate substitute, so we can reduce use fine aggregate.



Figure 3. Process of Taking CSW

Chemical analysis of the CSW can be viewed through by PSA testing (Particle Size Analysis) dan XRF (X-Rays fluorescence), as follows :

Table 3. PSA Analysis of CSW

No.	Particle Diameter (µm)	Statistics		
		Volume (%)	Surface Area (%)	Number (%)
1	< 20	100	100	100
2	< 10	98.500	99.700	99.998
3	< 8	92.300	98.400	99.990
4	< 6	79.600	94.900	99.900
5	< 4	60.500	87.600	99.700
6	< 2	36.000	71.500	98.000
7	< 1	16.200	44.800	86.700
8	< 0.4	0.220	1.040	4.930

Table 4. XRF Analysis of CSW

No.	Chemical Compounds	Prosentase	
		Weight (%)	Atom/ Molecul (%)
1	MgO	1.8284	3.6062
2	Al <sub>2</sub> O <sub>3</sub>	7.5603	5.8951
3	SiO <sub>2</sub>	<b>35.5793</b>	47.0789
4	S	0.5744	1.4243
5	K <sub>2</sub> O	0.7181	0.6061
6	<b>CaCO<sub>3</sub></b>	<b>48.0781</b>	38.1902
7	TiO <sub>2</sub>	0.5984	0.5955
8	Cr <sub>2</sub> O <sub>3</sub>	0.1169	0.0612
9	MnO <sub>2</sub>	0.1927	0.1763
10	Fe <sub>2</sub> O <sub>3</sub>	4.7531	2.3644

CSW did not directly used but must be done further research and treatment The treatment process of CSW to be used:

- CSW is usually still in a wet or humid conditions, so it have to be drained naturally by sun or with oven.
- After CSW dried, crushed and polished slabs CSW by milled or ground.
- After CSW crushed, then sieved with a sieve size of 4.75 mm (3/16 in) which is a standard sieve for fine aggregate.
- After CSW has been sifted, stored in a dry place and already can be used.



Figure 4. Processing of CSW

## 2.2 Mortar Composition

This research made five diferent compositions of fine aggregate and CSW, where the composition of cement and RHA is fixed. The five composition of fine aggregate and CSW are :

- CHWM-121 containing 30% CSW and 60% fine aggregate.
- CHWM-122 containing 40% CSW and 60% fine aggregate.
- CHWM-123 containing 50% CSW and 60% fine aggregate.
- CHWM-124 containing 60% CSW and 40% fine aggregate.
- CHWM-125 containing 70% CSW and 30% fine aggregate.

## 2.3 Fresh Mortar Tests

### 2.3.1 Consistency Test

Consistency test were performed according to ASTM C-305-82 to measure water cement rasio.

### 2.3.2 Setting Time

The measurements were conducted according to ASTM-1117-89.

## 2.4 Hardened Mortar Tests

### 2.4.1 Compressive Strength

Compressive strength testing was use a test specimen cube size 50 x 50 x 50 mm, testing were prepared according to ASTM C 579-01and the specimens were cured for 1–90 days. At each curing age, five cube specimens were tested for compressive strength.

### 2.4.2 Absorption

Absorption test was based on ASTM C 1403-00. The specimens is cube size 50 x 50 x 50 mm. The specimens were cured until 28 days before tested.

### 2.4.3 Shrinkage

Shrinkage test was based on ASTM C490-04 and use test specimen beam size 25 x 25 x 300 mm. Right after removed from mold, measured the shrinkage of the specimens until 28 days.

### 2.3.4 Density

Based on ASTM C-905-01 and use cube specimens size 50 x 50 x 50 mm. Specimens were cured in 28 days before tested.

## 3. RESULTS And ANALYSIS

### 3.1 Test Results for Fresh Concrete

#### 3.1.1 Consistency Test

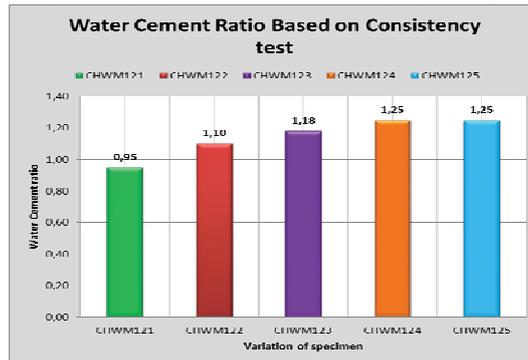


Figure 5. Graph of water cement ratio

Based on the results of consistency test, water cement ratio for CHWM-121 is 0,95 , CHWM-122 is 1,10 , CHWM-123 is 1,18 , CHWM-124 is 1,25 and CHWM-125 is 1,25 . The test result shows that CSW makes water cement ratio bigger.

#### 3.1.2 Setting Time Test

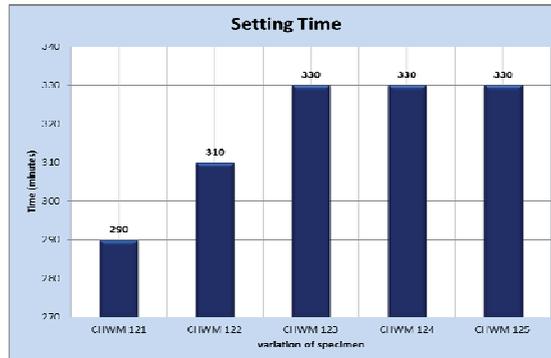


Figure 6. Graph of setting time

From the test result above, it shows that more CSW will make setting time longer.

### 3.2 Hardened Mortar Test

#### 3.2.1 Compressive Strength

Test of compressive strength used specimen cube size 50x50x50 mm, and tested when specimens reach age 3, 7, 14, 21, 28, 56 and 90 days.

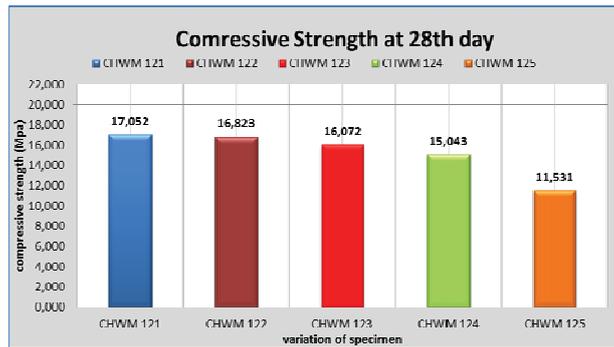


Figure 7. Histogram of Compressive Strength at 28th day

From the test result above, it shows that more CSW will decrease compressive strength.

### 3.2.2 Absorption

Absorption test used cube specimen size 50x50x50 mm and tested at 28th day.

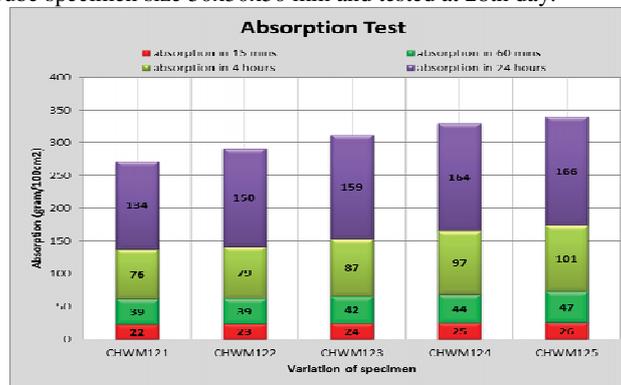


Figure 8. Graph of absorpt

From the test result above, concluded that mortar with more CSW will absorb more water.

### 3.2.3 Shrinkage

Shrinkage test used beam specimen with size 25x25x300 mm. And tested right after specimen removed from mold until 28th day.

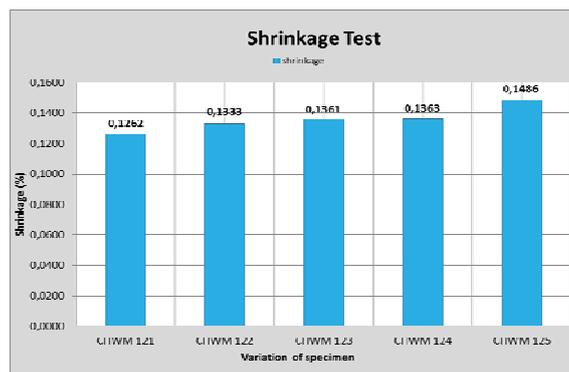


Figure 9. Graph of shrinkage

### 3.2.4 Density

Density test used cube specimen with size 50x50x50 mm and tested at 28th day.

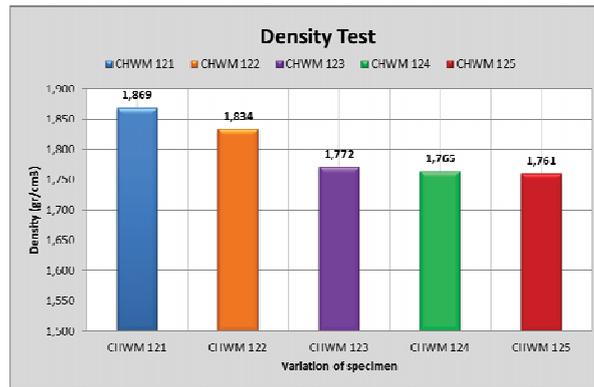


Figure 9. Graph of shrinkage

### 3.3 Application of Mortar With CSW and RHA for Construction materials.

From the test results of mortar with CSW and RHA, and compared with SNI 03 – 0691 – 1996 about specifics of paving block, concluded that mortar with composition 30% CSW and 70% fine aggregate can used to make paving block type C.

Table 5. Quality of paving block based on SNI 03 – 0691 – 1996

Quality	Compressive Strength (Mpa)		Wear resistance (mm/mins)		absorption max
	average	min	average	min	%
A	40	35	0.090	0.103	3
B	20	17	0.103	0.149	6
C	15	12.5	0.160	0.184	8
D	10	8.5	0.219	0.251	10

- A Quality Concrete bricks are used for road.
- B Quality concrete bricks are used for parking lot
- C Quality concrete bricks are used for pedestrian walk
- D Quality concrete bricks are used for park land and another function for non structural concrete.

## 4. CONCLUSIONS And RECOMENDATIONS

### 4.1 Conclusions

In this study, RHA and CSW used to partially substitute cement and fine aggregate. Based on analysis from test. The following conclusions can be drawn:

- a. Using CSW as a Partially replace of fine aggregate in mortar give effects on mortar. Mortar with more CSW need more water (based on consistency test result) and it made mortar reached setting time longer and produced more air cavity.
- b. Mortar containing 30% CSW and 70% fine aggregate made the highest compressive strength between the other compositions. Composition strength of this mortar at 28th day is 17,052 MPa.
- c. And mortar with 70% CSW and 30% fine aggregate has the smallest compressive strength, 11,531 MPa.
- d. So it can be concluded that more CSW composition in mortar will decrease compressive strength.
- e. From absorption test result, CHWC-121 could absorb 134 gram/100cm<sup>2</sup> and CHWC-125 could absorb water until 166 gram/100cm<sup>2</sup>. It can be concluded that more CSW composition in mortar will make mortar absorb more water.
- f. From shrinkage test, CHWC-121 has the smallest shrinkage, 0,1262%. And CHWC-125 has the highest shrinkage, 0,146%. It can be conclude that CSW will make mortar shrinks longer.
- g. From density test, CHWC-121 has the highest density value, 1,896 gram/cm<sup>3</sup>. And CHWC-125 has the smallest density value, 1,761 gram/cm<sup>3</sup>. So CSW decreases density value of mortar.
- h. Mortar with CSW can be used in industry as a non-structural material. Based on SNI 03 – 0691 – 1996 mortar with 30% CSW and 70% fine aggregate can be used to make paving block type C.
- i. Using of CSW in industry will reduce environmental pollution.

### 4.2 Recommendations

The following suggestions may be related to the research conducted are:

- a. Further research needs to be done on the use of CSW, in order to use the maximum percentage value of the mechanical properties of concrete.
- b. Use of CSW so great in the concrete mix, will decrease the compressive strength of concrete, so that further research is recommended to use must be adjusted to the amount of sand on the concrete.

- c. In this study the treatment of CSW proceed by manually, so that further research needs to be done on a good method to produce a CSW in standart.
- d. Need to use chemical ingredients added to the RHA and CSW mix concrete, in order to water cement ratio accordance with the composition of normal concrete.
- e. Use of CSW was able to be used as a complementary mixture of fine aggregate sand, it is necessary to do research on the economics of the use of CSW. So its use can be commercially exploited by the industry and can reduce the impact of pollution on the environment.

There are a lot of concrete sludge waste from each batching plan it so variated in Indonesia, so further research is needed on how much the use of CSW can offer.

## REFERENCES

- [1] Anagyagos, Nigoskatis. *Kuat Tekan, Density, Absorpsi Dan Modulus Elastisitas Mortar Campuran Semen, Abu Sekam Padi, Dan Precious Slag Ball Dengan Perbandingan 30%; 30%; 40%*. Departemen Teknik Sipil, Universitas Indonesia, Depok : 2011.
- [2] ASTM 1117-89. *Standard Test Methode for Time of Setting of Shotcrete Mixture by Penetration Resistance*, ASTM International, 100 Barr Harbor Drive, United States: 1994.
- [3] ASTM C 128-01. *Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [4] ASTM C 29M-97. *Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [5] ASTM C 136-01. *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [6] ASTM C 117-03. *Standard Test Method for Materials Finer than 75- $\mu$ m (No. 200) Sieve in Mineral Aggregates by Washing*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [7] ASTM C 117-03. *Standard Test Method for Materials Finer than 75- $\mu$ m (No. 200) Sieve in Mineral Aggregates by Washing*, ASTM International, 100 Barr Harbor

# The Role of Knowledge Management in Collaborative Design to Support Construction Process

Yani Rahmawati<sup>a</sup>, Christiono Utomo<sup>b</sup>, Nadjadji Anwar<sup>c</sup>

Faculty of Civil Engineering  
Institut Teknologi Sepuluh Nopember, Surabaya 60111  
Tel. : (031)5939510, Fax : (031)5939925  
<sup>a</sup>E-mail : yanirahmawati2012@gmail.com  
<sup>b</sup>E-mail : christionoutomo@gmail.com

## ABSTRACT

*Reworks, un-well-suited works of construction process with schedule, additional cost of unnecessary works, mistakes, lead time and delays, are some problems which are often met in construction process. Those problems are appeared related to bad or unexpected design. Design is fundamental due to the construction process. Building is built through the construction process of design, in which it is resulted from design process. In supporting the construction process, stakeholders (clients, project manager, quantity surveyors, designers, and contractors) are needed to be involved in design process. Collaborative design is needed to facilitate the integration of stakeholders in design process. Knowledge management is one important factor which supported the achievement of successful collaborative design. This research is conducted with purpose to explore the implementation of collaborative design in design process to support construction process, by using literature study and awareness research. Based from research, it is found that there is contradiction finding between result gained from literature study and awareness research based on the understanding of knowledge management which is caused the appearance of doubt in the role of collaborative design. Result gained from this research will be used to develop conceptual definition of dissertation.*

## Keywords

*Collaborative design, knowledge management, project performance*

## 1. INTRODUCTION

Problems are often met in construction process, in which it impacts to unsuitable works in construction process with schedule that has been planned before. This condition will lead to the failure of building objectification from design through construction process. Rework is one of problem which is met in construction process [1], in which it often appears related to the failure or incompatibility of building component design with building system design, whereas if the design is well designed, it will consider all aspect as whole system in building. Rework in construction process will cause additional cost [2, 3] and time [4]. Based from review, it can be concluded that there is a causal linkage between design and construction process. As in [5], problems which are appeared in construction process are related with bad or unexpected design which resulted from design process.

Based from identification of problems in construction process above, it can be discovered that the appearance of problems are related with design. Design is fundamental due to construction process, because design is used as guidance in construction process to build building [6]. Related with this statement, [7] stated that building is built not from trial and error, so the building should construct from best design. Best design can be achieved through the involvement of stakeholders and multiple experts in design process [8], as best solution which gained from multiple alternatives [1], or as an effort to share expertise, idea, responsibilities and source [9]. The need to involve stakeholders in design process is increasing based on the emerging of globalization and complexities of the building itself. Collaborative design is needed as an approach in design process to facilitate the integration of stakeholders and experts whom have different backgrounds in creating design. The achievement of well construction process is gained from successful collaborative design. Knowledge management is one of key success factor, in which it gives important role in collaborative design.

## 2. CONCEPTUAL BACKGROUND

Collaborative design is an approach which is used to facilitate the integration of participants with different background in design process; whereas the participants can work together simultaneously in producing best design as integrated shared solution [10]. Due to facilitate the integration of participants with different backgrounds, issues are appeared and emerging, which cause difficulties in achieving collaborative design goals. Different time and place availabilities of participants [14],

difficulties in achieving shared understanding [18], conflicts [19], and also different personality and attitude of participants [1] are some problems which appeared in collaborative design process. Researches in the area of collaborative design are developed based on the development of issues, in which researchers are finding solution that can be used to reduce or face the appearance of issues that can caused failure in achieving successful collaborative design. Based from literature review, Authors found that collaborative design is a settled knowledge in which it is proofed through researches that collaborative design is able to support the achievement of optimum design [11, 12]. Authors also found that there are three important factors that need to be considered in conducting successful collaborative design, which consist of physical, technical, and social factors. Physical factors are related with issues of difficulties in conducting meeting and doing collaborative design, which are caused by different time and place availabilities of participants whom involved in design process [10]. Solutions which can be used to solve the issue is creating system and tools based on information and communication technology (ICT) that can facilitate information sharing activities between participants whom dispersed located [13, 14, 15].

Conflicts, difficulties in negotiating alternatives, and limitation of media for integrating design objects are some emerging issue that appeared in collaborative design process, especially which facilitated by ICT. The emerging of issues in collaborative design is caused by difficulties in achieving shared understanding between participants [16]. Some solutions that invented through researches in solving the issues are related to technical factors, in which it includes knowledge management [17]. The knowledge management consists of facilities in storing the design process development [18], the use of similar software or media in processing design [19], the use of agent system [2], and also bordering the design development through criteria of design [20]. Issues in collaborative design process are then emerging to the social issues, which related with the personality of participants [1] and social relationship between participants [21]. The appearance of social issues is lead to difficulties in achieving best or optimum design [1], in which it is found that solutions related with social issues consist of personality and attitude consideration, and also the use of teamwork which has experience in working together in collaborative design process [21].

### **3. AWARENESS RESEARCH**

Awareness research is conducted with purpose reveal awareness of participants in design process about collaborative design's concept, to verify supported factors in collaborative design which is gained from literature study, and also to explore current practice of design process and implementation of collaborative design in design process. Respondents of awareness research are 36 experts whom consist of academician and stakeholders in Surabaya and have experience in design process. The research is done by using structured interviews in collecting data. Respondents were firstly asked about the current practice of design process by identifying criteria of collaborative design which were found in design process in order to explore the implementation of collaborative design, they were also asked about their understanding and viewpoints of collaborative design, and also the influence of factors which are gained from literature review in supporting the collaborative design process. Factors which are used in awareness research are representing each factor of physical factors, technical factors, and also social factors. Physical factors are representing by ICT support in conducting collaborative design process, in this paper called technology. Technical factors are representing by the use of similar software and shared understanding between participants, which are called software and perspective in this paper. And the last factor, social factors, are representing by personality of participants and also social relationship between participants, which are called personality and social in this paper. The awareness research results of participants' understandings and viewpoints of collaborative design's concept will be analyzed descriptively. The influenced factors of collaborative design will also analyzed descriptively by using score of mean and standard deviation comparison, in which the result will be plot in scatter plot diagram to analyze the importance of each factor in supporting collaborative design process.

### **4. RESULT AND DISCUSSION**

The main purpose of conducting awareness research is to explore current practice of design process, whether it was implementing collaborative design or not. The research is also conducted with purpose to reveal and identified the awareness of designers and stakeholders whom involved in design process about the implementation of collaborative design concept in supporting design process effectively and efficiently, in which according to findings revealed from awareness research, the role of knowledge management will be described as one important factor in supporting the achievement of successful collaborative design.

#### **4.1 CURRENT PRACTICES OF DESIGN PROCESS**

In order to explore the current practice of design process in Indonesia, whether it implemented concept of collaborative design or not, Authors identified criteria of collaborative design which found in design process. The criteria that asked through respondents consisted of the involvement of multiple stakeholders [8], effort to accomplish design together and simultaneously [10], and also the task interdependencies in design process [26]. Based from the findings which presented on Figure 1, Figure

2, and Figure 3; it can be found that mostly of design processes were implementing collaborative design concept, in which it can be concluded by using criteria of collaborative design attained from past researches; where it is concluded based on finding of all collaborative design criteria in design process, and none (0%) of respondents never find those criteria in design process. Based on this finding, respondents were then asked about their understanding related to concept of collaborative design through its definition and role. The level of understanding about collaborative design concept will influence the implementation in design process.

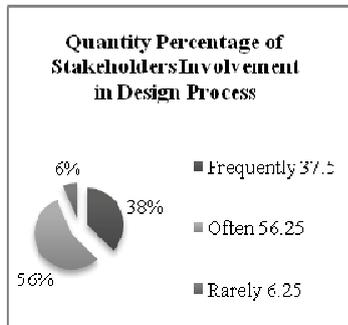


Figure 1: Quantity Percentage of Stakeholders Involvement in Design Process

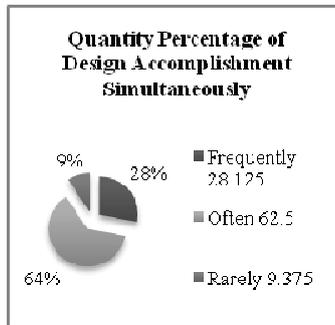


Figure 2: Quantity Percentage of Design Accomplishment Simultaneously

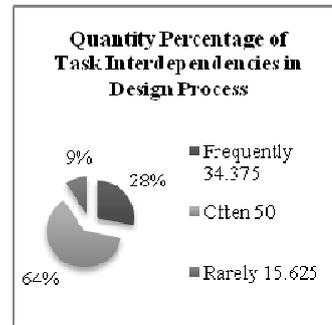


Figure 3: Quantity Percentage of Task Interdependency in Design Process

Figure 4 presents the percentage result of respondents' understandings and viewpoints about the concept of

collaborative design. Based on result it can be seen that there are some respondents (5,56%) whom do not understand yet about the concept of collaborative design, although actually they had experiences in collaborative design process. The lack understanding of collaborative design concept made them have negative viewpoints of the collaborative design role in supporting design process. As [10] stated that design resulted from collaborative design process need to be finished together by participants simultaneously, some respondents were argued about the role of collaborative design because of the essence of working together simultaneously will lead to support design process effectively. Some respondents are defining collaborative design as a collective work of design from participants involved. Collaborative design is not a collective work in design, where design should be finished together simultaneously, and the appearance of misunderstanding about collaborative design will affect to the design process and design resulted from the process [22].

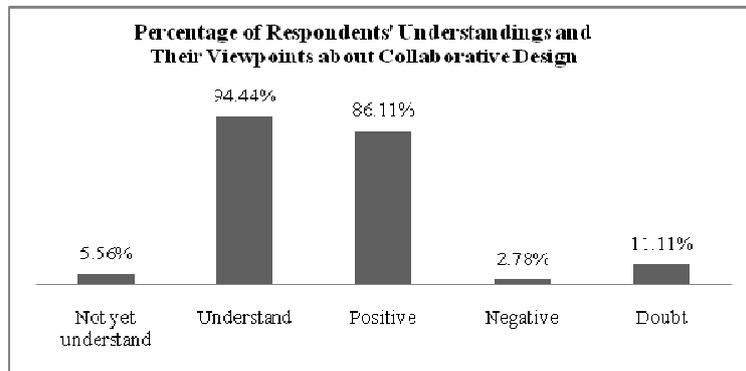


Figure 4: Awareness Research Result of Respondents' Understandings and Viewpoints

According to those finding it can be stated that the concept of collaborative design is mostly applied in current design practices, but main problem appeared due to perspectives of designers about the role of collaborative design in supporting the efficiency and effectiveness achievement in design process. Based on this finding, respondents were then interviewed about factors which made them had doubt in collaborative design role, in which it was found that problems related with knowledge management were main factor that caused respondents doubt about collaborative design role. It was also found that respondent had lack under-standing about factors related with knowledge management which able to support the achievement of successful collaborative design.

## 4.2 THE ROLE OF KNOWLEDGE MANAGEMENT

Due to awareness research, it was found that some respondents whom understand about the concept of collaborative design had doubt about the role of collaborative design in supporting design process. There are some problems which cause some of respondents had doubt about the concept of collaborative design, in which based on the interview it is found that the problems consist of difficulties in modifying design, difficulties in managing design which resulted from each participant, difficulties in achieving shared understanding between participants, and difficulties in making decision through multiple alternatives which are gained from participants. According to literatures, those problems related with knowledge management role in collaborative design [18, 20, 23]. As in [24], collaborative design process should be facilitated with tools or system that capable to facilitate each participant in modifying design, whereas transformation of design and design development as knowledge in design need to be stored [17] and classified [25]. Knowledge that has been stored can be traced by participants to know the process of design transformation and development, in which this activities support the achievement of shared understanding between participants. Knowledge in collaborative design need to be managed [18], beside the facilities of storing and modifying design [24], facilities in classifying knowledge is also needed to support the process of design development and decision making in collaborative design [2]. Based from review to researches in the area of collaborative design, it is found that knowledge management plays important role in the achievement of successful collaborative design [8, 9, 20].

Knowledge management is needed in supporting the achievement of successful collaborative design. The existence of lack understanding about knowledge management supports the appearance of doubt in the role of collaborative design in supporting collaborative design process. Based on literature study it can be found that the use of collaborative design which supported by knowledge management can be used as an approach to facilitate design process that involves participants with different backgrounds. But this finding was argued by respondents, because of their lack understanding about knowledge management in collaborative design. Related with findings found before, it is also found that factor of shared understanding (perspective) which is classified into technical factors in which it also related with knowledge management is factor which has the lowest score of importance in supporting collaborative design, in which the results can be seen in Figure 5 and Table 1. From interview to respondents, it was also found that problems related to technical factors are often solved with inappropriate approaches, in which it should be solved through the implementation of knowledge management but because of their lack understanding about knowledge management, the problems were then solved with social approaches, which lead to failure in achieving optimum design.

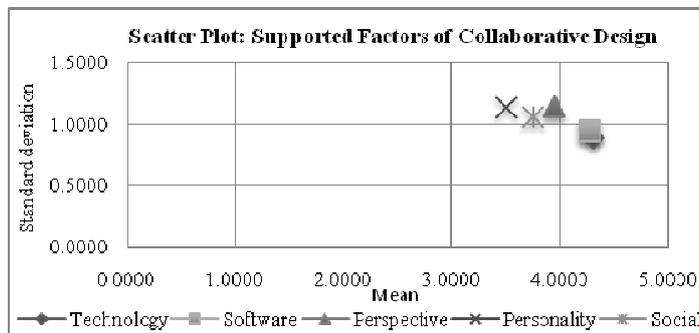


Figure 5 : Scatter Plot Diagram of Mean and Standard Deviation

Table 1 : Rank of Factors Based on Mean and Standard Deviation

Factors	Mean Score	Standard Deviation Score	Rank
Technology	4.3056	0.8886	I
Software	4.2778	0.9445	II
Social	3.7500	1.0522	III
Personality	3.5000	1.1339	IV
Perspective	3.9444	1.1450	V

One of problem that solved with inappropriate approach is conflicts which are appeared because of failure in achieving shared understanding of design development between participants. The problem should be solved through knowledge management,

whereas participants should identify the design development by tracing the storage of design process, but because of their lack understanding of knowledge management the problem was solved through social approach. Another problem that is solved using inappropriate approach is problem related with difficulties in modifying design, in which it should be solved through ICT based system and tools that applied in design software, but because of lack understanding of knowledge management the problem was also solved by using social approach. Based from findings in awareness research, it can be concluded that factor which influenced the appearance of doubt between designers and stakeholders in the role of collaborative design is their lack understanding about the concept of collaborative design itself and also knowledge management as an important factor in supporting the achievement of successful collaborative design process. This finding has contradiction with findings gained from literature review, in which the role of collaborative design is proofed through researches in facilitating design process that involved participants with different background effectively and efficiently [20], but it is argued by respondents because of their lack understanding of collaborative design and knowledge management.

## 5. CONCLUSION

There is contradiction between findings gained from literature review and awareness research, where respondents have doubt about the concept of collaborative design in facilitating design process effectively and efficiently, even that most design practices they were involved were implementing collaborative design concept. The respondents argued the finding of research in the area of collaborative design which is developed by researchers about collaborative design role in supporting design process. Based on awareness research by interviewing some respondents, it is found that the contradiction appeared because respondents has lack understanding about the concept of collaborative design itself and knowledge management as supported factor, in which it caused the appearance of doubt about collaborative design role in design process and the use of inappropriate approaches in collaborative design by applying social approaches in facing problems related with knowledge management. This situation will lead to difficulties in achieving best design which has to be accomplished in design process.

The situation will also impacted on failure in achieving optimum design as best shared solution that integrated between participants. Based from findings, it can be concluded that knowledge management plays important role in achieving successful collaborative design through the achievement of shared understanding between participants, in which it will lead to support the negotiation and decision making process in collaborative design. Successful collaborative design will contribute to support the construction process through best design that is resulted from collaborative design process. The finding gained from this research, related with contradiction finding from literature study about the lack understanding of knowledge management which caused the appearance of doubt in implementing collaborative design, will be used to develop the knowledge management model in supporting collaborative design process through dissertation research. Some factors that be used to develop the model consist of media and shared understanding as knowledge management factors, and also participants' behavior.

## REFERENCES

- [1] Vivacqua, AS., Garcia, ACB., and Gomes, A., (2011), "BOO: Behavior-Oriented Ontology To Describe Participant Dynamic In Collocated Design Meetings", *Journal Of Expert System With Application*, vol. 38., pp. 1139-1147.
- [2] Ren, Z., Yang, F., Bouchlaghem, NM., and Anumba, CJ., (2011), "Multi-disciplinary collaborative building design-a comparative study between multi-agent systems and multi disciplinary optimization approaches", *Automation in construction*, vol. 20, pp. 537-549.
- [3] Sonnenwald, DH., (1996), "Communication roles that support collaboration during the design process", *Design Studies*, vol. 17, pp. 277-301.
- [4] Shen, W., Hao, Q., and Li, W., (2008), "Computer supported collaborative design: Retrospective and perspective", *Computers in Industry*, vol. 59, pp. 855 – 862.
- [5] Formoso, CT., Tzotopoulos, P., Jobim, MSS., and Liedtke, R., (1998), "Developing a protocol for managing the design process in the building industry", *International Group for Lean Construction (IGLC – 6)*, Brazil, 13-15 August 1998.
- [6] Girard, P., and Robin, V., (2006), "Analysis of Collaboration for Project Design Management", *Computers in Industry*, vol. 57, pp. 817-826.
- [7] Webb, A., (1994), *Managing Innovative Projects*, Chapman and Hall, UK.
- [8] Kalay, YE., Khemlani, L., Choi, JW., (1998), "An Integrated Model to Support Distributed Collaborative Design of Buildings", *Automation in Construction*, vol. 7, pp. 177-188.
- [9] Patel, H., Pettitt, M., and Wilson, JR., (2012), "Factors of Collaborative Working: A Framework For A Collaboration Model", *Applied Ergonomics*, vol. 43, pp. 1-26.
- [10] Kvan, T., (2000), "Collaborative Design: What Is It?", *Automation in Construction*, vol. 9, pp. 409-415.
- [11] Adams, RS., Daly, SR., Mann, LM., Dall'Alba, G., (2011), "Being a Professional: Three Lenses into Design Thinking, Acting, and Being", *Design Studies*, vol. 32, pp. 588 – 607.
- [12] Ping, CS., Keung, CNY., and Ramanathan, M., (2011), "Integrated team design process – successful stories of Hong Kong MTR corporation projects", *Journal of Procedia Engineering*, vol. 14, pp. 1190-1196.
- [13] Gross, MD., Do, EYL., McCall, RJ., Citrin, WV., Hamill, P., Warmack, A., and Kuczun, KS., (1998), "Collaboration and coordination in architectural design: approaches to computer mediated teamwork", *Automation in Construction*, vol. 7, pp. 465-473.
- [14] Kolarevic, B., Schmitt, G., Hirschberg, U., Kurmann, D., Johnson, B., (2000), "An Experiment in Design Collaboration", *Automation in Construction*, vol. 9, pp. 73-81.

- [15] Woo, S., Lee, E., and Sasada, T., (2001), "The Multiuser Workspace As The Medium for Communication in Collaborative Design", *Automation in Construction*, vol. 10, pp. 303-308.
- [16] Saad, M., and Maher, M.L., (1995), "Shared Understanding In Computer-Supported Collaborative Design", *Computer Aided Design*, vol. 28, no. 3, pp. 183-192.
- [17] Dave, B., and Koskela, L., (2009), "Collaborative Knowledge Management- A Construction Case Study", *Automation in Construction*, vol. 18, pp. 894-902.
- [18] Gabriel, G.C., and Maher, M.L., (2002), "Coding and modelling communication in architectural collaborative design", *Automation in Construction*, vol. 11, pp. 199-211.
- [19] Anumba, C.J., Ugwu, O.O., Newnham, L., Thorpe, A., (2002), "Collaborative Design of Structures using Intelligent Agents", *Automation in Construction*, vol. 11, pp. 89-103.
- [20] Robin, V., Rose, B., and Girard, P., (2006), "Modelling Collaborative Knowledge to Support Engineering Design Project Manager", *Computers in Industry*, vol. 58, pp. 188-198.
- [21] Charnley, F., Lemon, M., and Evans, S., (2010), "Exploring The Process Of Whole System Design", *Journal of Design Studies*, vol. 32, no. 2, pp. 156-179.
- [22] Lu, S.C.Y., Elmaraghy, W., Schuh, G., and Wilhelm, R., (2007), "A scientific foundation of collaborative engineering". *Annals of the CIRP*, vol. 56, no. 2, pp. 605-634.
- [23] Liu, H., Tang, M., and Frazer, J.H., (2004), "Supporting dynamic management in a multi agent collaborative design system", *Journal of advance in engineering software*, vol. 35., pp. 493-502.
- [24] Leeuwen, J.P.V., and Fridqvist, S., (2006), "An information model for collaboration in the construction industry". *Computers in Industry*, vol. 57, pp. 809-816.
- [25] Chiu, M.L., and Lan, J.H., (2005), "Information and IN-formation, Information Mining for Supporting Collaborative Design", *Automation in Construction*, vol. 14, pp. 197-205.
- [26] Detienne, F., (2006), "Collaborative Design: Managing Task Interdependencies And Multiple Perspective", *Interacting With Computer*, Vol. 18, Hal. 1-20.

# The Analysis of Construction Type for Effective and Efficient Bridge Upper Structure with Value Engineering Method (Case Study in Singomoyo Bridge Development Project in Malang Regency)

Ir. Tiong Iskandar, MT.<sup>a</sup>, Ir. Deviany Kartika, MT.<sup>b</sup>

<sup>a</sup>Faculty of Civil Engineering and Planning  
National Technology Institute, Malang  
Tel : (0341) 551431 ext 125  
E-mail : [tiong\\_iskandar@yahoo.com](mailto:tiong_iskandar@yahoo.com)

<sup>b</sup>Faculty of Civil Engineering and Planning  
National Technology Institute, Malang  
Tel : (0341) 551431 ext 125  
E-mail : [devianykartika@yahoo.com](mailto:devianykartika@yahoo.com)

## ABSTRACT

*In globalization era, the more expensive construction cost and the auction transparency can cause the tightening world competition in relation to contractor service. Therefore a cost saving effort of construction is needed especially for the Singomoyo bridge upper structure in Malang regency.*

*Value Engineering method is one of the method analyses which proved effectively in saving the budget for construction projects. Value Engineering Job Plan consists of: Information, Speculation, Analysis and Proposal Phases. In order to get an optimal cost saving, we need to study the effectiveness of bridge upper structure used in the first contract. The best alternative construction selection analysis out of the several alternatives must consider cost and technical factors, and is followed up by cost calculation.*

*The finding of Value Engineering analysis shows the most effective and efficient bridge upper structure alternative by using the prestressed concrete girder. The initial cost for steel frame of upper structure was Rp. 2.615.552.816,61. After the implementation of value engineering analysis for the upper structure and the use of prestressed concrete girder for the upper structure, the cost is Rp. 1.741.886.599,65. The amount of cost that can be generated is Rp. 873,666,216.95. It is equal to 33.40% out of the initial construction cost with the use of the steel frame for bridge upper structure.*

### Keywords :

*Effective, Efficient, Cost saving*

## 1. INTRODUCTION

In globalization era when borders among countries are more opened, product and service from one place can reach another place more easily. As a result, only those who work with the principle of “doing the right things (efficient)” and “doing things right (effective)” will prevail in competition and win the market and further they will get much benefit from their efforts earlier and better” (Soeharto, 1998).

The fast development growth in Malang Regency will result in the more expensive construction cost (highway construction and maintenance department of Malang Regency, 2012). In the other side, there is higher public demand for transparency and accountability of development implementation according to Presidential Regulation no 54, 2010 on Goods and Service Provision whose funding sources are drawn from APBN (National Budget) and APBD (Regional Budget). Article 5 in the regulation mandates the principles of provision: efficient, effective, transparent, open, competitive, fair and non-discriminative and accountable. Such regulation will cause tight competition on the domain of construction executors who offer such service. One of alternative methods in an effort to tighten the budget cost is by implementing Value Engineering in construction project. Value Engineering is defined as “an organized attempt to analyze a problem with in an effort to achieve the desired functions with optimal total cost and final result”. [4].

The study will review some concerns, such as: identifying bridge upper structure construction with high cost rate in order to achieve the significant cost efficiency, finding the alternative construction type of bridge upper structure, analyzing some alternative types for bridge upper structure through the consideration of life cycle cost during planning period, carrying out comparison to study design that is supposed to follow the contract, and estimating efficiency obtained from the chosen alternative cost compared to the initial design.

Based on the concerns that have been discussed in the background section after learning information data and contractual documents thoroughly, carrying out the observation around site and analyzing the indicator fulfillment for the success of

Construction Project of Singomoyo Kebon Agung Bridge, the main problems that serve as analysis material for the study can be formulated as follows:

1. Could the construction type for the bridge upper structure implemented for the Construction Project of Singomoyo Bridge in Malang regency be considered as effective and efficient?
2. Are there any other more effective and efficient construction types?
3. How much efficiency is resulted from the implementation of value engineering?

The purpose of this study is to evaluate and analyze the efficiency and effectiveness of value effectiveness on construction of bridge upper structure for the project of Singomoyo Bridge in Malang Regency. The purpose of study can be summarized as follows:

- a. To analyze the efficient and effective bridge upper structure.
- b. To obtain the alternative bridge upper structure that is more effective and efficient through the application of value engineering on the Construction Project of Singomoyo Bridge in Malang Regency.
- c. To obtain the saved amount of bridge upper structure cost on Construction Project of Singomoyo Bridge in Malang Regency through the implementation of value engineering method and to know the amount of efficiency that can be done.

Based on the issues that have been described above, to avoid the deviation of discussion, it is important to determine the limits for present study. The following can be considered as the applied limits:

1. The analysis object is Construction Project of Singomoyo Bridge in Malang Regency.
2. The analysis and application of Value Engineering is used for bridge upper structure construction, especially for the bridge girders that must meet the characteristic and condition of the existing field.
3. The concerns that become the subject of Value Engineering analysis is beyond the issues that have relation with the policy from the owner, planner or executor of the project.
4. The price standard of basic unit for material, wage and equipment uses the price standard of highway construction and maintenance department for the year of 2011 and the price that is determined by the manufacturer of prestressed concrete and steel for bridge.
5. The analysis of unit price uses the analysis of work unit price applied in Malang Regency.

## 2. RESEARCH METHODOLOGY

The object of the study is The Construction Project of Singomoyo Bridge that is located in the border of Kecamatan Pakisaji and Kecamatan Wagir, Malang Regency. The bridge is situated in Kebonagung - Wagir Street and crosses Metro River. Traffic in the street is relatively high consisting of people and goods. The area is residential area that has high density. As one of its characteristics, Metro River has stable current because in its lower course there is dam that is controlled by irrigation department. Elevation between water surface and bridge floor is so limited while soil condition as its base is hard enough.

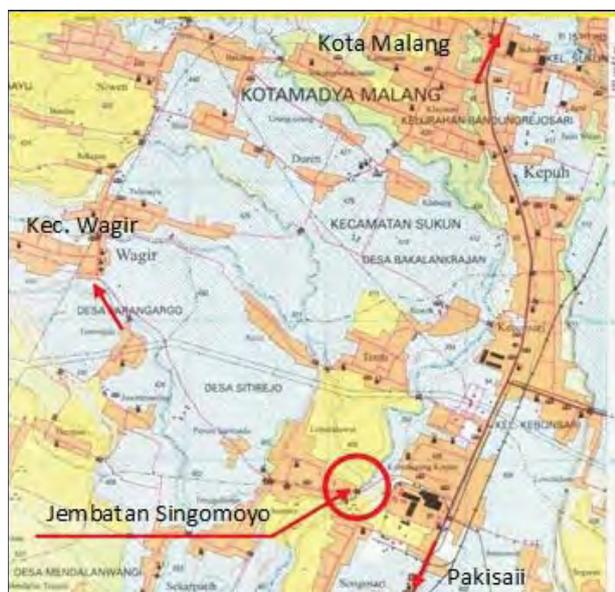


Figure 1. The Map of Singomoyo Bridge Location

Bridge structure has 1 (one) span. The design of upper structure construction uses steel frame construction. The abutment uses reinforced concrete construction and shaft foundation. The span length of the bridge is 40 m so the bridge is categorized into class A bridge. The width of the bridge is 1m + 7m + 1m.

Considering the fact that the construction planning uses steel frame construction, the cost tends to be more expensive. However after studying the field condition thoroughly, there is still possibility to apply other alternative constructions such as conventional concrete, prestressed concrete, composite girder, etc. It is assumed that cost efficiency measure must be taken without reducing the function value of the bridge. One way is to implement Value Engineering in planning construction project of Singomoyo Bridge, so the cost efficiency of construction can be estimated.

In the study the implementation of value engineering in the project uses Value Engineering Job Plan as its method or technique based on Dell'Isola theory (1975) described as value engineering job plan that comprises of information, speculation, analysis and proposal phases.

**2.1.1. Information Phase**

Information phase is carried out through the following steps:

1. Collecting project data that consists of design picture and RAB
2. Studying RAB to obtain each component and work cost
3. Determining work item cost information through the making of project model cost
4. Analyzing further in the form of function analysis.

**2.1.2. Speculation Phase**

After obtaining items to implement value engineering, the next step is to collect idea and think creatively in an effort to get the alternative design that can fulfill the basic function of the predetermined work item. In this creative phase, it is important to have creative approach toward alternative design that will meet the basic function of the predetermined work item.

**2.1.3. Analysis Phase**

Analysis phase has a purpose to select some best alternatives from the resulted alternatives during creative phase through some analysis/steps and assess those creative ideas based on the benefit and loss aspects in an attempt to obtain the cost efficiency from each evaluated idea. During the evaluation process, the some techniques can be applied such as zero one and evaluation matrix methods.

**2.1.3.1. Benefit and Loss Analysis**

Benefit and loss analysis is the roughest filtering phase among other estimation methods. Among creative ideas resulted from previous phases, the chosen ideas are Deep Galvanized Steel Frame, Reinforced Concrete Bending, Deep Galvanized Steel Girder, Prestressed Concrete Girder, and then the potential benefit and loss are put into table.

**2.1.3.2. Determining alternative rank**

One of steps in analyzing the creative ideas is to discuss the estimation subjectively because often it is difficult to obtain ideal value. Therefore, alternative rank from the potential structures is carried out.

Based on [7] , some aspects/criteria that will be reviewed and the estimation scale that will be implemented are as follows: Cost, Space Utilization, attractiveness/esthetic, implementation method, maintenance, implementation timing.

The following table shows each aspect/criteria:

Table 1. Criteria and Estimation Scale

No.	Criteria	Estimation Scale			
1	A : Cost	4 = Very Cheap	3 = Cheap	2 = Expensive	1 = Very Expensive
2	B : Space Utilization	4 = Very Proper	3 = Proper	2 = Improper	1 = Very Improper
3	C : Esthetic	4 = Very Good	3 = Good	2 = Bad	1 = Very Bad
4	D : Implementation Method	4 = Very Easy	3 = Easy	2 = Difficult	1 = Very Difficult
5	E : Maintenance	4 = Very Cheap	3 = Cheap	2 = Expensive	1 = Very Expensive
6	F : Implementation Timing	4 = Very Fast	3 = Fast	2 = Slow	1 = Very Slow

Source : analysis result

**2.1.4. Proposal Phase**

The determined alternative in analysis phase is followed up in this phase and then proposed to the project owner in the written form. The proposal must be carried out in careful and convincing way and presented with detail by using the chosen sketches and items.

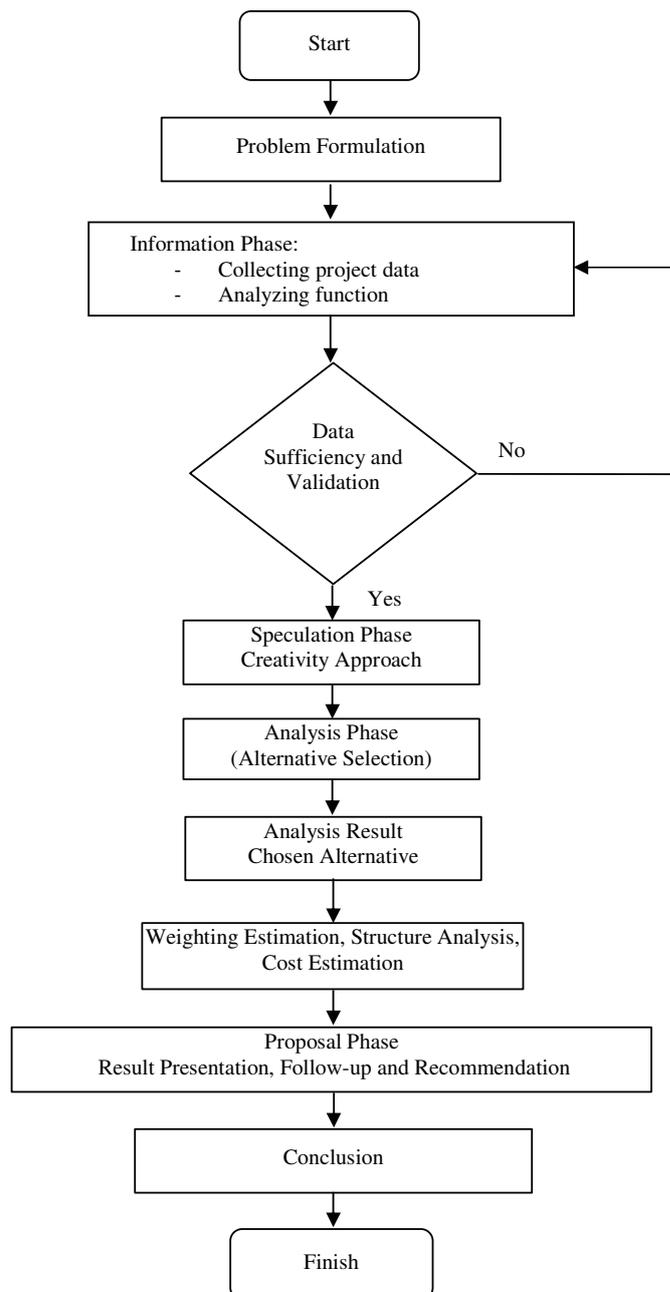


Figure 2. The flowchart of Value Engineering Job Plan

### 3. ANALYSIS AND DISCUSSION

#### 3.1. Information Phase

In the implementation of value engineering study, data about the entire planning of Singomoyo Kebonagung Bridge is required. The project information and technical data for each phase of project implementation are as follows:

The construction of upper structure

- |                     |   |
|---------------------|---|
| a. Project Name/job | : Improvement/The Construction of Singomoyo Kebonagung Bridge in Kec. Wagir |
| b. Location         | : Kecamatan Wagir   |
| c. Bridge Class     | : Class A (1m + 7m + 1m)  |
| d. Bridge Type      | : Austrian Steel Frame, the product of PT. Wagnei Biro Indonesia (WBI)      |

- e. Foundation (lower structure) : Shaft foundation with diameter of 2.5 m
- f. Bridge span : 40,0 m
- g. Project cost : Rp. 2,615,552,816.61,-

### 3.2. Analysis Phase

In this phase, input idea or alternative are analyzed so the selected idea gives more benefit seen from various aspects. The resulted alternative or idea is formulated and put into consideration in relation to their benefit and loss and then ranking is determined as a result of the estimation. The evaluation uses techniques such as zero-one method and evaluation matrix.

#### Benefit and Loss Analysis

Benefit and loss analysis is the roughest phase among the other estimation methods used in the estimation phase. Its first step is to enlist the potential benefits and losses of each alternative or idea. The following table shows the summary of benefits and losses of each alternative bridge upper structure.

Table 2. Benefit and loss analysis

No	Alternative / Idea	Benefits	Losses
1	Deep Galvanized Steel Frame	1. It is very light 2. The implementation method is very easy 3. It doesn't need maintenance 4. The implementation is very fast	1. The cost is so expensive 2. The material is difficult to obtain 3. It needs fabrication 4. The space utilization is not proper 5. The esthetic is bad 6. The construction age is 25 years
2	Reinforced Concrete Bending	1. It's easy to shape 2. Material is easy to get 3. It's durable against heat 4. The construction age is 50 years	1. The cost is expensive 2. The volume of concrete is big 3. The space utilization is not proper 4. The esthetic is bad 5. The implementation method is very difficult 6. The maintenance is very expensive 7. The implementation timing is very slow
3	Deep Galvanized Composite Steel Girder	1. The weight is light 2. The space utilization is proper 3. The esthetic is good 4. The implementation method is very easy 5. The maintenance is cheap 6. The implementation is very fast	1. The cost is expensive 2. The material is difficult to obtain 3. Fabrication is needed 4. Erection equipment is needed 5. The construction age is 25 years
4	Prestressed Concrete Girder	1. The concrete volume is small 2. The weight is light (type I) 3. The cost is cheap 4. The esthetic is very good 5. The space utilization is very proper 6. The maintenance is very cheap 7. The implementation method is easy 8. The implementation timing is fast 9. The construction age is 50 years	1. High quality concrete technology (fabrication) is needed 2. Prestressed technology is needed 3. The material is difficult to obtain 4. Erection equipment is needed

Source : analysis result

#### 3.2.1. Determining Alternative Ranking

One form of the creative idea analysis is to discuss the estimation in very objective way because it is so difficult to obtain the ideal value so ranking of each potential alternative for bridge upper structure construction must be taken into consideration. Then based on the aspects/criteria of review and estimation scale above, the following feasibility analysis for each alternative for bridge upper structure is determined:

Table 3. The Estimation Score on Criteria

No	Criteria	Criteria						Description
		A	B	C	D	E	F	
1	Deep Galvanized Steel Frame	2	1	1	2	2	2	
2	Reinforced concrete bending	1	2	2	1	1	1	
3	Deep Galvanized Composite Steel Girder	3	3	3	4	3	4	
4	Prestressed Concrete Girder	4	4	4	3	4	3	

Source: analysis result

From 4 alternatives for bridge upper structure, the best alternative is selected to be developed in the value engineering. Furthermore, the weight from each criterion is determined by using zero one method as follows:

Table 4. Zero One Method to Determine the Weight

Criteria	No.	Criteria						Total	Ranking
		A	B	C	D	E	F		
Cost	A	X	1	1	1	1	1	5	1
Space Utilization	B	0	X	1	1	1	1	4	2
Esthetic	C	0	0	X	1	1	1	3	3
Implementation method	D	0	0	0	X	0	1	1	5
Maintenance	E	0	0	0	1	X	1	2	4
Implementation timing	F	0	0	0	0	0	X	0	6

Source : analysis result

Description : 1 = more important, 0 = less important, X = same function

Table 5. Weighting

Criteria	No.	Ranking	Ranking Number	Weight
A : Cost	A	1	6	100.00
B : Space utilization	B	2	5	83.33
C : Esthetic	C	3	4	66.67
E : Maintenance	E	4	3	50.00
D : Implementation method	D	5	2	33.33
F : Implementation timing	F	6	1	16.67

Table 6. Relative Weighting for Alternative Selection

No	Alternative	Criteria						Total	Ranking	Selected
		A	B	C	E	D	F			
		<b>100</b>	<b>83.33</b>	<b>66.67</b>	<b>50.00</b>	<b>33.33</b>	<b>16.67</b>			
1	Deep Galvanized Steel Frame	2	1	1	2	2	2	549.99	3	
		200.00	83.33	66.67	100.00	66.66	33.33			
2	Reinforced concrete bending	1	2	2	1	1	1	500.00	4	
		100.00	166.67	133.33	50.00	33.33	16.67			
3	Deep Galvanized Composite Steel Girder	3	3	3	3	4	4	1,099.99	2	
		300.00	250.00	200.00	150.00	133.32	66.67			
4	Prestressed Concrete Girder	4	4	4	3	3	3	1,299.99	1	1
		400.00	333.33	266.67	150.00	99.99	50.00			

Source : analysis result

### Cost and Efficiency Estimation

a. The amount of initial cost

Construction cost for upper structure (steel frame) including the work cost of reinforced concrete and steel for vehicle floor with the length of 40.0 m is Rp. 2.615.552.816,61 .

Table 7. The construction cost for upper structure (Existing)

No	Description	Unit	Volume	Unit Price	Price
<b>I Structure Work</b>					
1	K350 Concrete	m3	128.00	1,080,728.89	138,333,297.98
2	U32 Helical Reinforced Steel	kg	12,045.38	16,148.84	194,518,899.35
	<b>Sub Total</b>				<b>332,852,197.33</b>
<b>II Upper Structure Work (Steel Frame)</b>					
1	A.40 steel frame provision	kg	91,580.00	21,616.88	1,979,673,413
2	The delivery of steel frame to location (Malang)	kg	91,580.00	1,213.79	111,158,927
3	The Installation of steel frame & reaction	kg	91,580.00	2,049.81	187,721,479
4	Joint Expansion (100 ,100, 15)	M'	28.00	148,100.00	4,146,800
	<b>Sub Total II</b>				<b>2,282,700,619.27</b>
	<b>Total</b>				<b>2,615,552,816.61</b>

b. The cost estimation of the selected alternative

The following is the construction cost estimation for alternative bridge upper structure with the span length of 35.0 m. The cost estimation consists of cost for the alternative upper structure construction work and reinforced concrete and steel work for vehicle floor including the handrail.

Table 8. The cost of Alternative Upper Structure Construction (Prestressed Girder)

No	Description	Unit	Volume	Unit Price	Price
<b>I</b>	<b>Structure Work</b>				
1	K350 Concrete	m3	115.20	1,080,728.89	124,499,968.18
2	U 32 Helical Reinforced Steel	kg	10,843.79	16,148.84	175,114,631.47
3	Handrail	m3	72.00	150,000.00	10,800,000.00
	<b>Sub Total</b>				<b>310,414,599.65</b>
<b>II</b>	<b>Upper Structure Work (Prestressed Concrete Girder)</b>				
1	Material				
	a. PCI Girder	piece	5.00	216,160,000.00	1,080,800,000.00
	b. Diaphragm	piece	20.00	2,128,000.00	42,560,000.00
	c. Plat Deck	piece	140.00	504,000.00	70,560,000.00
2	Erection				
	a. PCI Girder	piece	5.00	39,200,000.00	196,000,000.00
	b. Diaphragm	piece	20.00	392,000.00	7,840,000.00
	c. Plat Deck	piece	140.00	140,000.00	19,600,000.00
3	Elastomer	piece	10.00	1,411,200.00	14,112,000.00
	<b>Sub Total</b>				<b>1,431,472,000.00</b>
	<b>Total</b>				<b>1,741,886,599.65</b>

Source: analysis results

#### 4. PROPOSAL PHASE

This phase is the final phase of the value engineering process. The phase consists of the presentation of conclusion and recommendation of the value engineering result to the concerned parties. The following table shows the summary of the proposal about upper structure work for Singomoyo Bridge.

Table 9. The Upper Structure Work Proposal for Singomoyo Kebonagung Bridge

<b>Project Name :</b>	
Improvement/Construction of Singomoyo Kebonagung Bridge in Kec. Wagir	
<b>Plan in Initial Contract</b>	
Bridge Class	: Class A (1m+7m+1m)
Foundation (Lower Structure)	: Shaft Foundation with Diameter of 2.5 m
Distance between Abutments	: 40.0 m
Upper Structure	: Austrian Steel Frame, The product of PT. Wagnei Biro Indonesia (WBI)
<b>Proposal</b>	
<b>Alternative :</b>	
Bridge Class	: Class A (1m+7m+1m)
Foundation (Lower Structure)	: Shaft Foundation with Diameter of 2.5 m
Distance between Abutments	: 35.0 m
Upper Structure	: Prestressed Concrete Girder
After considering the alternative upper structure for more efficient and effective bridge, the following result is obtained :	
<b>Cost</b>	
Initial Contract	Alternative
Rp. 2,615,552,816.61	<b>Rp. 1,741,886,599.65</b>
<b>Cost Efficiency Percentage</b>	
<b>Alternative (Selected) :</b>	

33.40% out of the initial contract
------------------------------------

Source : analysis result

## 5. CONCLUSION

From the value engineering analysis applied for the upper construction of Singomoyo Bridge in Malang regency, the following conclusions are obtained:

1. The implemented steel frame bridge as the existing construction type of bridge upper structure for Construction Project of Singomoyo Bridge in Malang Regency is not the effective and efficient alternative after the consideration of both the used material and the cost.
2. After the implementation of value engineering analysis for bridge upper construction of Singomoyo Bridge in Malang regency, the prestressed concrete girder as the upper construction type is selected as the more effective and efficient alternative without reducing the function and the capacity of the bridge service.
3. The upper construction cost for steel frame of Singomoyo Bridge was Rp. 2,615,552,816.61. After carrying out the value engineering analysis on upper structure construction and the resulted selection of the prestressed concrete girder, the cost of prestressed concrete girder is Rp. 1,741,886,599.65. The resulted efficiency is Rp. 873,666,216.95. The value is equal to 33.40% out of the initial cost of the upper structure construction.

## REFERENCES

- [1] Badan Penelitian Dan Pengembangan PU, Departemen Pekerjaan Umum, 1995. *Spesifikasi Elemen Struktur Jembatan Jalan Raya*, Jakarta.
- [2] Chandra, S. 1986, *Introduction and the Application of Value Engineering for Efficiency*, Jakarta.
- [3] Dell'Isola, Alphonse J, 1975. *Value Engineering In the Construction Industry*, Published by Van Nostrand Reinhold Company, New York.
- [4] Dharmayanti, 2007. *Rekayasa Nilai Proyek Villa Bukit Ubud*, [http://ejournal.unud.ac.id/abstract/2%/20rekayasa%20%20nilai%20\(chandra\).pdf](http://ejournal.unud.ac.id/abstract/2%/20rekayasa%20%20nilai%20(chandra).pdf)
- [5] Dinas Bina Marga Kabupaten Malang. 2012 *Perkembangan Indek Kemahalan Konstruksi tahun 2006 sampai dengan 2011*.
- [6] Dinas Bina Marga Kabupaten Malang, 2012. *Perkembangan Kenaikan harga Material, Upah dan Sewa Alat Mulai tahun 2006 sampai dengan 2012*.
- [7] Direktorat Jenderal Bina Marga, 1992. *Bridge Management System*, Jakarta.
- [8] Perpres 54. 2010 *Tentang Pengadaan Barang dan Jasa*.
- [9] Rumintang, Anna. 2008. *Analisa Rekayasa Nilai Pekerjaan Struktur Gedung Teknik Informatika UPN Veteran Jawa Timur*, Jurnal Rekayasa Perencanaan Vol 4 No 2.
- [10] Setiawan, Agus. 2008. *Perencanaan Struktur Baja dengan Metode LRFD*. Erlangga, Jakarta.
- [11] Soeharto, Iman. 2001. *Manajemen Proyek Dari Konseptual Sampai Operasional*, Edisi Ke II, Jilid II, Erlangga, Jakarta.
- [12] Soeharto, Iman. 2010. *Manajemen Proyek* Edisi I, Cetakan Ke III, Paramita, Surabaya.

# Organisational Culture: The Case of Indonesian Construction Industry

Debby Willar<sup>a</sup>

<sup>a</sup>Civil Engineering Department, Manado State Polytechnic, Manado 95252  
E-mail : debby\_willar@yahoo.com

## ABSTRACT

*Despite the complexities involved in measuring culture of the construction industry, this culture is regarded as being worthy of research, especially in relation to the organisational culture needed to improve organisational performance. Questionnaire surveys were distributed to selected representative G-7 Indonesian civil engineering contractors in order to assess the organizational culture profiles of the construction companies adopting the Organizational Culture Assessment Instrument (OCAI), which is based on the Competing Values Framework. The findings from the study indicates that different culture types are emphasized in the six cultural dimensions of OCAI, reflecting various elements of cultural values that exist in an organization's operating activities. A comparison between the dominant characteristics of the organizational culture type within Indonesian construction companies, possessing a culture type similar to that of other global construction companies, shows the differences that exist with construction industries elsewhere in the world. Having different pictures of culture profiles in the construction industries suggests that the culture profiles within the construction industry might reflect the construction market demand and business environment, in each country, and the goals of each construction company.*

**Keywords:** *Competing Values Framework, organizational culture, construction industry, Indonesia.*

## 1. INTRODUCTION

Current research within the construction management area has revealed evidence that organizational culture is considered to be a determinant factor in contributing to the organization competitiveness [1], quality management systems [2], sustainability [3], performance and effectiveness [4]. The 'people' in organizations are collectively bounded by the organizational culture which in turn reflects organization characteristics [5]. In this study, the term 'organizational culture' is going to be defined as the shared values and underlying assumptions within construction organizations, which motivate and support organizations to operate effectively.

Focusing on an investigation of the link between organisational culture and effectiveness of an construction organisation, [2] provides a list of organisational culture-performance link studies which were conducted by researchers in different parts of the world, between 1990 and 2004. From the list, it can be concluded that various kinds of organisational culture dimensions have been proven to be connected with short and long-term performance, direct or indirect performance, low and high performance, and growth and profitability of an organisation.

Current research in Indonesian construction and project management has not pursued a more comprehensive study of the organizational culture profiles of Indonesian construction companies and the link to effective organizational performance. In the interviews conducted as part of a pilot survey by the author, some of the respondents, all local contractors, stated that they had never considered undertaking any organizational culture investigation and thus were unaware of what types of culture their companies possessed. They observed that, in their view, organizational culture was demonstrated by characteristics such as, commitment, loyalty, and good team work.

This current study is aimed at diagnosing the dominant culture types in the six cultural dimensions of Organizational Culture Assessment Instrument (OCAI). Further analysis was made in regard to comparing the dominant characteristics of Indonesian construction companies' culture profile with other global construction companies. The method of analysis is carried out primarily by comparing measures obtained from the OCAI of [1], in order to determine the current dominant culture types of the respondent organizations that appear to enable them to operate effective organizational and management practices, that overcome the business environment's demands and challenges, that in turn will lead to have the potential for having organization effective performance.

## 2. JUSTIFICATION FOR CHOOSING THE COMPETING VALUES FRAMEWORK

There are a number of well-established and well-recognized models and instruments, which are used for identifying and measuring organizational culture. One of the most widely used theoretical models is the Competing Values Framework (CVF),

which was developed in [6]. It has the aim of helping organizations in understanding themselves and supporting the development of effective organizational phenomena. Indeed, the CVF “has been shown empirically to reflect the current thinking of organizational theorists on organizational values and resulting in organizational effectiveness” [7].

The CVF was eventually selected as being the most suitable organizational culture model to use in the context of this study, due to its suitability in identifying the profiles or types of organizational culture of construction companies, together with providing a measure of the strength of the individual characteristics that make up those profiles. The research is considered timely as many Indonesian construction companies do not perceive the importance of organizational culture, and therefore, a model is needed, which is easy to assimilate and which allows better visualization of how this complex phenomenon operates within their companies and of how a deeper understanding of corporate culture can assist business and process improvement within their organizations.

The CVF consists of four major culture types (clan, adhocracy, hierarchy, market) that are theorized to compose cultural profiles within various kinds of organizational contexts [8]. These authors further explain that an organization can possess either a predominant internal or external focus, and may either be wishing to achieve flexibility and discretion, or stability and control. This combination of factors creates four potential cultural categories, each representing a distinct set of cultural values. The four major culture types that emerge from the framework (Figure 1) are briefly described by [1] as follows:

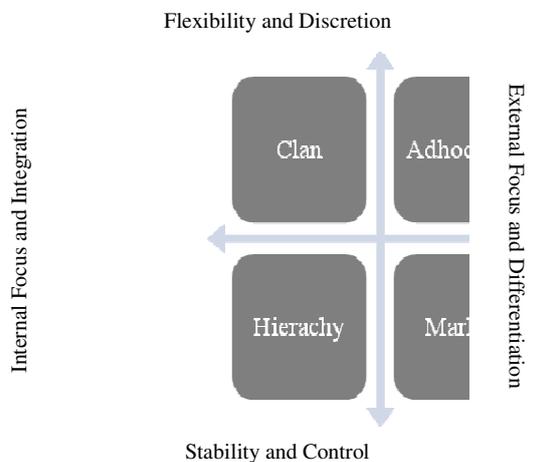


Figure 1: The Competing Values Framework

In construction research on organizational culture profiles, [9], [10], [11], [12], and [2] used the Organisational Culture Assessment Instrument (OCAI), which is based on the CVF, to identify the culture profiles of construction companies in each country of their research domain. They found that the tool is helpful in providing a comprehensive picture of a company’s organisational culture and the values that characterize each culture, as well as providing a comparison standard for culture profile interpretation. The six cultural dimensions of OCAI represent the culture climate in an organisation which forms a cumulative representation of an organisational culture [13]. The cultural dimensions with associated cultural types of the OCAI are presented in Table 1.

Table 1: OCAI traits and typologies

Cultural Dimensions	Culture Types			
	Clan Culture	Adhocracy Culture	Market Culture	Hierarchy Culture
Dominant Characteristics	It is a very personal place. It is like an extended family. People seem to share a lot of themselves.	It is a very dynamic and entrepreneurial place. People are willing to stick their necks out and take risks.	It is very results-oriented. A major concern is with getting the job done. People are very competitive and achievement-oriented.	It is a very controlled and structured place. Formal procedures generally govern what people do.
Organisational Leadership	The leader is generally considered to exemplify	The leader is generally considered to exemplify entrepreneurship,	The leader is generally considered to exemplify a no-nonsense, aggressive,	The leader is generally considered to exemplify

	mentoring, facilitating, and nurturing.	innovation, or risk taking.	results-oriented focus.	coordinating, organising, or smooth-running efficiency.
Management of Employees	The management style is characterised by teamwork, consensus, and participation.	The management style is characterised by individual risk taking, innovation, freedom, and uniqueness.	The management style is characterised by hard-driving competitiveness, high demands, and achievement.	The management style is characterised by security employment, conformity, predictability, and stability in relationships.
Organisation Glue	The glue that holds the organisation together is loyalty and mutual trust. Commitment to this organisation runs high.	The glue that holds the organisation together is commitment to innovation and development. There is an emphasis on being on the cutting edge.	The glue that holds the organisation together is the emphasis on achievement and goal accomplishment.	The glue that holds the organisation together is formal rules and policies. Maintaining a smooth-running organisation is important.
Strategic Emphases	It emphasizes human development. High trust, openness, and participation persist.	It emphasizes acquiring new resources and creating new challenges. Trying new things and prospecting for opportunities are valued.	It emphasizes competitive actions and achievement. Hitting stretch targets and winning in the marketplace are dominant.	It emphasizes permanence and stability. Efficiency, control, and smooth operations are important.
Criteria of Success	Success is on the basis of the development of human resources, teamwork, employee commitment, and concern for people.	Success is on the basis of having the most unique or newest products. It is a product leader and innovator.	Success is on the basis of winning in the marketplace and outpacing the competition. Competitive market leadership is key.	Success is on the basis of efficiency. Dependable delivery, smooth scheduling, and low-cost production are critical.

Source: [1]

### 3. RESEARCH METHODOLOGY

The respondents to the questionnaire for this study were drawn from 74 construction companies listed as grade 7 (G-7) contractors - the highest grade of Indonesian contractor qualification. A minimum of three responses and a maximum nine responses in each company involved in the questionnaire giving a total of 403 respondents: 67 Quality Management Representatives (QMRs), 215 Managers (Ms) and 121 Project and Site Engineers (Es). These groups of respondents represented the following levels of seniority (high - QMR), (middle - M), and (low - E) in the organizational structure.

Using the OCAI questionnaire developed by [1], a respondent rated a set of statements that relate to six cultural dimensions, i.e., dominant characteristics (DC), organisational leadership (OL), management of employees (ME), organisational 'glue' (OG), strategic emphasis (SE), and criteria of success (CS); the rating level is based on whether these dimensions are similar (or not) with the current situation in a respondent's company. This instrument is used to identify the most closely fitting type of culture for the company, i.e., whether it is predominantly a Hierarchy (H), Market (M), Clan (C), or Adhocracy (A) culture.

### 4. RESULTS AND ANALYSIS

#### 4.1 Results of Construction Companies' Culture Profiles

By individually plotting each of the questions under the six cultural dimensions on the Organizational Culture Assessment Instrument (OCAI) worksheet, the analysis of the companies six cultural dimensions was focused on indicating types of culture that most dominant in the six dimensions.

Figure 2 presents an example of the OCAI results of the dominant culture type for ‘strategic emphasis’ dimension from one of the company respondents. The dominant Market type (33) was emphasized in this dimension, followed by Clan type (24), and a slightly balanced of Hierarchy (22) and Adhocracy (21) types.

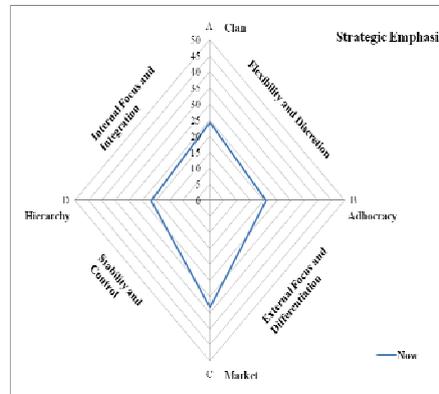


Figure 2: Dominant ‘Market’ type in the dimension of strategic emphasis

Table 2 summarises the dominant culture types of the six cultural dimensions possessed by most of the 74 construction companies. Overall, respondents perceived that the dominant characteristics or the core values of the construction companies is most represented by the ‘Clan culture’ (41.9%). The core values of ‘Clan type’ in this first dimension is the sense of ‘family’ and the importance of ‘sharing’. In reference to the style of the organization leader, most of the construction companies are strongly Hierarchy oriented (29.7%), with the leaders being hard drivers, producers, and competitors. The management style used to manage employees is strongly Clan oriented (56.8%) which is characterized by the value of team work, consensus, and participation. The organization glue that holds companies together is also the Clan culture (66.25%); loyalty and mutual trust are key norms of this Clan type in this fourth cultural dimension. The companies’ strategic emphasis is strongly Market oriented (35.1%), the Market culture having a competitive and achievement focus. Success criteria of companies as perceived by employees as the Clan culture (45.9%) that believes that their success lies on the development of human resources, commitment, and concern for people.

Table 2: Dominant culture types of six cultural dimensions

Cultural dimensions	‘C’ type		‘A’ type		‘M’ type		‘H’ type		***	
	n	%	n	%	n	%	n	%	n	%
1 <sup>st</sup> Dominant characteristics (DC)	31	41.9	11	14.9	22	29.7	5	6.8	5	6.8
2 <sup>nd</sup> Organisational leadership (OL)	18	24.3	8	10.8	21	28.4	22	29.7	5	6.8
3 <sup>rd</sup> Management of employees (ME)	42	56.8	4	5.4	11	14.9	13	17.6	4	5.4
4 <sup>th</sup> Organisational glue (OG)	49	66.2	3	4.1	7	9.5	5	6.8	10	13.5
5 <sup>th</sup> Strategic emphasis (SE)	13	17.6	6	8.1	26	35.1	15	20.3	14	18.9
6 <sup>th</sup> Criteria of success (CS)	34	45.9	-	-	11	14.9	23	31.1	6	8.1

Note: ‘C’ = Clan, ‘A’ = Adhocracy, ‘M’ = Market, ‘H’ = Hierarchy, \*\*\*= no dominant type;  
 [shaded cells] = most prevalent culture types possessed by respondents in each cultural dimension.

#### 4.2 Analysis of the Results

The findings from the study of the identification of dominant culture types within Indonesian construction companies indicates that the organisational culture within most Indonesian construction companies is predominantly of the Clan type, where the

company is focused on internal maintenance with flexibility, family-like relationships having a concern for people, and sensitivity towards its customers. This predominant culture type is also emphasized most in the cultural dimension related to how employees are managed, how the organisation is held together, and how the organisation's success in its achievements is defined. This finding is fundamental to the perspective of organisational culture within Indonesian construction companies. With the rapid and remarkable growth rate in the construction industry, it is important for this sector to recognise its individual and collective cultural patterns, in order that they can be used to evaluate companies current operational activities, achievements, and future successes. In addition, it needs to be recognised that adoption of the predominant company cultural profile allows companies to adapt and respond to challenges, and hence later set up appropriate cultural changes or maintain and strengthen the existing fundamental culture profile.

The dimension labeled 'organisational leaderships' is related to the dominant leadership style and approach used by leaders and managers in those companies which are more hierarchy-focused than the other three culture types. This indicates that the leaders and managers are generally considered to exemplify coordinating, organising, and smooth-running efficiency. For the surveyed companies, this finding confirms that the role of leaders and managers is to set an example in the day-to-day operational activities of the companies [14], [15] and [16], to become the focal points within the organisation in which the operational activities are largely governed by standardized procedures.

The dimension labelled as 'strategic emphasis', the area of emphasis that drives the organisation's strategy, in this study is 'Market type dominant', wherein the company emphasizes permanence and stability; efficiency, control and smooth operations, as the important company strategies. This finding suggests that current form of Indonesian construction strategy is focused more on profit and goal accomplishment, due to high competitiveness in both domestic and international markets. Contractors' focus on profit and market-orientation, in fact, is in line with of The Ministry of Public Work's policy to enforce Indonesian construction to take a role in global markets, as the industry can no longer just depend on the domestic market [17].

A comparison between the dominant characteristics of organisational culture type within Indonesian construction companies, possessing a culture type similar to that of other global construction companies, shows the differences that exist with construction industries elsewhere in the world. Hong Kong construction companies appear to emphasize the strong Clan type [18], while the Hierarchy type dominates the construction industry in Thailand [19]. From surveys conducted by [1], they found that, on average, the Market type was the predominant culture profile in the construction sector. A similar finding was reported by [10] for Finnish construction companies. In the case of the construction industry in China, a mixture of culture types exists, with Hierarchy – Market culture dominance being reported by [11] and Hierarchy – Clan culture dominance reported by [20]; the culture profiles of Chinese contractors varieties between geographical regions [20]. The Turkish construction industry has a mixture of Clan and Hierarchy cultures [12]. Having different pictures of culture profiles in the construction industries suggests that the construction industry has not yet been able to define 'a typical' culture profile, such as those based on Cameron and Quinn's culture typologies. The culture profiles within the construction industry might reflect the construction market demand and business environment, in each country, and the goals of each construction company. Reference [11] state that the understanding of organisational cultures (overlaid with national cultures) is an important element of any business enterprise.

## 5. CONCLUSIONS

The finding of this study is that Clan culture is most dominant within the highest grade of Indonesian construction companies qualification, while the style of organisational leadership is a hierarchical dominance. As common for an organisation in doing business, Indonesian construction companies emphasize Market type in their strategy settings. The identified organisational culture profiles most emphasized within Indonesian construction companies contributes to the recognition of the current contractor's cultural pattern, and this can be a basis for a company to consider further measures for matching the current culture profiles with the future demands of its environment, including future challenges and opportunities to be faced by the company. This will then advantage the company in setting up appropriate culture changes and/or strengthening its current culture profile in order to possess the most adaptable organisational culture; that culture will, in turn, help the company to successfully deal with the complexities of construction business entities.

Different countries have different and specific national cultures, different market demand and business environments, and as well as the goals of each construction company, which might influence a company's culture.

## ACKNOWLEDGMENT

This research project is funded by DIKTI Scholarships on behalf of The Ministry of Education and Culture of The Republic of Indonesia.

## REFERENCES

- [1] Cameron, K. S. and Quinn, R. E., Diagnosing and Changing Organizational Culture, Based on the Competing Values Framework, Revised ed., Jossey-Bass, San Fransisco, 2006.
- [2] Yong, K. T. and Low, S. P., Organizational culture and TQM implementation in construction firm in Singapore, *Construction Management and Economics*, 26(3), 237-248, Mar, 2008.
- [3] Yip Robin, C. P. and Poon, C. S., Cultural shift towards sustainability in the construction industry of Hong Kong, *Journal of Environmental Management*, 90(11), 3616-3628, Agt, 2009.
- [4] Coffey, V., *Understanding Organisational Culture in the Construction Industry*, Spon Press, London, 2010.
- [5] Cheung, S. O., Wong, P. S. P. and Wu, A. W. Y., Towards an organizational culture framework in construction, *International Journal of Project Management*, doi:10.1016/j.ijproman.2010.01.014.
- [6] Quinn, R. E. and J. Rohrbaugh. 1983. A spatial model of effectiveness criteria: Toward a competing values approach to organizational analysis. *Management Science* 29 (3):363-377.
- [7] Cooper, R. B. and Quinn, R. E., Implications of the competing values framework for management information systems, *Human Resource Management*, 32(1), 175-201, Apr, 1993.
- [8] Choi, Y. S., M. Seo, D. Scott and J. Martin. 2010. Validation of the Organizational Culture Assessment Instrument: An application of the Korean Version. *Journal of Sport Management* 24:169 - 189.
- [9] Thomas, R., M. Marosszeky, K. Karim, S. Davis and D. McGeroge. 2002. The importance of project culture in achieving quality outcomes in construction. Paper read at Proceedings of IGLC-10, at Gramado, Brazil. <http://www6.ufrgs.br/norie/iglc10/papers/98-ThomasEtAl.pdf> (accessed August 28, 2009).
- [10] Nummelin, J., Measuring organizational culture in construction sector - Finnish sample, in *Joint International Conference on Construction Culture, Innovation and Management (CCIM)*, Dubai, 2006.
- [11] Liu, A. M. M., S. Zhang and M. Leung. 2006. A framework for assessing organisational culture of Chinese construction enterprises. *Engineering, Construction and Architectural Management* 13 (4):327-342.
- [12] Oney-Yazıcı, E., Giritli, H., Topcu-Oraz, G. and Acar, E., Organizational culture: The case of Turkish construction industry. *Engineering, Construction and Architectural Management* 14 (6), 519-531, 2007.
- [13] Rameezdeen, R. and N. Gunarathna. 2003. Disputes and construction industry cultures. *AACE International Transactions* ProQuest Central:CD241.
- [14] Ahmed, S. M., Aoieong, R. T., Tang, S. L. and Zheng, D. X. M., A comparison of quality management systems in the construction industries of Hong Kong and the USA, *International Journal of Quality & Reliability Management* 22 (2), 149-161, 2005.
- [15] Müller, R. and Turner, J. R., Matching the project manager's leadership style to project type, *International Journal of Project Management* 25 (1), 21-32, 2007.
- [16] Müller, R. and Turner, R., Leadership competency profiles of successful project managers. *International Journal of Project Management* 28 (5), 437-448, 2010.
- [17] Surtiningsih and Abidin, N., Penandatanganan Pakta K3 [The signing of the treaty of health and safety in construction]. In *Bulletin BPKSDM* Jakarta: Badan Pembinaan Konstruksi dan Sumber Daya Manusia Departemen Pekerjaan Umum, 2009.
- [18] Cheng, W. M., A study on the organizational culture and Total Quality Management implementation of construction companies in Hong Kong, Department of Real Estate and Construction, The University of Hong Kong, Hong Kong, 2005.
- [19] Novana, M. and Ogunlana, S. O., Organizational culture profile of construction companies in Thailand, paper read at The Joint International Conference on Construction Culture, Innovation and Management (CCIM): Sustainable Development through Culture and Innovation Executive, Dubai, 2006.
- [20] Zhang, S. B. and Liu, A. M. M., Organisational culture profiles of construction enterprises in China, *Construction Management and Economics* August 2006 (24), 817-828, 2006.

## Intelligence Functions in Construction

**Prof Krishna Mochtar, ST, MSCE, PhD.<sup>a</sup>**

<sup>a</sup>Department of Civil Engineering  
Indonesia Institute of Technology, Tangerang 15320  
Tel : (021) 7560545. Fax : (021) 7560542  
E-mail : kmochtar@yahoo.com

### ABSTRACT

*Pricing is one of the most important aspects in marketing concept, including in the construction industry. Up until today, there is only one pricing strategy predominantly used in construction: cost-based pricing. There are two problems with this pricing logic: underpricing or overpricing a bid offer. Considering problems with a cost-based strategy, alternate pricing strategies in construction using market-based approach are proposed. The heart of these models is intelligence functions in a company. This paper reviews and explores pricing strategy and intelligence functions in construction. First, it explores a new marketing concept, including alternate pricing strategies. Second, marketing intelligence systems developed and used in manufacturing industries are explored, including marketing research, marketing information systems, and decision supports systems. It also explores the current developments and practices of intelligence functions in construction. Third, findings of a survey administered to contractors to investigate intelligence functions are presented. In conclusion, "marketing intelligence systems" in construction is a subject that is seldom discussed by researchers. It is found that contractors use mostly traditional intelligence activities. It is recommended that contractors should develop particularly computers related intelligence activities such as using the Internet and developing MISs/DSSs.*

**Keywords:** *marketing, pricing, contractors, intelligence system, decision support system*

## **1. INTRODUCTION**

The construction industry in most countries in the world is one of extreme competitiveness, with high risks, and generally low profit margins when compared to other areas of the economy. Consequently, pricing is one of the most important aspects of marketing in construction. But unlike in other industries, transactions and contracting in construction are conducted through the competitive bidding process, so that pricing mostly takes place in the bidding process. Consequently, up until today, there has been only one pricing strategy predominantly used in construction: cost-based pricing. The typical procedure in cost-based pricing involves estimating the project cost, then applying a markup for profit. There are two problems with this pricing strategy. Since the price is set based on internal cost and margin requirements, the price that results could be too high or too low relative to offers made by competing organizations with comparable reputation. First, it is possible to grossly underprice a project using cost-based pricing and not only forgo high levels of profitability but also risk incurring great losses that can threaten the survival of the company. The second possible consequence of cost-based pricing is overpricing. What generally happens in these situations is that the project is overpriced relative to the owner's estimated cost and the offers of competing bidders, resulting in losing the bid.

## **2. NEW MARKETING CONCEPT**

The new concept of marketing stresses the importance of the market orientation of a firm's activities. A market orientation is made manifest by the development of firm skills. They include acquiring knowledge about customers and other market participants, sharing that knowledge widely throughout the organization, achieving consensus on its meaning, and taking action to deliver superior customer value [1, 2, 3]. Managers [4, 5] and scholars [2, 6, 7] are in broad agreement that a superior learning capability is an important contributor to competitive advantage, one of the most important marketing principles. An important distinction is that the objective is to learn about customers, not just to learn from them. Beside the customer needs, one of the most important marketing intelligence functions is to learn about competitors by identifying their strategies, determining their objectives, assessing their strengths and weaknesses, and finally estimating their reaction patterns [8]. Finally, the firm can learn from experience, continuously making improvements in the way it does repetitive tasks [9]. A recent study [10] suggests that each of these learning styles make a unique contribution to organizational effectiveness. All these studies support the need for marketing intelligence activities within a firm.

### **2.1. Alternate Pricing Strategies in Construction**

Considering the problems with a cost-based strategy and the benefits of new concepts of marketing, a series of "market-based pricing" models in construction are developed [12]. First, a hybrid-pricing model, a variation of the current cost-based pricing approach, that includes additional market information. Second is a more market-based hybrid pricing model with the main information of market data collected through marketing intelligence so that a cost target can be set. Third, a market-based pricing model with the main information used of market data collected through marketing intelligence. The big assumption of third model is the belief that the company is always able to find ways and methods to construct the project below the market price with a reasonable profit. The heart of these models is market intelligence functions in a company.

## **3. MARKETING INTELLIGENCE SYSTEMS**

A definition of marketing intelligence system is the system for capturing the necessary information for business marketing decision-making [13]. The fundamental purpose of marketing intelligence is to help marketing managers make decisions they face each day in their various areas of responsibility. As directors of their firms' marketing activities, marketing managers have an urgent need for information or marketing intelligence. They might need to know about the changes that could be expected in customer purchasing patterns, the shape of the firms' demand curve, or any of a number of other issues. These issues could affect the way they plan, solve problems, or evaluate and control the marketing effort, most importantly pricing policies [14].

According to Kotler [8] marketing managers often carry out marketing intelligence by reading books, newspapers, and trade publications; talking to customers, suppliers, distributors, and other outsiders; and talking with other managers and personnel within the company. According to Safford [15], there is a need for competitive intelligence in all business- large and small- regardless of the product or the industry. Consequently, four steps are involved in competitive price information: collection of competitive price information through intelligence activities, careful analysis of this information, development of strategy based upon the above, and finally action. Furthermore, there are 12 valuable sources of information on pricing in terms of developing competitive intelligence: the firm's own salesmen and other field representatives, printed price lists, rumors, especially rumors of change, friendly customers particularly if found reliable over the years, distributor and other advisory groups, bids and quotations made by governmental bodies, newspapers/journals and advisory services, annual and other financial reports containing interesting data on competitive capital and research programs, government and other publications, direct inquiry to competitors and contacts with counterparts among them, tangible proof from customers, and finally marketing survey/research [15]. Hutt and Speh [13] claim that a comprehensive business marketing intelligence system might include formal marketing research studies, market potential and sales forecasting, financial and accounting performance analysis, new product research, and secondary data files. Marketing intelligence is clearly a broad and complex function whose effectiveness will dramatically affect the quality of marketing decisions, including pricing decisions.

### 3.1. Marketing Research

Marketing research involves certain basic elements that apply generally. In any context, the research study must be planned, a data-gathering instrument designed, and a sampling plan designed. The data must then be gathered, processed, analyzed, and reported [13]. Traditionally, marketing research is responsible for this intelligence function. Marketing research is the firm's formal communication link with the environment. It generates, transmits, and interprets feedback information originating in the environment relating to the success of the firm's marketing plans and the strategies employed in implementing those plans [14]. The findings of a survey of marketing research executive conducted by the American Marketing Association indicate that companies use marketing research in pricing activities, including cost analysis, profit analysis, price elasticity, demand analysis, and competitive pricing analysis [16]. The marketing research function within a firm has no single form of organization and it is dynamic and ever changing. Small firms are likely to have a one-person market research operation, while large firms are more likely to have either a research department with some personnel or both a corporate marketing research unit and smaller-scale divisional marketing units. It could be centralized or decentralized, depending on the organizational structure of the firm itself. Large firms are likely to spend a larger proportion of the marketing budget on research, approximately 3.5% of the average marketing budget, than are small firms (only 1.5% of the average marketing budget) [17].

### 3.2. Marketing Information Systems and Decision Support Systems

Marketing information systems (MISs) and decision support systems (DSSs) are not competitive mechanisms for marketing research projects in gathering marketing intelligence but, rather, complementary ones. MIS is a set of procedures and methods for the regular, planned collection, analysis, and presentation of information for use in making marketing decisions [18, 19, 20]. The key word in the definition is "regular", since the emphasis in MIS is the establishment of systems that produce information needed for decision making on a recurring basis rather than for one-time research studies such as most marketing research projects. In designing an MIS, the thrust is a detailed analysis of each decision maker who might use the system in order to secure an accurate, objective assessment of each manager's decision making responsibilities, capabilities, and style. It considers not only the types of information but also the form in which the decision-makers like to receive it. Then designers attempt to specify, get approval for, and subsequently generate a series of reports that go to the various decision-makers [21].

However, there are problems with MIS: many decision-makers are reluctant to disclose to others what factors they use and how they combine these factors when making a decision in a particular issue, different managers typically emphasize different things and have different data needs, the systems do not lend themselves to the solution of ill-structured problems [14]. As these problems with MIS became more apparent, the emphasis in supplying marketing intelligence on a more regular basis changed from the production of preformatted, batch reports to decision support system (DSS) mode. DSS is a coordinated collection of data, systems, tools, and techniques with supporting

software and hardware by which an organization gathers and interprets relevant information from business and the environment and turns it into a basis for marketing action [22]. According to Sprague and Carlson [23], a DSS concentrates on the design of data systems, model systems, and dialog systems that can be used interactively by managers. The data system in a DSS includes the processes used to capture and the methods used to store data coming from marketing, finance, and manufacturing, as well as information coming from any number of external or internal sources. One of the important trends in the development of DSS is the explosion in the last few years in databases. There are thousands of databases that can be accessed on line via computer. The model system includes all the routines that allow the user to manipulate the data to conduct the kind of analyses the individual desires. Whenever managers look at data, they have a preconceived idea of how something works and what is interesting and worthwhile in the data [24]. Furthermore, with the advent of neural network technology, marketing and sales professionals can now access the knowledge of experts with only a few taps on their computer keyboard.

### **3.3. Marketing Intelligence in Construction**

According to Diamant [25], it is important to know whom you are bidding against. Services giving the information are available by subscription, such as Dodge Reports and Brown Letters, in areas where the bid project is. For special cases, such as in overseas marketing strategy, Kelley and Kohne [26] stress the importance of local representatives for furnishing marketing intelligence and advice in local customs, and legal and tax implications. This is also true for companies who enter a new local market area.

According to Groob et al. [27], effective marketing in construction begins with marketing intelligence and strategic planning and moves through management, to sales follow-up. A plan based on thorough marketing intelligence allows the company to anticipate and take full advantage of new business opportunities [28]. Other researchers like Gladden and Ollitt [29] and Preece and Male [30] also stress the importance of effective marketing research and selling techniques to strengthen the useful application of the marketing plan.

There are several interesting findings concerning the marketing intelligence practices of top U.S. construction contractors in a survey conducted by Arditi and Davis [31]. This finding indicates that most contractors are already practicing a market-oriented approach, rather than a sales-oriented or production-oriented approach in their daily business practices. It seems that the belief that construction business enterprises are left behind in marketing practices, especially in market orientation and marketing intelligence, is not totally true.

Information technology is developing rapidly with major impact on the industry and the life styles of people. It can no longer be viewed as an enhancement to traditional business procedures, but rather as an innovative agent that enables new and different alternatives to organizing and operating business enterprises, including construction businesses [32]. Andi [33] claims that it is easy to find construction company websites that include information on the strengths of the company, such as a list of services offered, experience of field staff, financial stability, innovative methods used, and others. An Internet site dedicated to the construction industry, The Global Construction Network (GCN), is also available nowadays. It offers anyone connected to the Internet a place to start when seeking information and services involving construction.

Bidding decision, including the estimation of optimum markup, represent major decision problems for contractors formulating successful business strategies [34]. For example, in a study attempting to uncover the underlying factors that characterize the bidding decision making process, Ahmad and Minkarah [35] found that bidding decisions are greatly influenced by subjectively evaluated criteria, such as type of job, location, size of job, need for work, owner, subcontractors, degree of hazard, and degree of difficulty. The usual practice is to make bid decisions on the basis of intuition, derived from a mixture of gut feeling, experience, and guesses [36]. The problem, as such, lends itself more to analogy-based solutions, for which neural networks could provide a more suitable and practical solution [37]. Very few DSSs are based on this approach in construction. For example, Moselhi et al. [34] developed an analogy-based DSS for bidding in construction coded in user-friendly software, called DBID.

## **4. SURVEY FINDINGS**

As part of this research, a mail survey was conducted to 100 Asosiasi Kontraktor Indonesia (AKI) contractors in 2011 regarding intelligence functions in construction [12] with 30 data responses processed . Findings are presented in this section.

In one question, contractors are asked to describe the current marketing intelligence practices used by their company in the last one year for each intelligence action (see Table 1). The choices (with the scoring used) are never (1), sometimes (2), often (3), and always (4). Table 1 presents data that concerns respondent companies' marketing intelligence practices, both in terms of percent of respondents, and average scores of each type of action. Table 1 indicates that the three most popular types of intelligence actions are "talking to current and prospective clients", "talking to managers within the company", and "reading trade publications" with average scores of 3.55, 3.28, and 3.14 respectively. Information about clients, key competitors, and the environment allows managers to base price decisions more on the realities rather than on guess and intuition. One way to do this is by talking to current and prospective clients which is the most popular intelligence practice. It appears that the culture that puts clients as the highest priority is already in place in construction. By acquiring information about a client such as the services that the client highly appreciates, a contractor can deliver superior value, a key to success in marketing. The objective of communicating with clients should stress not only learning from clients, but also learning about them. It could be done in a formal meeting in the bidding process or after project completion for input in future projects. It could also be done in informal meetings in the negotiation process or after project completion for future projects.

As mentioned above, delivering of superior value alone is not sufficient in effective marketing; information about key competitors and knowledge about the market environment are part of the formula for success. There are many ways to acquire information about competitors and the market environment as discussed in previous sections. It appears that talking to managers within the company is very often practiced in construction so that it is the second most popular intelligence action. This finding is in line with Safford's [15] and Kotler's [8] belief discussed in previous sections that managers and other personnel within the company constitute one of the most valuable sources of information in terms of advancing competitive intelligence even though alerts must be in place to avoid invalid information. One possibility that makes this practice popular is that it is relatively easy and cost-free; this information can be retrieved in periodic formal meetings or in informal conversations such as in the morning before managers get busy with their routine daily tasks, or when they have lunch or dinner together.

Table 1. Marketing Intelligence Practices Characteristics

Types of Action	Respondents as Percentage	Average Scores
Reading newspapers/journals		3.08
never	3.3	
sometimes	20.9	
often	40.7	
always	35.2	
Reading trade publications		3.14
never	2.2	
sometimes	18.7	
often	41.8	
always	37.4	
Talking to current and prospective clients		3.55
never	0.0	
sometimes	6.6	
often	31.9	
always	61.5	
Talking to subcontractors/suppliers		2.97
never	2.2	
sometimes	26.4	
often	44.0	
always	27.5	
Talking to managers within the company		3.27
never	0.0	
sometimes	13.2	

often	46.2	
always	40.7	
Conducting marketing research project		2.08
never	27.5	
sometimes	42.9	
often	22.0	
always	6.6	
Establishing internal marketing information/decision support systems		2.87
never	6.6	
sometimes	27.5	
often	38.5	
always	27.5	
Purchasing information from research agency		1.68
never	49.5	
sometimes	37.4	
often	8.8	
always	4.4	
Monitoring and analyzing rumors		2.18
never	16.5	
sometimes	56.0	
often	20.9	
always	6.6	
Collecting and analyzing competitors' bids		2.14
never	22.0	
sometimes	48.4	
often	23.1	
always	6.6	
Training company's staff in marketing/sales issues		2.66
never	7.7	
sometimes	31.9	
often	47.3	
always	13.2	

Note: 1=never; 2=sometimes; 3=often; 4=always

Table 1. (Continued)

Parameters	Respondents as percentage	Average Scores
Searching market information through the Internet		2.27
never	14.3	
sometimes	50.5	
often	27.5	
always	6.6	
Searching and analyzing owners' and competitors' information during bid preparation		2.76
never	7.7	
sometimes	29.7	
often	41.8	
always	20.9	

Note: 1=never; 2=sometimes; 3=often; 4=always

The third most popular intelligence practice is reading trade publications. Trade publications such as *Dodge Reports* and *Brown Letters* are available by subscription. General information regarding past bids and future project bids is available in such publications. Even though more detailed investigation is needed, this information can be used as a preliminary guideline to the subsequent actions in marketing intelligence. Because they are relatively

cheap and easily obtainable, most contractors subscribe to trade publications to help them make marketing and pricing decisions.

Table 1 also indicates that the three least popular types of intelligence action are "purchasing information from research agency", "conducting marketing research project", and "collecting and analyzing competitors' bids" with average scores 1.68, 2.08, and 2.14 respectively. The least popular action is purchasing information from a research agency, an action that is categorized by Kotler [8] as one way to improve the quality and quantity of marketing intelligence. Even though research agencies could gather data for a much lower cost than if a company has done it on its own, it seems that there are problems in making use of outside marketing research organizations. One possible problem may be that there are not many research agencies offering such services in construction: it may therefore be difficult to find such an agency that can deliver a company's information needs. Another possible problem may be that the cost of purchasing such information is an important burden, considering that profit margins in construction are one of the lowest compared to other industries.

The second least popular intelligence action is conducting marketing research projects, generally undertaken for unique projects with specific objectives. The nature of the marketing research project process is a long and costly because it includes problem determination, planning, sampling design, data gathering, data analysis, and finally reporting. It seems that it is inappropriate in the construction industry's environment where the majority of the clients are one time buyers, where each construction project has unique needs, and where the time between determining project needs and bidding is very short. Consequently, conducting a marketing research project may be difficult and inefficient if implemented in construction. On the other hand, establishing internal marketing information/decision support systems (MIS/DSS) is quite popular (average score 2.87; ranked 6<sup>th</sup> out of 13 actions) particularly compared to marketing research project practices (average score 2.08; rank 12<sup>th</sup> out of 13 actions). The majority of contractors (66%) claims they often or always establish such MIS/DSS systems. As mentioned in previous sections, MIS/DSS provides continuous monitoring of new trends in market changes, while marketing research for individual projects is not able to generate that kind of information. Establishing MIS/DSS is also simpler than the complex and lengthy marketing research procedures. It appears that MIS/DSS fits construction industry characteristics better.

The third least popular action is collecting and analyzing competitors' bids. Even though many bidding strategy models require information about competitors' bids, it seems that only few contractors (29.7%) often or always seek this information. There might be three reasons that can explain this finding. The first reason might be that it requires many hours of work to collect and analyze competitors' bids, while contractors are already busy with their daily tasks. The second reason might be that most contractors do not know about the existence of these models, because they do not or rarely read scholarly journals. Even though the average score of "reading newspapers/journals" is relatively high (3.08; rank 4<sup>th</sup> out of 13), it is difficult to differentiate between those who read newspapers and trade magazines and those who read scholarly journals. More investigation is needed to clarify this issue. The third reason why contractors do not often collect and analyze competitors' bids might be that the bidding models are too complex and unreliable.

It is interesting to note that despite the rapid development of Internet and associated information technologies as discussed in previous sections, the majority of contractors (64.8%) claim they never or only sometimes search for market information through this technology, resulting in an average score of 2.27 (rank 9<sup>th</sup> out of 13 actions investigated). More workshops seem to be highly needed on how contractors can use effectively thousands of free databases and web-sites related to information that can be used for marketing purposes, particularly pricing.

## 5. CONCLUSION

Marketing intelligence systems are highly developed in the manufacturing industry as the result of the new concepts of marketing that stress the importance of the market orientation of a firm's activities. Marketing intelligence systems include marketing research, marketing information systems, and decision support systems. With the rapid development of computer technology and the frequent occurring problems with marketing information systems

implementation, decision support systems have become the most popular marketing intelligence system in manufacturing industries.

In construction, there is only one pricing strategy predominantly used: cost-based pricing, because of the belief that it is the most appropriate approach in bidding system in construction transactions. Consequently, a marketing intelligence system is a subject that is seldom discussed by researchers. The importance of marketing intelligence becomes clear as proposed alternate pricing strategies that use a market-based approach become available because market based pricing strategies highly depend on marketing intelligence functions.

In a survey of top Indonesian AKI contractors, it was found that marketing intelligence practices currently used by contractors include mostly traditional activities such as "talking to current and prospective clients", "talking to managers within the company", and "reading trade publications". More involved intelligence gathering methods such as "conducting marketing research project", "developing MISs/DSSs", and "using the Internet" are not used extensively. The possibilities of conducting marketing research projects in the construction environment must be explored. On the other hand, the development of databases in a company that contain information about owners and competitors is one important starting step; given the anticipated rapid breakthrough developments in computer and information technologies in the future, the Internet and MISs/DSSs will become two most important intelligence tools in making pricing decisions.

## REFERENCES

- [1] Slater, S.F., Naver, J. "Market Orientation and Learning Organization." *Journal of Marketing*, 59(July), 1995, pp. 63-74.
- [2] Day, G.S. "The Capabilities of Market-Driven Organizations." *Journal of Marketing*, October, 1994, pp. 37-52.
- [3] Kohli, A.K., Jaworski, B.J. "Market Orientation: The Construct, Research Propositions, and Managerial Implications." *Journal of Marketing*, 54(April), 1990, pp. 1-18.
- [4] de Geus, A. "Planning as Learning." *Harvard Business Review*, 66(March-April), 1988, pp. 70-74.
- [5] Stata, R. "Organizational Learning- The Key to Management Innovation." *Sloan Management Review*, Spring 1989, pp. 63-74.
- [6] Glazer, R. "Marketing in an Information-Intensive Environment: Strategic Implications of Knowledge as an Asset." *Journal of Marketing*, 55(October), 1991, pp.1-19.
- [7] Sinkula, J.M. "Market Information Processing and Organizational Learning." *Journal of Marketing*, 58(January), 1994, pp. 35-45.
- [8] Kotler, P. "*Marketing Management*" 13th edition, Prentice Hall, New Jersey, 2008.
- [9] Slater, S.F. "Developing a Customer Value-Based Theory of the Firm." *Journal of the Academy of Marketing Science*, 25(2), 1997, pp. 162-167.
- [10] Slater, S.F, Naver, J. "Competitive Strategy in the Market-Focused Business." *Journal of Market-focused Management*, 1(20), 1996, pp. 159-174.
- [11] Best, R.J. "*Market-Based Management Strategies for growing customer Value and Profitability.*" 6<sup>th</sup> edition, Prentice Hall, New Jersey, 2012.
- [12] Mochtar, K. "*Pricing Strategy in Construction.*" Penerbit Teknik Sipil ITI, Indonesia Institute of Technology, Serpong, October 2011.
- [13] Hutt, M.D. and Speh T.W. "*Instructor's edition Business Marketing Management A Strategic View of Industrial and Organizational Markets.*" 7th Edition, The Dryden Press, Chicago, 2001.
- [14] Churchill Jr., G.A. "*Marketing Research Methodological Foundations.*" 9<sup>th</sup> edition, The Dryden Press, Sixth Edition, Firth Worth, 2004.
- [15] Safford, Jr., A.T. "Developing a System of Competitive Intelligence." *AMA Management Report Pricing: The Critical Decision*, Marketing Division American Management Association, Inc, No. 66, New York, 1961.
- [16] Kinnear, T.C., Root, A.R. "1988 Survey of Marketing Research." *American Marketing Association*, Chicago, 1988.
- [17] Parasuraman, A. "Research's Place in the Marketing Budget." *Business Horizons*, 26(March-April), 1983, pp. 25-29.
- [18] Cox, D.F., Good, R.E. "How to build a marketing Information System." *Harvard Business Review*, 45(May-June), 1967, pp. 145-154.
- [19] Fletcher, K., Buttery, A., Deans, K. "The Structure and Content of the Marketing Information System: A Guide for Management." *Marketing Intelligence and Planning*, 6(4), 1988, pp. 27-35.
- [20] Potter, A., Laska, R. "*The EIS Book: Information Systems for Top Managers.*" Dow-Jones Irwin, Homewood, Illinois, 1990.
- [21] McLeod, Jr., R., Rogers, J.C. "Marketing Information Systems: Their Current Status in Fortune 1000 Companies." *Journal of Management Information Systems*, 1 (Spring), 1985, pp.57-75.
- [22] Little, J.D.C. "Decision Support Systems for Marketing Managers." *Journal of Marketing*, 43 (Summer), 1979, p. 11.
- [23] Sprague, Jr., R.H., Carlson, E.D. "Effective Decision Support Systems." Prentice-Hall, New Jersey, 1982.
- [24] Little, J.D.C., Cassettari, M.N. "Decision Support Systems for Marketing Management." American Management Association, New York, 1984, p. 14.
- [25] Diamant, L. "Construction Estimating for General Contractors." John Wiley and Sons, New York, 1988.

- [26] Kelley, W.L., and Kohne, R.E. "Overseas Marketing Strategy." *Issues in Engineering Journal of Professional Activities*, 108(2), 1982, pp 115-121.
- [27] Groob, J., Shockey, K., Watters, L., Aluise, T. "Proven Tips for Marketing Professional Services" *Journal of Management in Engineering*, 3(1), ASCE, 1987, pp 28-37.
- [28] Smallowitz, H. "Engineering a Marketing Plan." *Civil Engineering-ASCE*, 57(8), 1987, pp.70-72.
- [29] Gladden, S.C. and Olitt, A. "Marketing and Selling A/E and Other Engineering Services." ASCE Press, New York, 1996.
- [30] Preece, C., Male, S. "Promotional Literature for Competitive Advantage in UK Construction Firms." *Construction Management and Economics*, 15, 1997, pp. 59-69.
- [31] Arditi, D. and Davis, L. "Marketing of Construction Services." *Journal of Management in Engineering*, 4(4), ASCE, 1988, pp. 297-315.
- [32] Ahmad, I.U., Russel, J.S., Abou-Zeid, A. "Information Technology and Integration in the Construction Industry." *Construction Management and Economics*, Vol13, 1995, pp. 163-171.
- [33] Andi, G. "Construction Engineering and Management and Future Ideas." Special Problems, Civil and Architectural Engineering Department, Illinois Institute of Technology, Chicago, 1998.
- [34] Moselhi, O., Hegazy, T., and Fazio, P. "DBID: Analogy-Based DSS for Bidding in Construction." *Journal of Construction Engineering and Management*, ASCE, 119(3), 1993, pp 466-479.
- [35] Ahmad, I. and Minkarah, I. "Questionnaire Survey on Bidding in Construction." *Journal of Management in Engineering*, ASCE, 4(3), 1988, pp. 229-243.
- [36] Ahmad, I. "Decision Support System for Modeling Bid/no bid Decision Problem." *Journal of Construction Engineering and Management*, ASCE, 116(4), 1990, pp. 595-608.
- [37] Moselhi, O. and Hegazy, T. "Discussion of Bidding Strategy: Winning over Key Competitors." *Journal of Construction Engineering and Management*, ASCE, 118(1), 1992, pp.151-165.

# Sharia-Compliant Financing in Indonesia Infrastructure Projects

Ayomi Dita Rarasati<sup>a</sup>, Bambang Trigunaryah<sup>b</sup>, Eric Too<sup>c</sup>

<sup>a</sup>Science and Engineering Faculty, Queensland University of Technology, Brisbane, Australia 4000  
E-mail : ayomi.rarasati@student.qut.edu.au

<sup>b</sup>Science and Engineering Faculty, Queensland University of Technology, Brisbane, Australia 4000  
E-mail : bambang.trigunaryah@qut.edu.au

<sup>c</sup>Business and Law Faculty, University of Southern Queensland, Australia 4300  
E-mail : eric.too@usq.edu.au

## ABSTRACT

*As the adoption of project financing is gaining momentum, there is a concurrent need of innovation in project financing scheme in order to accelerate infrastructure assets provision in Indonesia. As the largest Muslim population in the world, sharia-compliant financing offers tremendous potential as a source for infrastructure financing for Indonesia. To realize this potential, there is a need of a framework to guide its adoption. Hence this paper discusses the potential implementation of Islamic finance to fund infrastructure projects in Indonesia. Through comparative analysis, this paper illustrates how Islamic principles can be incorporated into Indonesian infrastructure project financing.*

### Keywords

*Sharia-compliant financing, infrastructure financing, project financing*

## 1. INTRODUCTION

Infrastructure plays an important role in supporting a nation's economic growth and competitiveness. Accelerating infrastructure provision is one of the main priorities in Indonesia's national development. In order to fulfill infrastructure needs, a huge amount of funding would be required and the government cannot rely solely on the national budget. Therefore, funding sources from private sectors should be created in a mode of infrastructure investment and project financing scheme.

Infrastructure investment has flowed steadily into Indonesia infrastructure development. Before the financial crisis in 1990s, in fact Indonesia was one of East Asia's private infrastructure success stories with majority of investments were concentrated respectively in energy, telecommunication, transport, water and sanitation sectors. However, the crisis has resulted in a huge plunged in the investment flow. Hence, investment in infrastructure should be expanded once more.

In 2005, the government of Indonesia (GOI) embarked on a comprehensive program of infrastructure reforms, and issued the first Infrastructure Policy Package. In the same year, the GOI also established the Policy Committee for Accelerating the Provision of Infrastructure (KKPPI). The GOI also started to organize annual events associated with infrastructure investment or infrastructure summit to attract more infrastructure investors. Several laws and regulations on the subject of private sectors participation in infrastructure provision had been enacted after a thorough reform.

In Indonesia, the concept of project financing for the provision of public infrastructure is still developing. As the adoption of project financing is gaining momentum, there is a concurrent need of innovation in project financing scheme in order to accelerate infrastructure assets provision. One area of recent innovation is Islamic financing. In particular, the scheme of *sharia*-compliant project financing (or Islamic project financing) is expected to be one of the best alternatives in Indonesia infrastructure financing.

This paper proposes a model that can be used as a framework for implementing Islamic project financing in the provision of infrastructures in Indonesia. The paper begins with the discussion on infrastructure financing need and project financing in infrastructure development. It then examines the principles of *sharia*-compliant financing and how they can be incorporated into project financing. Finally, the paper proposes a project financing model, which is in compliant with Islamic principles that can be used to finance infrastructure projects.

## 2. INFRASTRUCTURE FINANCING DEMAND

Infrastructure investment is a complex and multifaceted aspect of the national economies. Benefits of infrastructure can be maximized by formulating the respond of private sector in infrastructure policies. Such policies should not result in wasteful

duplication of infrastructure facilities. They should enhance complementarities and synergisms between public and private infrastructure providers. Infrastructure project financing involves combination of project promoters (sponsors and investors), lenders, government, contractors, suppliers and customers [1]. The funding includes loans, bond issuances, and equipment leasing. Infrastructure funding can be divided as a shared services, public private partnership (PPP), and outsourcing in accordance with the main responsibility which are taken such as public sector, public and private sector, and private sector respectively [2].

The use of private participation in infrastructure (PPI) projects can potentially improve efficiency in infrastructure projects transactions [3]. Within PPI, management in infrastructure project is also more effective [1]. PPI project also associates with societal benefits achievements as it may improve infrastructure efficiency [4]. Project financing, as a scheme of PPI implementation, then becomes important in infrastructure investment not only because of the financial scheme, but also to address institutional problems [1].

Project financing is a structured financing that needs a Special Purpose Vehicle (SPV) in the form of a company to run the project and sponsors to contribute equity and debt. An SPV can consist of sponsors, equity investors, off-take purchasers, bondholders, lenders, government, constructors, suppliers and operator. All the stakeholders are managed through contracts and arrangements. Mostly, major portion of project financing is the long-term debt financing. The projected cash flow is the primary source to reimburse the loan when the asset acts as only the collateral [5]. Therefore the payback depends on detailed evaluation of cash flow. It also needs contractual and arrangement among sponsors. Project financing is usually implemented in a green field project which tends to be a non-recourse or limited recourse.

The success of project financing implementation in infrastructure provision can be influenced by several factors, which include investment policy clarity; credibility and financial viability of the infrastructure agency; transparency and competitive bidding; and restructuring and improvement in fiscal environment. Good credit enhancement mechanism, sustainable capital markets, efficient and effective bureaucratic process, and legally enforceable and fair contracts are also the factors that could affect infrastructure project financing [6].

In order to attract more investment in Indonesia infrastructure development, there are some challenges that need to be addressed. Good governance and regulatory framework are considered the major challenges [7, 8]. Poor governance and inadequate legal system and institutional framework undermine service provision, which could keep investors away. Lack of clear policy indicates that the program is not integrated with the infrastructure needs. Strengthening the regulatory framework could remove obstacles in private sector involvement in infrastructure sector.

### 3. SHARIAH-COMPLIANT PROJECT FINANCING

Infrastructure investment is suitable to be financed with Islamic financing scheme, because infrastructure is an asset and it does not contain any activities that are prohibited in Islamic law. The use of Islamic finance in infrastructure project has been noted in some Islamic countries especially in energy and housing projects [9, 10, 11, 12, 13, 14]. Some types of Islamic financial instrument that might be suitable in infrastructure investment are:

- *Mudarabah*: cooperation between two parties which the first party gave 100% equity to the second party as the executor and profit will be shared based on agreement. In *mudarabah*, the second party is not liable for loss unless the loss occur due to mismanagement or negligence of second party. Therefore *mudarabah* is also called as trusty financing.
- *Musyarakah*: also known as partnership or joint venture, is the cooperation among two or more parties that each party shares equity with covenant that profit and losses will be shared together.
- *Ijara*: also known as leasing, is a hiring or renting of an asset to gain benefit of its usufruct.
- *Istisna*: is an order to a manufacturer to produce a specific asset for the purchaser (manufacture-sale). The payment term can be arranged in advanced or in credit.
- *Sukuk*: the Islamic investment certificate/bond.
- *Murabaha*: also known as mark-up sale, this type of finance is based on transaction cost and there is fee to compensate the service. The fee itself has been determined and agreed by both parties and written in the contract (*aqd*). In *murabaha*, the asset should be real although it is not necessarily tangible. Therefore the seller must state the original price and the additional expenses in truth. In conventional infrastructure procurement, this scheme is identical to cost plus fee contract. *Murabaha* has been implemented in real estate investment.
- *Kafalah*: is a guarantee given by insurer to a third party in order to fulfill obligation of second party or borne.

Although Indonesia is not an Islamic state, the total Muslim population in this country is the largest in the world. It is, therefore, conceivable that Indonesia can also implement Islamic principles for financing its infrastructure provision. To facilitate this, there is a need for a framework to guide its adoption.

Islamic finance has become prevalent in financial matter. *Sukuk*, for example, is one of the most innovative amongst Islamic investment. It attracts Islamic banks, Islamic insurance companies and *shariah* managed funds that cannot invest in conventional securities [15]. *Sukuk* is a tradable asset-backed, therefore it must be supported by real asset such as land, building or equipment. It is also issued for a fixed period of time which varies from short-term (three months) to medium-term (five or ten years) [15, 16]. Although most of *sukuk* structures are based on *murabaha* or *ijarah*, there are several forms that have been implemented such as *salam sukuk* structure and *musyarakah sukuk* structure.

Islamic finance has several advantages compared to the conventional finance. Islamic finance is observed as financial intermediation competitiveness [17], therefore it is now considered as one of the fastest growing financial segments in the world. The business area of Islamic finance has been broadening in many aspects such as private equity, project finance, *sukuk*, or other wealth management movement. The regulatory and legal frameworks recently have been evolved. Islamic finance nowadays has been internationally recognized and will contribute to global financial integration. Since Islamic intermediation is an asset-based and risk-centered sharing, it is more closely related to real economic sector [18].

#### 4. THE IMPLEMENTATION OF SHARIA-COMPLIANT PROJECT FINANCING IN INFRASTRUCTURE

Several papers started discussing Islamic project financing in infrastructure in the late 1990s. The financial model and contract agreement of Western project financing was modified by integrating Islamic financing in power plant project. Therefore it allows Islamic and Western financiers to finance the project without compromising any religious principles or financial interest [19]. Then it continued with *istisna* scheme to finance light railway and power plant projects developed using the build own operate (BOO) and build own operate transfer (BOOT) arrangement [20]. In 1999, an integrated model of Islamic and Western project financing was proposed by synthesizing *mudarah* security. It combined *murabahah* facility and call option to derive profit sharing ratio endogenously [21].

An innovative way to gain capital in infrastructure projects is by combining Islamic and Western finance (co-financing), which lead to a creation of a new structure of financing, or finding other ways to mitigate risks [22]. The Equate Petrochemical project is an example of project successfully delivered using this financing model. The project used *ijara*, *istisna* and *murabaha* structures [23]. Since then, there had been several more co-financed deals in infrastructure projects, such as the Kuala Lumpur Light Rail Transit 2 project, Thuraya Space Telecommunications project, Shuaiba power plant project, the TAG and Mersin Motorways project, and the Kuala Lumpur International Airport. However, the number of projects which used co-financed structures is not plenteous. There are factors that need to be considered such as improving understanding in Islamic finance and Islamic project financing.

There are potential sources of problem when projects with Islamic scheme attempt to suit Western financing. The first source of problem is the lack of cohesive regulatory body, in this context is the *shariah* boards [13]. There is uncertainty regarding *shariah* boards' decision which somehow unpredictable and subjective. The *Shariah* board needs to ensure that every transaction acknowledges the cultural, moral, ethical and religious principles. The board will examine the investment structure and documentation to approve an Islamic investment. The *Shariah* board will make a decision whether the project can be implemented based on *fiqh*, *shariah* principles as well as the decision on the duration of financing [9]. Although the board will consider similar transactions, there is no guarantee the decision will be the same because a fatwa is only valid for one specific case. Those situations make *shariah* board holds a significant decision in project endorsement. Typically, Islamic financing is utilized in a short term or medium term finance. Therefore the *shariah* board should also understand and analyze infrastructure project condition in term of financial duration. The second source of problem is that Islamic finance scheme requires lender to share project risks in contrast with Western finance scheme which lender reluctant to share the risks [13]. This circumstance may cause risk enhancement from Western lenders perspective. The third source of problem is institutional problem which can increase financial cost [22]. However, it can be diminished by establishing an *adl* (trustee), a uniform Islamic finance body and accounting practices.

Government guarantees are less needed when the profit sharing is high and sponsor's own capital is big. However, government financial guarantees are still necessitated in order to increase the creditworthiness and to raise the debt capacity of the project [24]. Government can provide financial guarantee by first analyzing project risks and then determining the type of government support given.

Based on the above discussion, Figure 1 describes a concept model of Islamic project financing in Indonesian infrastructure. The model is developed based on two categories which are infrastructure project financing scheme and Islamic financing concept. The model is influenced by *shariah* board decision, the contracts, investment method, risks and financial guarantee. Co-financing and off-takers will both reciprocally influence the implementation of Islamic project financing in infrastructure.

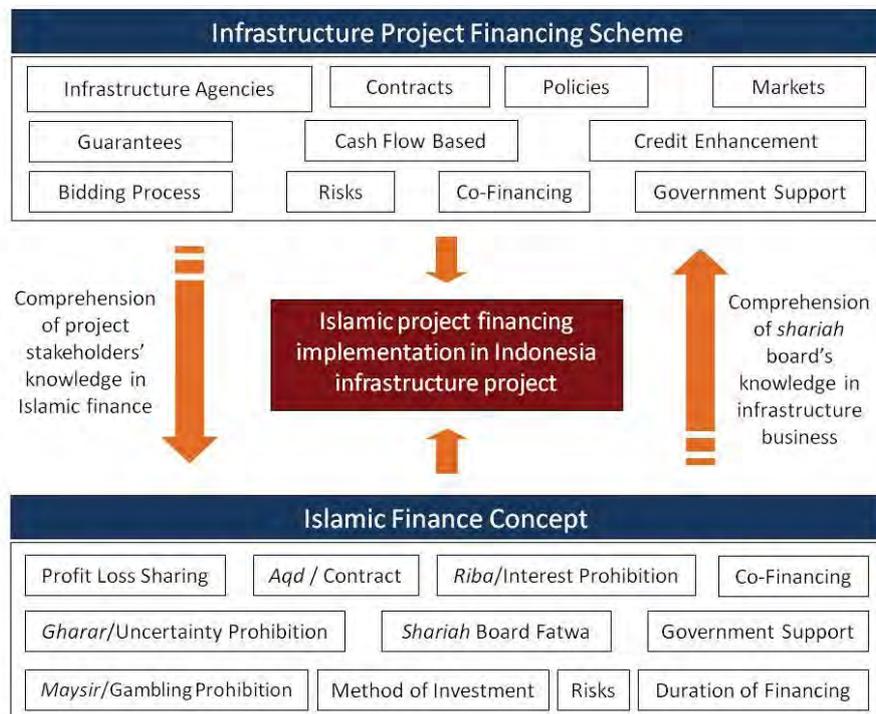


Figure 1: The concept model to implement Islamic project financing in infrastructure

## 5. SUMMARY

Within the scheme of Islamic finance and infrastructure characteristics, infrastructure investment is suitable to be financed with Islamic financing scheme because infrastructure is an asset and it does not contain any activities that are prohibited in the *shariah law*. However, as shown in Figure 1, there are factors that can influence Islamic project financing implementation. The factors are related to infrastructure project financing scheme and Islamic finance concept. Both knowledge on infrastructure business and Islamic finance should be well-known by all stakeholders. Without knowing both concepts comprehensively, the implementation of Islamic project financing in Indonesian infrastructure can be hindered, for example, by project stakeholders' acceptance of Islamic finance or the *shariah* board's decision on Islamic financing transaction. Additionally, every factor in each category should not stand alone, rather should somehow correlate and influence each other.

## REFERENCES

- [1] R. A. Brealey, I. A. Cooper, and M. A. Habib, "Using Project Finance to Fund Infrastructure Investments", *Journal of Applied Corporate Finance*, vol. 9, no. 3, pp. 25-39, 1996.
- [2] A. Joha, and M. Janssen, "Public-Private Partnerships, Outsourcing or Shared Service Centres?: Motives and Intents for Selecting Sourcing Configurations", *Transforming Government: People, Process and Policy*, vol. 4, no. 3, pp. 232-248, 2010.
- [3] P. C. Annez, "Urban Infrastructure Finance from Private Operators: What have we learned from recent experience?", World Bank Publications, vol. 4045, 2006.
- [4] M. F. Gorman, "Evaluating the Public Investment Mix in US Freight Transportation Infrastructure", *Transportation Research Part A: Policy and Practice*, vol. 42, no. 1, pp. 1-14, 2008.
- [5] S. Gatti, *Project Finance in Theory and Practice: Designing, Structuring, and Financing Private and Public Projects*, Burlington: Academic Press, 2012.
- [6] J. P. Gupta, and A. K. Sravat, "Development and Project Financing of Private Power Projects in Developing Countries: A Case Study of India", *International Journal of Project Management*, vol. 16, no. 2, pp. 99-105, 1998.
- [7] D. Moccerro, "Improving the Business and Investment Climate in Indonesia", Organisation for Economic Co-operation and Development, Economic Department Working Paper No. 638, ECO/WKP(2008)46, 2008.
- [8] M. E. Osius, and C. Carlson, "International Financing Sources in Support of "Pro-Poor/Pro-Growth" Infrastructure Development", in Povnet Conference, 2004.
- [9] M. J. T. McMillen, "Islamic Shari'ah-Compliant Project Finance: Collateral Security and Financing Structure Case Studies", *Fordham International Law Journal*, vol. 24, no. 4, pp. 1184-1264, 2001.
- [10] H. Amin, "Choice Criteria for Islamic Home Financing: Empirical Investigation among Malaysian Bank Customers", *International Journal of Housing Markets and Analysis*, vol. 1, no. 3, pp. 256-274, 2008.

- [11] M. S. Ebrahim, "Can an Islamic Model of Housing Finance Cooperative Elevate the Economic Status of the Underprivileged?", *Journal of Economic Behavior & Organization*, vol. 72, no. 3, pp. 864-883, 2009.
- [12] J. Gavin, "Islamic Finance Makes Headway in the Energy Sector", *Petroleum Economist*, 2010.
- [13] A. J. Alexander, "Shifting Title and Risk: Islamic Project Finance with Western Partners", *Michigan Journal of International Law*, vol. 32, no. 3, pp. 571-612, 2011.
- [14] M. K. Lewis, "Accentuating the Positive: Governance of Islamic Investment Funds", *Journal of Islamic Accounting and Business Research*, vol. 1, no. 1, pp. 42-59, 2010.
- [15] R. Wilson, "Innovation in the Structuring of Islamic *Sukuk* Securities", *Humanomics*, vol. 24, no. 3, pp. 170-181, 2008.
- [16] A. A. Jobst, "The Economics of Islamic Finance and Securitization", International Monetary Fund, WP/07/117, 2007.
- [17] A. Ahmed, "Global Financial Crisis: An Islamic Finance Perspective", *International Journal of Islamic and Middle Eastern Finance and Management*, vol. 3, no. 4, pp. 306-320, 2010.
- [18] M. Hasan, and J. Dridi, "The Effects of the Global Crisis on Islamic and Conventional Banks: A Comparative Study", International Monetary Fund, WP/10/201, 2010.
- [19] M. H. Khan, "Designing an Islamic Model Project Finance", *International Financial Law Review*, vol. 16, no. 6, pp. 13, 1997.
- [20] R. Wilson, "Islamic Project Finance and Private Funding Schemes", *IJUM Journal of Economics and Management*, vol. 5, no. 1, pp. 41-60, 1998.
- [21] M. S. Ebrahim, "Integrating Islamic and Conventional Project Finance", *Thunderbird International Business Review*, vol. 41, no. 4-5, pp. 583-609, 1999.
- [22] J. Camacho, "Islamic financing for Large Infrastructure Projects", <http://people.hbs.edu/mdesai/IFM05/Camacho.pdf>, accessed on 7 November 2010, 2005.
- [23] B. C. Esty, "The Equate Project: An Introduction to Islamic Project Finance", *Journal of Project Finance*, vol. 5, no. 4, pp. 7, 2000.
- [24] M. K. Hassan, and I. Soumaré, "Financial Guarantee as an Innovation Tool in Islamic Project Finance", in ERF 13th Annual Conference, 2006.

# DETERMINATING SIGNIFICANT FACTORS INFLUENCING CEMENT COMPRESSIVE STRENGTH AT PADANG CEMENT COMPANY

Rahmayanti Dina<sup>(a)</sup>, Putri Nilda Tri<sup>(b)</sup>, Fithri Prima<sup>(c)</sup>

<sup>a</sup>Faculty of Engineering, Industrial Engineering Department, Andalas University, Padang 25000  
E-mail : dina@ft.unand.ac.id

<sup>b</sup>Faculty of Engineering, Industrial Engineering Department, Andalas University, Padang 25000  
E-mail : nilda@ft.unand.ac.id

<sup>c</sup>Faculty of Engineering, Industrial Engineering Department, Andalas University, Padang 25000  
E-mail : ima\_044@yahoo.com

## ABSTRACT

*Product quality control is an important factor in industrial field. Continuous quality control enables company to detect abnormality in haste and anticipate them. PT Semen Padang always control their product quality in order to keep their product meet consumer's need. The fluctuation of cement compressive strength for the last few periods urge the company to evaluate, improve and sustainable quality standard. Research was done to indentify mandatory factors influencing cement compressive strength. Data processing was done using SPSS and Minitab 15. This reseach give recomendation to PT Semen Padang, it should control composition of C<sub>3</sub>S, H Pijar dan SO<sub>3</sub> in order to keep cement compressive strength standard. Besides, workshop about Statistical Process Control by using Minitab and SPSS is needed to be presented by the company for quality control process in future.*

**Keyword:** quality, cement compressive strength, linear regressions

## 1. INTRODUCTION

Product quality control in the production process is a very important factor for industry, because of good quality control and done continuously will able to detect abnormalities quickly that can be taken anticipation. Low qualities products can cause company lose customers. PT Semen Padang always try to maintain the quality of the product in order to meet market demand. Cement quality required by the customer is bonding time, compressive strength, heat hydrasi, expansion / contraction of cement, and resistance of cement to environmental influences such as acid / sulfuric (durability). Compressive strength is an indicator of quality most preferred by PT Semen Padang in line with consumer demand.

Primarily related to quality of cement compressive strength there is a need of PT Semen Padang to determine mandatory factors affecting it. Knowing the most significant factors PT Semen Padang can optimize both in terms of methods, materials, and also reduce costs optimally.

This research is carried out to identify factors that influence the compressive strength of cement by evaluating it at some recent time period. This research also compare between actual evaluation and standards specified compressive strength (SNI and internal standard) in order to determine deviations (gap analysis); determining the mandatory factors affecting the compressive strength of cement includes: a) identification of variables that affect the compressive strength, b ) statistical data processing and c) conduct an analysis of the mandatory factors affecting the compressive strength of cement; obtaining follow-up recommendations for improvement in the form of a work program based on the evaluation results.

Scope of this research are; 1) statistical analysis to look at the factors that affect mandatory focused on the compressive strength of cement contained cement mill cement mill Indarung V ie X (CM X) XI and cement mill (CM XI), 2) cement product observed are the product of cement type I and PCC; 3) data compression strength for 2 years (2010-2011).

## 2. RESEARCH METODOLOGY

This research is explanatory quantitatively using linear regression. Measuring the influence of independent variables on the dependent variable, and predict the dependent variable using the independent variables. Gujarati (2006) defines a regression analysis as the study of the relationship of explained variable with one or two variables that explain (the explanatory). The first variable is also known as the dependent variable and the second variable is also called independent variable. If more than one independent variable, the regression analysis is called multiple linear regression. Because influence several variables will apply to dependent variable.

This research used free CaO; C3S; insoluble part (BTL); SO<sub>3</sub>; Missing incandescent; sieve on 45, and blaine as independent variables and Cement Compressive Strength as the dependent variable.

Steps being taken in this research are :

1. Understanding current practice

At this stage of understanding of the cement production process in detail, and the things that affect the quality of the cement itself.

2. Formulation of the problem

The problem formulation in this research is how to determine the most significant factors affecting the compressive strength of cement and PT Semen Padang to optimize both in terms of methods, materials, cement makers to reduce the cost of optimally

3. Research Objectives

The objectives of this research were:

- a. Identifying the factors that influence the compressive strength of cement
- b. Determining the dominant factor affecting the compressive strength of cement
- c. Get recommendations for improvement follow

4. Literature Review

Literature review conducted to find the most appropriate method is used to solve the problem

5. Dependent and independent variables

Variables in this study were divided into dependent and independent variables.

- a. Independent variables are : free CaO; C3S; insoluble part (BTL); SO<sub>3</sub>; Missing incandescent; sieve on 45, and blaine.
- b. Dependent variables are : Compressive Strength Cement

6. Verification of data

Data verification is done by studying, organizing and sorting data associated with semen quality, especially compressive strength.

7. Data processing

Data processing begins by testing the assumptions of the multiple linear regression model. At least there are five tests that must be conducted on the assumption of a regression model that normality test, auto-correlation, multikolinieritas test, heteroscedasticity test and linearity test. The next stage is to determine the equation of the linear regression between the independent variables and the dependent variable. Of free and bound variable relation calculated the P-value and VIF to determine the significance of the independent variables to the dependent variable.

8. Analysis and discussion

At this stage, the analysis and interpretation of the results obtained processing.

9. Conclusion

This stage consists of the conclusion of the materials that need follow-up recommendations by PT. Semen Padang for improvement.

For clarity, the stages of this research can be seen in the figure below:

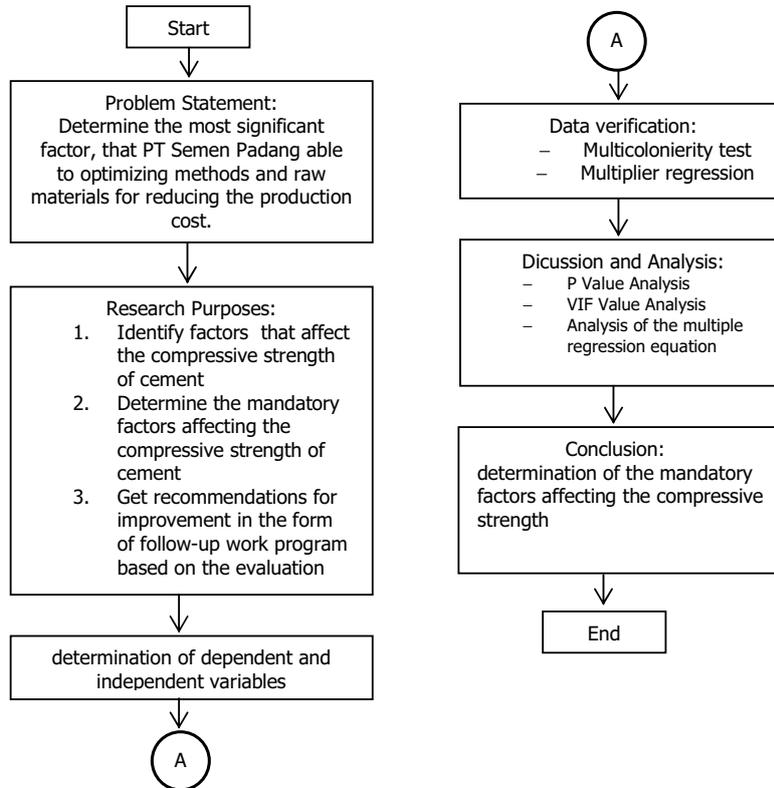


Figure 1: Research Methodology

### 3. DISCUSSION

#### 3.1. Multiple Regression Analysis of Test Requirement

Test requirements analysis is needed to determine whether the analysis of the data for testing hypotheses can be continued or not. Several data analysis techniques demanding test requirement analysis. Analysis of variance requires that data came from a normally distributed population and the groups were compared homogen. Because of that variance analysis requires test normality and data homogeneity. Regression analysis, in addition to requiring normality test also require linearity test, heterokedasitas test, autocorrelation test, and test multicollinearity test

Normality test data to show that the sample data came from a normally distributed population. There are several techniques that can be used to test normality of data, among others: with SPSS, which see the ratio of skewness and kurtosis.

Table 1. Descriptive Statistic

	Descriptive Statistics			
	Skewness		Kurtosis	
	Statistic	Std. Error	Statistic	Std. Error
Unstandardized Residual	-,020	,140	,239	,280
Valid N (listwise)				

From the above results of SPSS can be seen that the ratio of skewness and kurtosis is between -2 to +2, it can be said that data were normally distribution.

### 3.2. Linearity test

Linearity test is useful to see the linearity between dependent variable (compressive strength) with independent variable (C3S, BTL, free CaO, H Incandescent, Sieve on 45, Blaine, SO3).

Table 2. ANOVA Table

ANOVA Table			Sum of Squares	df	Mean Square	F	Sig.
KT3H * SO3	Between Groups	(Combined)	26257,187	77	341,002	1,379	,037
		Linearity	3754,246	1	3754,246	15,185	,000
		Deviation from Linearity	22502,941	76	296,091	1,198	,158
	Within Groups		55379,899	224	247,232		
	Total		81637,086	301			

The result showed that the value of F is 1.198 with a significance 0.158 (above 0.05). It means linear model regression.

### 3.3. Heteroscedacity Test

Heteroscedacity occur when the variance regression error ( $\sigma^2$ ) for some value of  $x$  change. Detection constant or not constant error variance to do with drawing the graph between the residues  $Uy$  ( $y - Uy$ ). If the line that limits the distribution of points relative error variance is constant.

If the graph looks the points spread above and below the Y axis, there is no particular pattern. It can be concluded that there is no heterokedasitas.

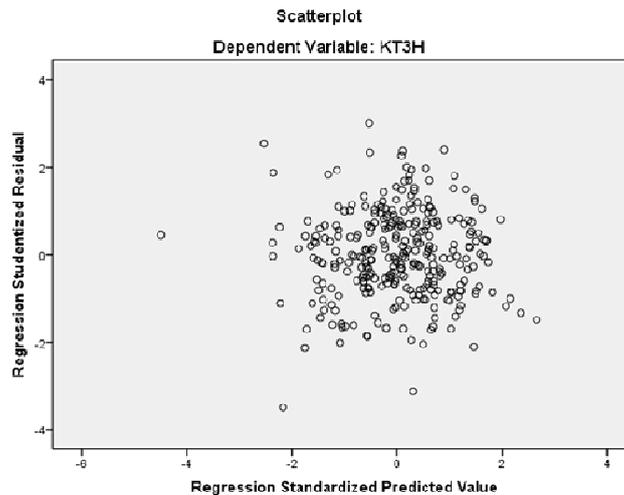


Figure 2. Scatterplot

### 3.4. Autocorrelation test

Autocorrelation is occurred when two errors in the regression  $\epsilon_t$  and  $\epsilon_{t-1}$  are not independent or  $Cov(\epsilon_t, \epsilon_{t-1}) \neq 0$ . Autocorrelation usually happened when the variable measurement is done in a specific time interval.

Table 3. Model Summary

Model Summary					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,590 <sup>a</sup>	,348	,333	13,45346	1,375

a. Predictors: (Constant), Blaine, Sieve\_On45, C3S, H\_Pijjar, CaO\_Bebas, SO3, BTL

b. Dependent Variable: KT3H

Apparently Durbin-Watson coefficient magnitude of 1.375, nearly 2. Thus, it can be concluded that the regression between variables C3S, BTL, free CaO, H Incandescent, Sieve on 45, Blaine, SO3 not happen autocorrelation.

### 3.5. Multicollinearity test

Multicollinearity test is used to determine significant relations (correlation) between the independent variables. If there is a high correlation (significant), means that there is same aspect measured at independent variable. It is not feasible to determine the contribution of independent variable and dependent variable.

Table 4. Collinearity statistic

Model	Collinearity Statistics	
	Tolerance	VIF
1 (Constant)		
CaO_Bebas	,935	1,070
C3S	,966	1,035
BTL	,466	2,147
SO3	,719	1,390
H_Pijjar	,474	2,111
Sieve_On45	,989	1,012
Blaine	,826	1,211

a. Dependent Variable: KT3H

Multicollinearity test is done with SPSS regression test, with value of VIF (variance inflation factor) as standard and correlation coefficients between the independent variable. The criteria used are: 1) If the value of VIF around the 1 or have a tolerance close to 1, it is said there is no multicollinearity problem in the regression model, 2) If the correlation coefficient between the independent variable is less than 0.5, there is no multicollinearity problem.

Apparently VIF value close to 1 for all independent variables. Similarly, the tolerance value close to 1 for all independent variables. It can be concluded that the regression between the independent variables C3S, BTL, free CaO, H Incandescent, Sieve on 45, Blaine, SO3 not happen multicollinearity between independent variables.

### 3.6. Multiple Linear Regression

Linear regression is used to determine significant factor or mandatory factor affecting compressive strength of cement. Data processing is performed by using the software Minitab 15. P-value is the standard value (significance) so that the smallest value of the observed test statistic is still significant. P-value always compared to the value of  $\alpha$ .  $\alpha$  is 0.05 with 95% confidence level. This means that 95% of study have been considered correct, started from collecting data, and the processing and obtaining result. Comparisons with  $\alpha$  P-value:

- If  $p\text{-value} < \alpha$ , reject  $H_0$
- If  $p\text{-value} \geq \alpha$ , do not reject  $H_0$

Example: Cement Mill X PCC CS 3 DAYS, based on the results of processing software Minitab 15, it can be inferred from the P-value and VIF sorting factors that influence the compressive strength is: BTL, H Incandescent, C3S, Sieve on 45, SO3 and Blaine.

Regression equations were obtained:

$$\text{CS 3 DAYS} = 219 + 0,56 \text{ CaO Bebas} + 0,567 \text{ C3S} - 3,46 \text{ BTL} - 11,0 \text{ SO3} - 10,3 \text{ H Pijjar} - 1,61 \text{ Sieve on 45} + 0,0150 \text{ Blaine}$$

It can be concluded that the addition of C3S significantly increase the pressure, while the addition of BTL, H Incandescent significantly decrease the pressure.

#### 4. CONCLUSION

From the research it can be concluded as shown in the following table:

Cement Types	increasing compressive strength	decreasing compressive strength
CEMENT MILL X PCC CS 3 DAYS	C3S	H Pijar
CEMENT MILL X PCC CS 7 DAYS	C3S	H Pijar
CEMENT MILL X PCC CS 28 DAYS	C3S	H Pijar
CEMENT MILL XI PCC CS 3 DAYS	C3S	H Pijar
CEMENT MILL XI PCC CS 7 DAYS	C3S	H Pijar
CEMENT MILL XI PCC CS 28 DAYS	C3S	H Pijar
CEMENT MILL X TYPE I CS 3 DAYS	C3S	SO3
CEMENT MILL X TYPE I CS 7 DAYS	C3S	SO3
CEMENT MILL X TYPE I CS 28 DAYS	C3S	SO3
CEMENT MILL XI TYPE I CS 3 DAYS	C3S	SO3
CEMENT MILL XI TYPE I CS 7 DAYS	C3S	SO3
CEMENT MILL XI TYPE I CS 28 DAYS	C3S	SO3

From the table above shows that the quality of clinker C3S primarily on factors greatly influence increasing compressive strength for both types of cement. While the addition of H pijar and SO3 factor on Cement Mill effect decreasing compressive strength (CS) of PCC and Type 1 sequentially. For more details, the factors that affect the compressive strength can be seen based formulation of regression:

1. Cement Mill X PCC CS 3 days  
 Equation of multiple regression :  
 $CS\ 3\ DAYS = 219 + 0,56\ CaO\ Bebas + 0,567\ C3S - 3,46\ BTL - 11,0\ SO3 - 10,3\ H\ Pijar - 1,61\ Sieve\ on\ 45 + 0,0150\ Blaine$
2. Cement Mill X PCC CS 7 days  
 Equation of multiple regression :  
 $CS\ 7\ DAYS = 300 + 0,29\ CaO\ Bebas + 0,583\ C3S - 3,73\ BTL - 17,6\ SO3 - 14,9\ H\ Pijar - 1,96\ Sieve\ on\ 45 + 0,0218\ Blaine$
3. Cement Mill X PCC CS 28 days  
 Equation of multiple regression :  
 $CS\ 28\ DAYS = 436 - 1,79\ CaO\ Bebas + 0,439\ C3S - 3,73\ BTL - 25,9\ SO3 - 23,2\ H\ Pijar - 2,48\ Sieve\ on\ 45 + 0,0280\ Blaine$
4. Cement Mill X Type I CS 3 days  
 Equation of multiple regression :  
 $CS\ 3\ DAYS = 89,8 + 4,01\ CaO\ Bebas + 1,29\ C3S - 5,32\ BTL - 35,5\ SO3 - 3,46\ H\ Pijar - 0,125\ Sieve\ on\ 45 + 0,0365\ Blaine$
5. Cement Mill X Type I CS 7 days  
 Equation of multiple regression :  
 $CS\ 7\ DAYS = 300 + 0,29\ CaO\ Bebas + 0,583\ C3S - 3,73\ BTL - 17,6\ SO3 - 14,9\ H\ Pijar - 1,96\ Sieve\ on\ 45 + 0,0218\ Blaine$
6. Cement Mill X Type I CS 28 days  
 Equation of multiple regression :  
 $CS\ 28\ DAYS = 298 + 0,59\ CaO\ Bebas + 1,03\ C3S - 6,33\ BTL - 61,1\ SO3 - 9,63\ H\ Pijar - 0,914\ Sieve\ on\ 45 + 0,0501\ Blaine$
7. Cement Mill XI PCC CS 3 days  
 Equation of multiple regression :  
 $CS\ 3\ DAYS = 233 + 2,10\ CaO\ Bebas + 0,570\ C3S - 1,38\ BTL - 7,29\ SO3 - 7,63\ H\ Pijar - 1,85\ Sieve\ on\ 45 + 0,00250\ Blaine$
8. Cement Mill XI PCC CS 7 days  
 Equation of multiple regression :

- CS 7 DAYS = 320 + 1,36 CaO Bebas + 0,670 C3S - 0,841 BTL - 27,3 SO3 - 8,88 H Pijar - 2,32 Sieve on 45 + 0,00885 Blaine
9. Cement Mill XI PCC CS 28 days  
 Equation of multiple regression :  
 CS 28 DAYS = 470 + 0,55 CaO Bebas + 0,790 C3S - 0,16 BTL - 31,1 SO3 - 16,3 H Pijar - 3,46 Sieve on 45 + 0,0051 Blaine
10. Cement Mill XI Type I CS 3 days  
 Equation of multiple regression :  
 CS 3 DAYS = 56,4 - 0,12 CaO Bebas + 0,960 C3S - 5,06 BTL - 21,5 SO3 - 0,64 H Pijar - 1,62 Sieve on 45 + 0,0496 Blaine
11. Cement Mill XI Type I CS 7 days  
 Equation of multiple regression :  
 CS 7 DAYS = 320 + 1,36 CaO Bebas + 0,670 C3S - 0,841 BTL - 27,3 SO3 - 8,88 H Pijar - 2,32 Sieve on 45 + 0,00885 Blaine
12. Cement Mill XI Type I CS 28 days  
 Equation of multiple regression :  
 CS 28 DAYS = 260 - 5,26 CaO Bebas + 0,667 C3S - 8,59 BTL - 51,0 SO3 - 2,78 H Pijar - 2,49 Sieve on 45 + 0,0665 Blaine

## ACKNOWLEDGEMENT

The author would like to thank to Quality Assurance Department, Padang Cement Company for the reseach grant.

## REFERENCES

- [1] Creswell, J.W. Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research. New Jersey: Prentice Hall. 2004.
- [2] Creswell, J.W. Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. California: Sage Publications, Inc. 2008.
- [3] Groat, L. & Wang, D. Architectural Research Methods. New York: John Wiley & Sons. Inc.2002.
- [4] Amitava Mitra. Fundamental of Quality Control and Improvement, Macmillan Publishing Company, Newyork. 1993.

# Structural Behavior of Hollow Round Pile with Spiral Stirrup as Transverse Reinforcement

Gambiro<sup>a</sup>, Abdi Pasya Reihan Beyruni<sup>b</sup>, M. Reza Avrianto<sup>c</sup>

<sup>a</sup>Research and Development Departement  
PT. Wijaya Karya Beton  
Jalan Raya Jatiwaringin 54 Pondok Gede  
Bekasi 17411  
Tel. : (021) 84973363, Fax : (021) 84973391  
Email : [gambiro\\_s@wika-beton.co.id](mailto:gambiro_s@wika-beton.co.id), [gambiro\\_s@yahoo.com](mailto:gambiro_s@yahoo.com)

<sup>b</sup>Engineering Departement  
PT. Wijaya Karya Beton  
Jalan Raya Jatiwaringin 54 Pondok Gede  
Bekasi 17411  
Tel. : (021) 84973363, Fax : (021) 84973391  
Email : [abdi-pasya@yahoo.com](mailto:abdi-pasya@yahoo.com)

<sup>c</sup>Research and Development Departement  
PT. Wijaya Karya Beton  
Jalan Raya Jatiwaringin 54 Pondok Gede  
Bekasi 17411  
Tel. : (021) 84973363, Fax : (021) 84973391  
Email : [reza@wika-beton.co.id](mailto:reza@wika-beton.co.id)

## ABSTRACT

Hollow round pile besides used as deep foundation of building, is also often used as a foundation of maritime building (wharf, dolphine, etc.). Pile foundation in maritime buildings have a special chaeacteristic are the free length. Fixity of pile is at certain depth below the sea-bed depend on soil parameter. Depth of sea water level to sea-bed is varies 10 - 15 metres.

When wharf or dolphine subject to eccentric lateral/hirizontal forces, the structure will be torsion/twisted. The same condition is occured for pile. The knowledge of torsional moment capacity is very important things, because will ensure strength and stability of structure. The phenomenon of torque on the hollow round section, especially on concrete, not been widely discussed and applied. The calculation method of torsional moment capacity is usually ACI 318's formulas. These formulas are developed based on theory of twisted rectangular beam.

This research is be done to know structural behavior of hollow round pile torsioned and effect of direction and spiral stirrup spacing. Samples are hollow round piles with spiral spacing varies and get torsional forces. Torsional forces were be got as the result of forces with certain distance to be the arm of moment. The rotation was got from measurement of the resultant of force arm. Relation between torsional force and rotation will be analysed to know the torsional moment capacity of sample. Spiral stirrup is studied its effect to torque moment capacity.

The result of this research will be compared to formula from concrete code.

## Keywords

*hollow round pile, torque/torsional moment, torque moment capacity, rotation, spiral stirrup*

## 1. INTRODUCTION

Hollow round piles can be twisted, mainly occurs in piles that is not entirely embedded in the ground, as the foundation of the building dock (*wharf, dolphine*). Torque moment will cause cracks on the surface of piles. Failure to crack it in daily practice is minimized by the shear strength of concrete and spiral reinforcement.

The study was done to know the behavior of hollow round piles piles having twisting and influence the direction and distance of the spiral reinforcement. The objective to reach is to understand the behavior of a hollow round piles having torsional, study the effect of spiral reinforcement dimensions and distance, and know the torque capacity with a variety of spiral reinforcement. Torque force was generated from a horizontal force that works with a certain eccentricity distance form the moment arm. Forces and rotation that occurs analyzed by creating a relationship of some parameters.

## 2. TORQUE MEMBERS HAVING A ROUND HOLLOW CROSS SECTION

### 2.1. Forces and Stiffness of Torque

Analysis of torque on a solid circular cross-section can be applied directly to a hollow circular cross section having outer radius ( $R_o$ ) and inner radius ( $R_i$ ). The equation below can be used for analysis of torque. The equation is :

$$T = \frac{\pi}{2} (R_o^4 - R_i^4) G \frac{\theta}{L} \quad (1)$$

While the polar moment of area,  $J$ , is:

$$J = \frac{\pi}{2} (R_o^4 - R_i^4) \quad (2)$$

### 2.2. Member Deformation due Twist

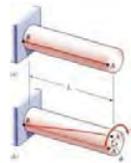


Figure 1. Deformation twisted member

Torsional angle that occurs on the member proportional to the work torque moment and the length of the member. Means more length of the twisted member round, the smaller torque moment occurs. Deformation that occurs in a twisted rod does not always change the shape (distortion). For round rod (solid or hollow) which are torsional, each slice section will remain flat and without distortion (This is because the circular cross section is Axisymmetry).



Figure 2. Illustrations of a torque rod round

For non-circular cross section (*tidak-axisymmetric*), rods will be distorted when subject to torsion.



Figure 3. Illustration of distorted rod

**2.4. Shear Stress Distribution based on Elastic Approach**

a. Round Section

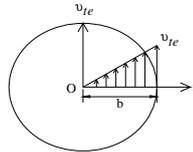


Figure 4. Torsional elastic distribution for round section

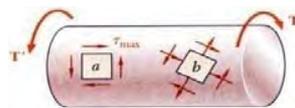
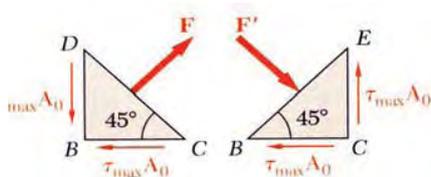


Figure 5. The difference in the element of pure shear conditions (a) and torsional shear (b)

Review of stress that occurs on the element(b) according to Figure 5 is as follows :



$$F = 2(\tau_{max} A_0) \cos 45 = \tau_{max} A_0 \sqrt{2}$$

$$\sigma_{45} = \frac{F}{A} = \frac{\tau_{max} A_0 \sqrt{2}}{A_0 \sqrt{2}} = \tau_{max}$$

Element (b) having the tensile stress at 2 sides and the compressive stress at 2 another sides. mempunyai besaran tegangan yang sama dengan elemen (a)

**2.5. Torsional Cracks**

As well as bending, twisting rod also fractured. To calculate the torsional cracks using the following formula :

Reinforcement concrete :  $T_{cr} = v_{cr} \frac{A_{cp}^2}{P_{cp}}$  (3)

$v_{cr} = f_{cr}$  (4)

Prestressed concrete :  $v_{cr} = f_{cr} \sqrt{1 + \frac{f_{pc}}{f_{cr}}}$  (5)

$f_{cr} = 0.33 \sqrt{f'_c}$  (6)

**2.6. Analysis of Torsional Moment Capacity**

Torsional moment capacity can be calculated by equation as follows :

$$\frac{A_t}{s} = \frac{T_n}{2A_{ch} f_{yv} \cot \theta} \quad (7)$$

$$A_t = \frac{A_t}{s} p h \left( \frac{f_{yv}}{f_{yt}} \right) \cot \theta^2 \quad (8)$$

$$\text{Total } \left( \frac{A_v + t}{s} \right) = \frac{A_v}{s} + 2 \frac{A_t}{s} \quad (9)$$

In this equation  $\phi T_n \geq T_u$ , so that

$T_n \geq \frac{T_u}{\phi}$  where :  $\theta =$  crack angle to the axis of the beam

$$= 45^\circ \text{ for reinforced concrete}$$

$$= 37.5^\circ \text{ for prestressed concrete}$$

$$\Phi = 0,75 \text{ (torsional reduction factor)}$$

where  $t$  is the walls thickness of hollow cross section at the location where tension is being examined.

### 3. SAMPLING METHOD AND METHODOLOGY OF RESEARCH

#### 3.1 Sampling Method

Piles specimen are modeled as a a twisted rods. Moment of torque resulting from the horizontal force acting on a certain distance to form moment arm. Piles specimen consists of 8 pieces of each 300mm diameter length  $L = 3$  m with technical details as follows:

1. Specimen number 1 with dual spiral reinforcement spaced 50 mm  $\varnothing$  4 mm by two pieces .( Rotated the direction of spiral) (BU-1).
2. Specimen number 2 with single spiral reinforcement spaced 50 mm  $\varnothing$  4 mm by two pieces .( Rotated the direction of spiral) (BU-2).
3. Specimen number 3 with single spiral reinforcement spaced 50 mm  $\varnothing$  4 mm by two pieces .( Rotated Opposite the spiral) (BU-3).
4. Specimen number 4 with single spiral reinforcement spaced 100 mm  $\varnothing$  4 mm by two pieces .( Rotated the direction of spiral) (BU-4).

#### 3.2 Set up of Equipment and Specimen

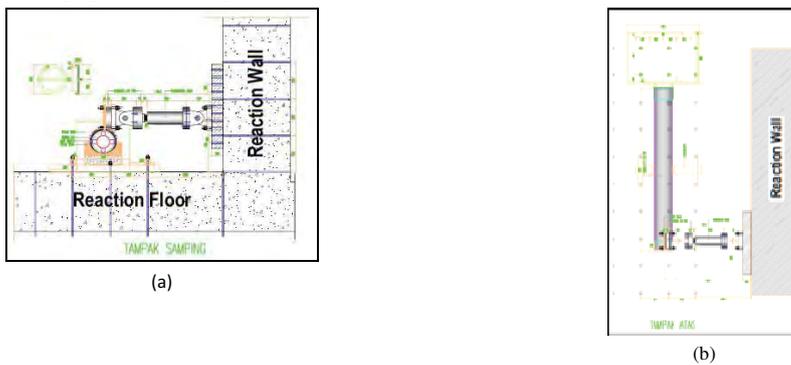


Figure 6. Testing scheme



Figure 7. Set up of Equipment and Specimen

#### 3.3 Methodology of Testing

- a. Specimens were given torque moment until crushed.
- b. Made the relationship chart between torsional moment versus rotation
- c. Torque moment is produced from the lateral force acting on a moment arm within 30 cm of the center of specimen.
- d. Rotation obtained from the transducer mounted and observed lateral movement is lateral movement, then converted into rotation.

## 5. ANALYSIS, TESTING RESULT AND DISCUSSION

### 5.1. Torsional Moment Capacity of Hollow Round Pile

The calculation of torsional moment capacity based on equation in ACI 318-11 Section 11.5.1. Torque capacity of a reinforced concrete cross-section consists of two parts, namely the torque capacity of the concrete and the torque capacity of the longitudinal and the spiral reinforcement. Torque capacity of concrete itself is :

$$T_{u,c} = \frac{\phi \sqrt{f'_c}}{3} \times \frac{A_{cp}^2}{P_{cp}} \times \sqrt{1 + \frac{3f_{ps}}{\sqrt{f'_c}}} \quad (10)$$

Transversal reinforcement :  $A_t = \frac{T_{u,s} \cdot S}{2 \cdot A_0 \cdot f_{yv} \cdot \cot \theta}$  (11)

$$T_{u,s} = \frac{A_t \cdot 2 \cdot A_0 \cdot f_{yv} \cdot \cot \theta}{S} \quad (12)$$

Longitudinal reinforcement :  $A_l = \frac{A_t}{S} \times \phi \times \frac{f_{yv}}{f_{yl}} \cot^2 \theta$  (13)

$$T_u = T_{u,c} + T_{u,s} \quad (14)$$

From equation (10), (11), (12), (13) and (14) obtained a theoretical torque moments as follows:

Tabel 1 : Momen teoritis benda uji

No.	Nama Benda Uji	Jarak Spiral (mm)	Ø Spiral (mm)	Jumlah Spiral	M <sub>torsi</sub> teoritis (t.m)
1	BU-1	50	4	2	3.445
2	BU-2	50	4	1	2.334
3	BU-3	50	4	1	2.334
4	BU-4	100	4	1	1.777

## 5.2. Discussion

### Pattern of Specimen Cracking



(a) BU-1



(b) BU-2



(c) BU-3



(d) BU-4

Figure 8. Pattern of cracked hollow circular piles had a torque moment.

From Figure 8 shows that the pattern of cracks that occur always correspond with the direction of the torque moment working. The pattern of spiral reinforcement does not affect fracture pattern forms. However, the number and spacing of the spiral reinforcement can increase the capacity of torque moment.

**BU-1**

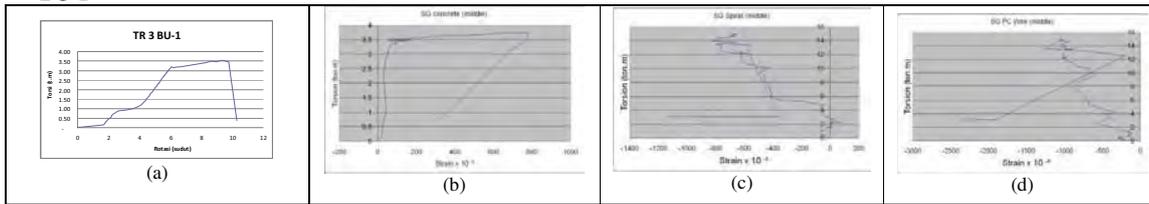


Figure 9 : (a). Relationship between torque momen vs rotation BU-1, load vs  $\epsilon_{\text{beton}}$  BU-1, load vs  $\epsilon_{\text{spiral}}$  BU-1, load vs  $\epsilon_{\text{PC wire}}$  BU-1.

Spiral installed two dual. Torque moment is working in the direction of the spiral. Exfoliation concrete occurs until look the spiral reinforcement. The pattern of crack is opposite with the directional of spiral reinforcement. Based on figure 9a cracks occur at torque moment 3.15 ton.m and  $5\sigma$  rotation. Then broken at torque moment 3.5 ton.mm and  $5\sigma$  rotation. Observations of the result of transducer correlated with strain gauge in concrete. Ratio of  $M_{t, \text{uji}}/M_{t, \text{teori}} = 0.91$ . In Table 1 shows that the the spiral is closed yield and concrete already far exceeds the allowable tensile stress. While stress in PC wire is still far below yield stress. From the results of stress that occurs torque strength is more influenced by the strength of the spiral and concrete. While PC wire is not too much effect resist torque.

**BU-2**



Figure 10 : (a). Relationship between torque momen vs rotation BU-2, load vs  $\epsilon_{\text{beton}}$  BU-2, load vs  $\epsilon_{\text{spiral}}$  BU-2, load vs  $\epsilon_{\text{PC wire}}$  BU-2.

Spiral is installed in one layer. Torque moment is working in the direction of the spiral. Exfoliation concrete occurs until look the spiral reinforcement. The pattern of crack is opposite with the directional of spiral reinforcement. The damage is more severe than the test results to the BU-1, so that there is a correlation number or sectional area the spiral or the spiral with the level of damage. At the initial torque load is rotated around the pile as far as  $0.5\sigma$  working torque moments though still small. Possible tools for turning positioning themselves so that they can work full rotating specimen. Cracks occur at torque moment 2.9 ton.m and  $2.5^\circ$  rotation. And then ultimate moment decreased until broken at torque moment 2.7 ton.m and  $3.5^\circ$  rotation. Ratio  $M_{t, \text{uji}}/M_{t, \text{teori}} = 1.26$ . Reading of strain gauge at BU-2 found similar condition with BU-1, however spiral reinforcement at BU-2 had not yield.

**BU-3**

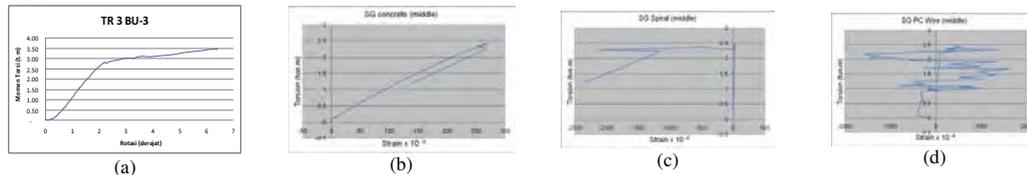
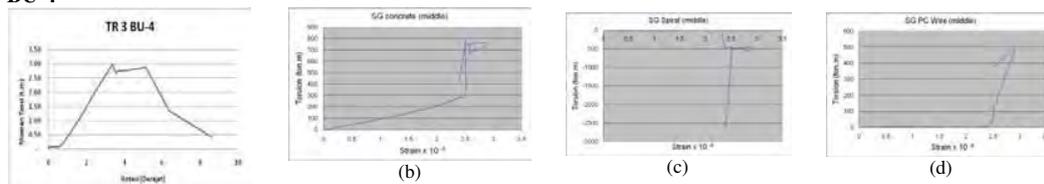


Figure 11 : (a). Relationship between torque momen vs rotation BU-3, load vs  $\epsilon_{\text{beton}}$  BU-3, load vs  $\epsilon_{\text{spiral}}$  BU-3, load vs  $\epsilon_{\text{PC wire}}$  BU-3.

Spiral is installed in one layer. Torque moment is opposite with the direction of the spiral. Exfoliation concrete occurs until look the spiral reinforcement. The pattern of crack is same with the the directional of spiral reinforcement. The damage is much less than the test results to the BU-1 and BU-1, so that there is a correlation with the directional of spiral to level of damage. At the initial torque load, the pile has rotated around the pile as far as  $0.5\sigma$  working torque moments though still small. Possible tools for turning positioning themselves so that they can work full rotating specimen. Cracks occur at torque moment 2.87 ton.m and  $2.95^\circ$  rotation. And then ultimate moment increased until broken at torque moment 3.5 ton.m and  $7^\circ$  rotation. Ratio  $M_{t, \text{uji}}/M_{t, \text{teori}} = 1.19$ . In Table 3 shows the spiral has been broken up so concrete failure occurred despite the stress in the concrete is much smaller than the BU-1 and BU-2. This possibility occurred because the load was opposite direction to the spiral. And the torque moment that happens is 2.87 t.m

**BU-4**



(a)

Figure 12 : (a). Relationship between torque momen vs rotation BU-4, load vs  $\epsilon_{\text{beton}}$  BU-4, load vs  $\epsilon_{\text{spiral}}$  BU-4, load vs  $\epsilon_{\text{PC wire}}$  BU-4.

Spiral is installed in one layer more tenuous the spiral distance 100 mm . Torque moment is working in the direction of the spiral. Exfoliation concrete occurs until look the spiral reinforcement. The pattern of crack is opposite with the the directional of spiral reinforcement. The damage is much less than the test results to the BU-1 and BU-1, so that there is a correlation with the directional of spiral to level of damage. At the initial torque load, the pile has rotated around the pile as far as  $0.5 \sigma$  working torque moments though still small. Possible tools for turning positioning themselves so that they can work full rotating specimen. Cracks occur at torque moment 2.87 ton.m and  $2.9^\circ$  rotation. And then ultimate moment increased until broken at torque moment 3.5 ton.m and  $7^\circ$  rotation. Ratio  $M_{t, uji}/M_{t, teori} = 1.66$

From the analysis above shows that the formula used ACI 318 2011 which is relatively close to the test results, so that the formula can be used. While the test specimen 2 and 3, the both of test specimen underwent the test load torque in the opposite direction. At the direction of rotation yield slightly larger than the rotation in the opposite direction, so that it can be said that the rotation can be done in both directions.

Tabel 2 : Strain and stress for material with tor momen torsi

Sample	No	Position Strain Gauge	E Material (MPa)	Strain ( $\times 10^6$ )	Stress (MPa)
BU-1	1	Spiral	2.10E+05	1141	239.61
	2	PC Wire	1.90E+05	2390	454.10
	3	Concrete	3.00E+04	782	23.46
BU-2	1	Spiral	2.10E+05	1028	215.88
	2	PC Wire	1.90E+05	2280	433.20
	3	Concrete	3.00E+04	1233	36.99
BU-3	1	Spiral	2.10E+05	2363	496.23
	2	PC Wire	1.90E+05	1552	294.88
	3	Concrete	3.00E+04	272	8.16
BU-3	1	Spiral	2.10E+05	2630	552.3
	2	PC Wire	1.90E+04	6102	1159.38
	3	Concrete	3.00E+04	781	23.43

Tabel 2 : Ratio  $M_{t, uji}$  to  $M_{t, theoretical}$  dan rotation

No.	Sample	$M_{t, teoritis}$ (t.m)	$M_{t, uji}$ (t.m)	Ratio $M_{t, uji} / M_{t, teoritis}$	Rotasi (degree)
1	BU-1	3.445	3.13	0.91	9.8
2	BU-2	2.334	2.94	1.26	3.5
3	BU-3	2.334	2.78	1.19	7.8
4	BU-4	1.777	2.95	1.66	4.5

## 6. CONCLUSION

1. The test results are close to the torque moments calculated using the formula torque moment of ACI 318-11, so that the testing method used can be accounted for.
2. Torque moment calculation procedure in hollow circular piles can also be justified scientifically.
3. Rotation in the opposite direction to the direction of the spiral is only slightly different from the direction of rotation.
4. The addition of the effective spiral reinforcement (by narrowing the distance between the spiral) increases torque capacity torque on the cross section.

## REFERENCES

- [1] Bambang Budiono, "Design of Reinforced Concrete Structure", lectures of Faculty of Civil Engineering and Environment, Institut Teknologi Bandung
- [2] Edward G. Nawy, "Prestressed Concrete : A Fundamental Approach", Second Edition, 1995
- [3] -, "Building Code Requirements for Structural Concrete (ACI 318M-11)", ACI 318 Committee and Commentary
- [4] T.H.G. Megson, "Structural and Stress Analysis", Elsevier Butterworth Heinemann, Chapter 11, pp. 288 – 291, Second Edition, 2005.
- [5] Gambiro, Abdi, Reza, "Report of Torsion Testing of Hollow Spun Pile", Departemen Research and Development, PT. Wijaya Karya Beton, Indonesia, 2012.



## Corrosion of Concrete Using Portland Composite Cement and Rice Husk Ash under Simulated Acid Rain Environment

Irma Aswani Ahmad<sup>a</sup>, Herman Parung<sup>b</sup>, M. Wihardi Tjaronge<sup>b</sup>, Rudy Djamaluddin<sup>c</sup>

<sup>a</sup>Doctoral Student, Civil Engineering Department, Hasanuddin University, Makassar 90245  
E-mail : irmaaswani\_lakampi@yahoo.com

<sup>b</sup>Professor, Civil Engineering Department, Hasanuddin University, Makassar 90245  
E-mail : parungherman@yahoo.co.id

<sup>b</sup>Professor, Civil Engineering Department, Hasanuddin University, Makassar 90245  
E-mail : tjaronge@yahoo.co.jp

<sup>c</sup>Associate Professor, Civil Engineering Department, Hasanuddin University, Makassar 90245  
E-mail : rudy0011@hotmail.com

### ABSTRACT

Cement production, which results in higher CO<sub>2</sub> levels, has a negative impact on environment. This phenomenon has caused the emergence of a new type of environmentally friendly cement, such as cement composites. Some previous studies have recommended the use of rice husk ash (RHA) as a partial replacement of cement. In Indonesia, Ordinary Portland Cement (OPC) has been difficult to find in the market, thus many constructions use composite cement, known as Portland Composite Cement (PCC). On the other hand, rainfall becomes high acidity level. This will be an issue in the construction of concrete, which causes concrete deterioration if value of pH is below 6. The purpose of this study is to investigate corrosion caused by acid rainfall when used PCC cement mixed with RHA. RHA replacement level of 5%, by weight of cement was used in this study. The compressive strength design was 30 MPa. The simulated acid rain solution was prepared by mixing pure chemical reagents such as H<sub>2</sub>SO<sub>4</sub> and HNO<sub>3</sub> to reach value pH of 4. The deterioration was measured by the number of corrosion product using SEM test. The results indicate a decrease in the number of component corrosion that occurs by using ASP.

### Keywords

Corrosion, acid rain, portland composite cement, husk rice ash, SEM

**This Paper is Published in Advanced Material Research**

# The Study on Compressive Strength of Normal Concrete Containing Rice Husk Ash (RHA) and Concrete Sludge Waste (CSW) Designed for Moderate Strength

Essy A.<sup>a</sup>, Madsuri<sup>b</sup>, Marchin A.<sup>c</sup>

Faculty of Engineering, University of Indonesia, Depok 16424  
 E-mail : [essy@eng.ui.ac.id](mailto:essy@eng.ui.ac.id), [madsuri@eng.ui.ac.id](mailto:madsuri@eng.ui.ac.id), [marchinalfredo@yahoo.com](mailto:marchinalfredo@yahoo.com)

## ABSTRACT

*The use of concrete as construction materials in Indonesia is increasing, especially in ready mix concrete industry (Ready Mix Concrete). One of the problems that arise in the ready mix concrete industry, is to collect and dispose of the rest resulting from washing concrete mixer truck concrete after the concrete mix, produce and deliver to construction sites. On the basis of this, the purpose of this study was to determine the physical and mechanical properties of concrete containing waste slurry ready mix concrete (Concrete Sludge Waste) or collectively, CSW is also ditambahkan with rice husk ash (Rice Husk Ash) or also known as RHA . RHA and CSW function is as a partial replacement of cement and fine aggregate. Physical and mechanical properties to be tested that include concrete compressive strength, modulus of elasticity with the Pundit, permeability, and density. Based on test results obtained from the optimum compressive strength is the composition of the mixture of 92% cement, 8% RHA, 70% sand and 30% CSW of 32.12 MPa at 28 days. Similarly, the test characteristics of concrete such as modulus of elasticity of the other hard to come by using a Pundit 32133.33 MPa, penetration testing on the permeability of 19.67 mm, and for the density of 2.056 g/cm<sup>3</sup>. From the results of such testing according to SNI for non-structural concrete, can be used as paving blocks, kanstin, parking lot and other non-structural concrete.*

## Keywords

*Rice Husk Ash, Concrete Sludge Waste, compressive strength, modulus of elasticity, permeability, density.*

## 1. INTRODUCTION

currently is to collect and dispose of the remainder resulting from washing concrete mixer truck concrete after the concrete mix, produce and deliver to the construction site, which eventually removed and piled on vacant land just like that. Waste disposal can harm the environment and reduce the aesthetic value of the location - the location of disposal. Reduction in residual waste solution is mixing concrete by the use of return (Reuse) material that is proper to use, and reprocessing (Recycle) are the remaining material. In order to be utilized as a construction material other material that is friendly to the environment. The goal is to achieve sustainable development (sustainable construction) that can be used and carried by the community. In this research, in addition to the concrete mix of cement, fine aggregate, coarse aggregate and water, the addition of Rice Husk Ash (Rice Husk Ash) or called the RHA, the burning of rice husk waste which has elements that are useful for improving the quality of concrete, have a nature Pozolan and contain silica which is very prominent, if the element is mixed with cement will result in a higher power. Ready mix concrete waste (Waste Concrete Sludge) is the rest of the concrete resulting from the leaching process of concrete mixer truck which is also called CSW. CSW is taken from the accumulation in the batching plant with varying compressive strength that has been mixed. RHA and CSW utilized to partially substitute cement and fine aggregate. So in this study aims to determine the nature of the RHA and CSW Fisk to be used, Knowing the composition of the CSW is effective and can meet the target of the desired strength, Knowing the behavior of nature - the physical and mechanical properties of concrete containing RHA and CSW.

## 2. MATERIAL And METHODS

The research was conducted at the Department of Civil Materials Testing Laboratory, University of Indonesia. Methods The study was conducted by laboratory testing in accordance with the data from the literature study both SK SNI Standard Indonesia and foreign standards are ASTM and DIN.

### 2.1 Materials And Methods

#### 2.1.1 Cement

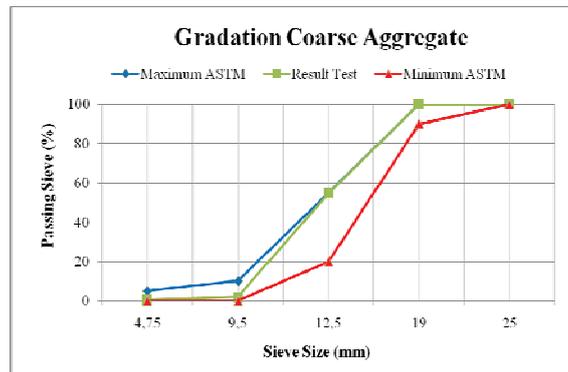
Type-I Portland cement (PCC) was used, which was manufactured by tiga roda. and its physical and chemical properties met the ASTM C150 specification.

#### 2.1.2 Coarse Aggregate

The large stones were crushed first; those with screened split 10 – 15 mm a mixed ratio were used as the coarse aggregate. The fineness modulus was 7,44%.

**Table 1. Coarse Aggregate Test**

No.	Physis and Mechanics	Result Test	Spec
1	Spesific Gravity	2,540	-
2	Spesific Gravity (SSD)	2,560	-
3	Water Absorpstion (%)	0,880	3
4	Bulk Density(gr/cm <sup>3</sup> )	1,425	Min 1,2
5	Loose Bulk Density (gr/cm <sup>3</sup> )	1,331	Min 1,2
6	Voids (%)	45,59	-
7	Water Content (%)	1,47	-
8	Fineness Modulus (%)	7,44	-



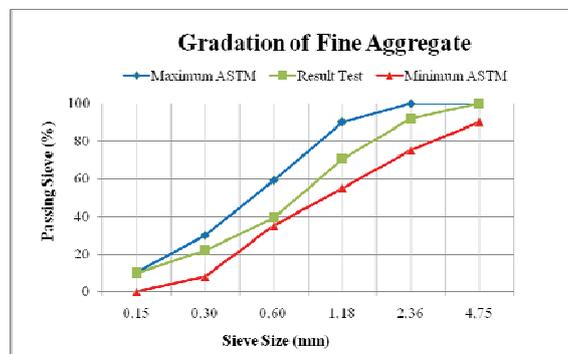
**Figure 1.** Gradation of Coarse Aggregate

### 2.1.3 Fine Aggregate

The sand was obtained from the Cimangkok, West Java and had a fineness modulus of 2,66%.

**Table 2. Fine Aggregate Test**

No.	Physis and Mechanics	Result Test	Spec
1	Spesific Gravity	2,090	-
2	Spesific Gravity (SSD)	2,179	-
3	Water Absorpstion (%)	4,280	3
4	Bulk Density(gr/cm <sup>3</sup> )	1,422	Min 1,2
5	Loose Bulk Density (gr/cm <sup>3</sup> )	1,304	Min 1,2
6	Voids (%)	34,64	-
7	Water Content (%)	13,64	-
8	Silt Content (%)	3,30	Max 5%
9	Fineness Modulus (%)	2,66	Zone 2



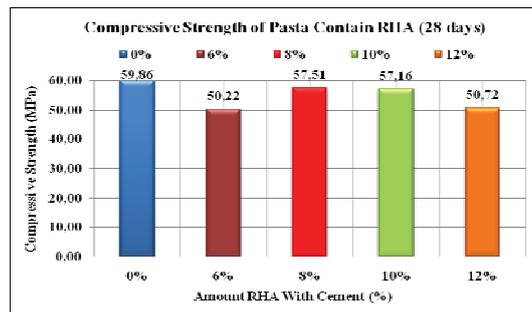
**Figure 2.** Gradation of Fine Aggregate

### 2.1.4 Rice Husk Ash (RHA)

Rice bran is the outer portion of the grain, which is a byproduct of rice milling process when done. While the ash or Rice Husk Rice Husk Ash called RHA is a waste burning rice husk has elements that are useful for improving the quality of concrete, has Pozolan nature and contain silica which is very prominent, if the element is mixed with cement will result in a higher power. Though there are in the rice husk SiO<sub>2</sub> reactive element that can be used as an ingredient made Pozolan concrete quality improvement (Priyosulistyo, 2001). chaff that was done burning, then crushed again to escape kesaringan 200-400 Mesh. As a whole from the chaff in the can of rice alone was only 5% or about 20% of the burning husks. Chemical analysis performed on the combustion of rice husk ash content of silica oxide showed a fairly high, as shown in the following table.

**Table 3.** Composition of Chemical Compounds RHA

Chemical Compounds	Amount (% Weight)
SiO <sub>2</sub>	93.4408
Al <sub>2</sub> O <sub>3</sub>	0.1031
P <sub>2</sub> O <sub>5</sub>	1.0129
S	0.2227
K <sub>2</sub> O	3.4808
CaO	0.7193
TiO <sub>2</sub>	0.0946
MnO <sub>2</sub>	0.2285
Fe <sub>2</sub> O <sub>3</sub>	0.6800
ZnO	0.0173



**Figure 3.** Histogram charts Strong Preliminary Research Findings Press CRHA (a mixture of cement + RHA) at 28 days

Based on preliminary research results graph CRHA compressive strength and cement mixtures containing RHA, the CRHA compressive strength obtained at 28 days with the most optimal composition of 92% cement and 8% at 57.51 MPa RHA. From the results of this preliminary study we used the optimal composition of RHA 8% of cement content for concrete mixtures containing RHA da CSW fit the normal concrete mix design plans based on SNI 03-2834 - 2000.

### 2.1.5 Concrete Sludge Waste (CSW)

Concrete Sludge Waste or CSW is the waste generated from washing truck mixer at the batching plant after producing and sending mixed concrete to construction sites. At the time of washing, the CSW to be like sludge which will then harden to form lumps. CSW function in this study aims to conserve the use of sand and own a maximum compressive strength and can also be used will be environmentally friendly building materials, appropriate such as paving blocks, bricks.





Figure 4. Process of Taking CSW

Chemical analysis of the CSW can be viewed through by PSA testing (Particle Size Analysis) dan XRF (X-Rays fluorescence), as follows :

Table 4. PSA Analysis of CSW

No.	Particle Diameter (µm)	Statistics		
		Volume (%)	Surface Area (%)	Number (%)
1	< 20	100	100	100
2	< 10	98.500	99.700	99.998
3	< 8	92.300	98.400	99.990
4	< 6	79.600	94.900	99.900
5	< 4	60.500	87.600	99.700
6	< 2	36.000	71.500	98.000
7	< 1	16.200	44.800	86.700
8	< 0.4	0.220	1.040	4.930

Table 5. XRF Analysis of CSW

No.	Chemical Compounds	Prosentase	
		Weight (%)	Atom/ Molecul (%)
1	MgO	1.8284	3.6062
2	Al <sub>2</sub> O <sub>3</sub>	7.5603	5.8951
3	SiO <sub>2</sub>	<b>35.5793</b>	47.0789
4	S	0.5744	1.4243
5	K <sub>2</sub> O	0.7181	0.6061
6	CaCO <sub>3</sub>	<b>48.0781</b>	38.1902
7	TiO <sub>2</sub>	0.5984	0.5955
8	Cr <sub>2</sub> O <sub>3</sub>	0.1169	0.0612
9	MnO <sub>2</sub>	0.1927	0.1763
10	Fe <sub>2</sub> O <sub>3</sub>	4.7531	2.3644

From the results of the PSA test, CSW has the smallest particle size of 0.4 µm and the number of particles that measure between 0.4 CSW - 1 µm as much as 16.42% of the total samples tested. While the test results of XRF, CSW to own most of the chemical composition containing SiO<sub>2</sub> and CaCO<sub>3</sub>.

CSW in this study did not directly used but must be done further research and treatment so as expected, here's how the processing of CSW to be used:

- CSW is usually still in a wet or humid conditions, it must first be dried by drying using the sun or can also be roasted.
- After CSW dried, crushed and polished slabs CSW by milled or ground.
- After CSW crushed, then sieved with a sieve size of 4.75 mm (3/16 in) which is a standard sieve for fine aggregate.
- After CSW has been sifted, stored in a dry place and already can be used



Figure 5. Processing of CSW

## 2.2 Design of Concrete Proportion

The concrete mixing proportions were for moderate strengths of 35 MPa, whereas the slump was 6 - 18 cm. The constituent contents of RHA and CSW are shown in Table 5.

Table 6. Material Composition

Sample Code	MATERIAL COMPOSITION				
	PC + RHA		Fine Aggregate		Coarse Aggregate
	PC	RHA	Sand	CSW	
CHWC-131	92%	8%	70%	30%	100%
CHWC-132	92%	8%	60%	40%	100%
CHWC-133	92%	8%	50%	50%	100%
CHWC-134	92%	8%	40%	60%	100%
CHWC-135	92%	8%	30%	70%	100%

## 2.3 Fresh Concrete Tests

### 2.3.1 Slump Test

Slump tests were performed according to ASTM 143 to measure the slumps for concrete containing RHA and CSW.

### 2.3.2 Unit Weight of Concrete

The unit weight of the fresh concrete was measured according to ASTM C138.

### 2.3.3 Initial Setting Time Test

The measurements were conducted according to ASTM C403.

## 2.4 Hardened Concrete Test

### 2.4.1 Compressive Strength

Compressive strength testing using a test specimen cube 100 x 100 x 100 mm, testing were prepared according to ASTM C39 and were cured for 1–56 days. At each curing age, five cube specimens were tested for compressive strength. the cube compressive strength of test specimens are converted into compressive strength of cylindrical specimens are shown in table 6.

**Table 7.** Conversion of compressive strength based on shape of sample tests

NO	Shape of sample test	Konversion Value (A.M. Neville)
1	Cube 10x10x10 (cm)	1,04
2	Cube 15x15x15 (cm)	1,00
3	Cylinder d=10, t=20 (cm)	0,86
4	Cylinder d=15, t=30 (cm)	0,83

### 2.3.2 Modulus of Elasticity

Modulus of elasticity is a measure of material stiffness or resistance to deformation. Modulus of elasticity is determined voltage change of strain in the elastic limit. Elastic region in concrete according to ASTM constrained between 0.00005 strain with 40% voltage at the maximum voltage. But in this study the elastic modulus testing using non-destructive testing device that is Pundit (Portable Ultrasonic Non-Destructive Digital Indicating Tester) that uses ultrasonic waves. The ability of this tool, besides knowing the quality of concrete, can also detect a thick layer of concrete that is damaged, or it cracks in the concrete. The relationship between modulus of elasticity and compressive strength of concrete according to SKSNI 1991 which were used by ACI are:  $E_c = 4700 \sqrt{f_c}$

The equation above shows that the magnitude of the modulus of elasticity of the concrete increases with increasing compressive strength of concrete.

### 2.3.3 Permeability

Permeability is the nature of the ease of escape of water or similar substances to penetrate the concrete surface. Rate of water passing ability of a material is expressed by the coefficient of permeability (k), which depends on the concrete surface area, water pressure, and duration of time. Concrete permeability testing to determine the effect of variations in cement and aggregates, or influences many kinds of concrete mixing operation, printing and maintenance, taking into account the basic information on the inside of the relative porosity of concrete is directly related to absorption, capillary channel, the resistance to freezing, preparation, lift and other so on. Factors affecting the quality kekedapan material, method of preparation of concrete, and concrete maintenance (Brook K.M, Murdock L.J, 1991).

### 2.3.4 Density

Based on ASTM C 642-97, this method involves the determination of density. This test is useful in developing the data needed for the conversion between mass and volume for the concrete. It can be used to determine compliance with spesifikasiuntuk concrete and to show the differences from place to place in mass concrete. The amount of density can be measured as follows:

$$[A/(C-D)].\rho = (\text{g/cm}^3)$$

Where :

- A = mass of oven-dried sample in air, (g)
- C = mass of surface dry sample (g)
- D = apparent mass of sample in water (g)
- $\rho$  = density of water (1 g/cm<sup>3</sup>)

### 3. RESULTS And ANALYSIS

#### 3.1 Test Results for Fresh Concrete

##### 3.1.1 Slump test

Based on the results of such testing, the average slump for normal concrete, CHWC131, CHWC132, CHWC133, CHWC134, CHWC135 is 80 mm, 66.67 mm, 61.67 mm, 70mm, 74.33 mm, 78.33 mm. Obtained that the value of the entire mixture into the slump slump plan is 60-180 mm.

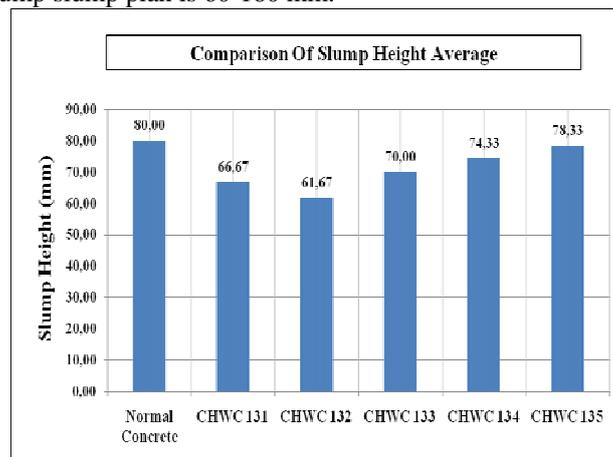


Figure 6. Graph of Slump

##### 3.1.2 Unit Weight of Concrete

Table 8. Result Test of Unit Weight Fresh Concrete

No	Measurement	Unit	Mixed Code					
			Normal	CHWC131	CHWC132	CHWC133	CHWC134	CHWC135
1	Weight of Cylinder (W1)	Kg	4,998	4,998	4,998	4,998	4,998	4,998
2	Weight of Cylinder + Water (W2)	Kg	14,75	14,75	14,75	14,75	14,75	14,75
3	Weight of Cylinder + Concrete (W3)	Kg	26,2	26,1	25,5	25,3	25,25	24,8
4	Weight of Concrete (W3 - W1)	Kg	21,20	21,10	20,50	20,30	20,25	19,80
5	Unit Weight of Concrete (W4) = ((W3-W1)/(W2-W1)) x 1000	Kg/m <sup>3</sup>	2174	2164	2102	2082	2077	2031
6	Purpose of Unit Weight of Concrete (W5)	Kg/m <sup>3</sup>	2190					
7	Yield (W5/W4)		1,0073	1,0121	1,0417	1,051	1,0546	1,0785
8	Voids [(Y-1)/Y] x 100 %	%	0,73	1,19	4,00	4,94	5,17	7,28

Based from table 10, More and more using csw, then water content is high. Large air content which is also caused due to a lack of good compaction at the time of testing.

##### 3.1.3 Initial Setting Time Test

Table 9. Results of Initial Setting Time Test

Test	Normal Concrete	CHWC 131	CHWC 132	CHWC 133	CHWC 134	CHWC 135
Initial Setting Time (Minutes)	117,4	134,3	135,2	142,4	145,2	146,8

Result of setting time for normal concrete is 117,4 minutes, then shown from table 11 more using CSW, more longer setting time.

### 3.2 Hardened Concrete Test

#### 3.2.1 Compressive Strength

Test of compressive strength using sample shaped a cubed size of 100x100x100 mm. The result obtained from cubed sized 100mm, converted to  $fc'$  cube size of 150x150x150 mm that ( $fc'$  cube 100mm / 1,04), then converted again to  $fc'$  shaped cylinder 150mm x 300mm of ( $fc'$  cube 150mm x 0,83). Tests performed at the age of 3, 7, 14, 21, 28, and 56 days of the results can be shown in the picture 7.

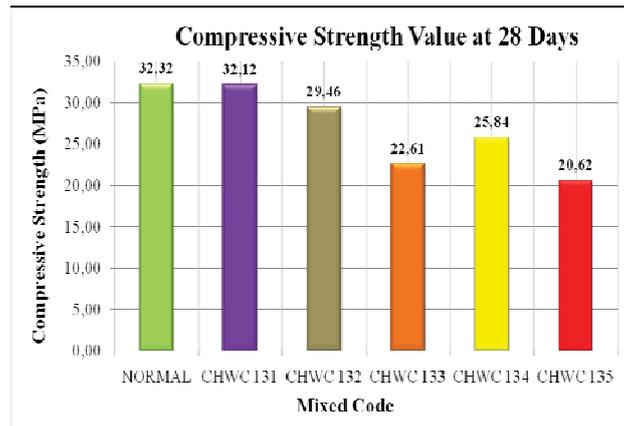


Figure 7. Histogram of Compressive Strength at 28 days

#### 3.2.2 Modulus of Elasticity with (PUNDIT)

Test of Modulus of elasticity for this study using non destructive equipment that is PUNDIT (*Portable Ultrasonik Non-Destructive Digital Indicating Tester*), that work is carried out using ultrasonic waves at concrete 28 days old. From the test results on PUNDIT test doing compare with the value modulus of elasticity from compressive strength of concrete at 28 days according to SKSNI 1991, using the formula:

$$Ec = 4700\sqrt{fc'}$$

Table 10. Result Test of Modulus Elasticity With PUNDIT

Mixed Code	Poisson Ratio	Compressive Strength (MPa)	ME PUNDIT (MPa)	Ec SKSNI (MPa)	Comparison
CHWC131	0,22	32,12	32.133,33	26.638,10	1,206
CHWC132	0,22	29,46	31.150,00	25.511,23	1,221
CHWC133	0,22	22,61	29.966,67	22.349,56	1,341
CHWC134	0,22	25,84	31.037,50	23.890,49	1,229
CHWC135	0,22	20,62	25.268,75	21.340,79	1,184
Average					1,250

Shown from table. 10 the comparation average value between modulus of elasticity ratio testing with PUNDIT, with the theoretical value according SNI is 1.25.

Comparison between the modulus elatisitas with compressive strength by the equation  $Ec = 4700\sqrt{fc'}$  not valid again for concrete that contain RHA and CSW. To obtain a new equation of the elastic modulus relationship with compressive strength used equation  $Ec = C\sqrt{fc'}$ . Where C is a constant of modulus of elasticity results for testing with the square root of compressive strength obtained from the research. C values of the test results can be seen in the table 11.

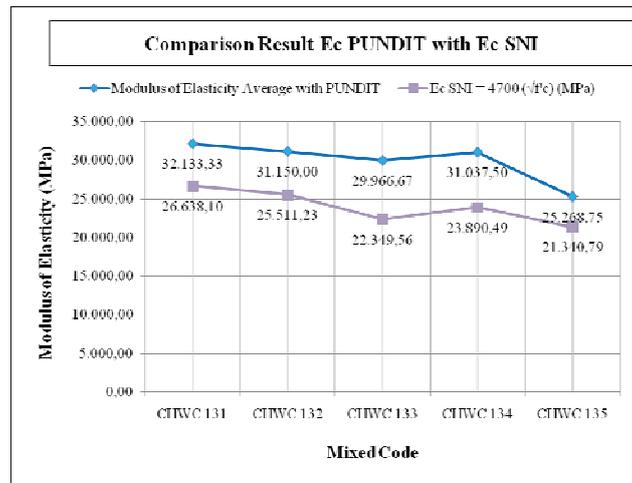


Figure 8. Graph of Modulus of Elasticity

Table 11. Value of New Constanta Modulus of Elasticity with Compressive Strength

Mixed Code	ME PUNDIT (MPa)	√fc (MPa)	Value of Constanta
CHWC 131	32.133,33	5,67	5667
CHWC 132	31.150,00	5,43	5737
CHWC 133	29.966,67	4,76	6296
CHWC 134	31.037,50	5,08	6110
CHWC 135	25.268,75	4,54	5566
			<b>5875</b>

Based on the table it can be determined the relationship between the modulus of elasticity equations with the compressive strength of concrete contain RHA and CSW at 28 days is  $E_c = 5875 \sqrt{f_c'}$ .

### 3.2.3 Permeability

Test of permeability performed at 28 days by using a cylindrical test with diameter 15 cm and length of 15 cm. Tests carried out with water pressure of 0.5 N / mm<sup>2</sup> at 72 hours or 3 days after the split and measured values of the incoming water penetration.

Table 12. Result of Average Penetration

Mixed Code	Pressure (MPa)	Time (Hours)	Compression Strength at 28 days (MPa)	Average of Penetration (mm)
CHWC131	0,5	72	32,12	19,67
CHWC132	0,5	72	29,46	21,33
CHWC133	0,5	72	22,61	23,44
CHWC134	0,5	72	25,84	17,22
CHWC135	0,5	72	20,62	25,56

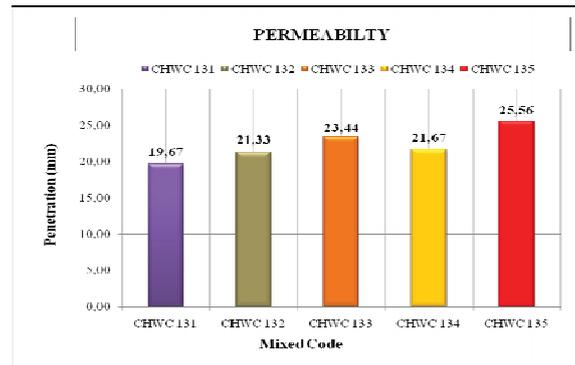


Figure 10. Histogram of Permeability

Shown on graph the value of greatest penetration is in from mixed code CHWC135 that is equal to 25.56mm, while the smallest penetration value is in from mixed code CHWC131 that is equal to 19.67 mm. CSW CHWC135 to own composition more than the other mixture of 70%. Then it can be analyzed that more using CSW it can be a higher penetration occurs.

### 3.2.4 Density

Test of density performed at 28 days by using a cube specimen size 100 x 100 x 100 mm. Result test of density can be shown at table 13.

Table 13. Result Test of Density

NO	Mixed Code	Age of Test (Days)	Water Density ( $\rho$ ) ( $\text{g}/\text{cm}^3$ )	Compressive Strength at 28 days (Mpa)	Density (Average) ( $\text{g}/\text{cm}^3$ )
1	NORMAL	28	1	32,32	2,286
2	CHWC131	28	1	32,12	2,056
3	CHWC132	28	1	29,46	2,047
4	CHWC133	28	1	22,61	1,918
5	CHWC134	28	1	25,84	1,934
6	CHWC135	28	1	20,62	1,865

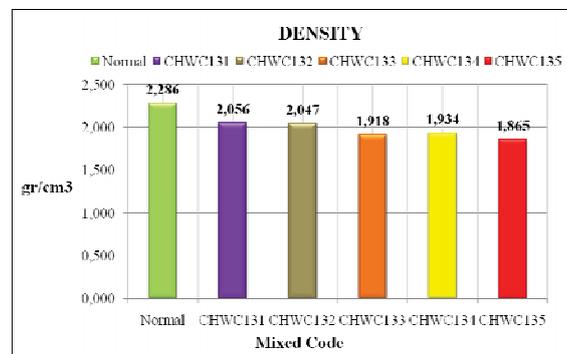


Figure 11. Histogram of Density

Shown at picture. 10, showed that the average density value the largest average occurs in CHWC131 mixture, while the average density value is the smallest average CHWC135 mixture. Then it can be analyzed that more using of CSW, the greater density obtained.

### 3.3 Using CSW Into Material of Construction

From the research, that the benefits from CSW can be used by the industry. In this study, the composition of the five concrete mixtures CHWC131, CHWC132, CHWC133, CHWC134, CHWC135 at 28 days reached the compressive strength of 32.12 MPa, 29.46 MPa, 22.61 MPa, 25.84 MPa and 20.62 MPa . Based from requirements of concrete brick (paving blocks) according to SNI 03-0691-1996 on quality requirements and classification of concrete brick, concrete contained RHA and CSW can being :

- A Quality Concrete bricks are used for road.
- B Quality concrete bricks are used for parking lot
- C Quality concrete bricks are used for pedestrian walk
- D Quality concrete bricks are used for park land and another function for non structural concrete..

Table 14. Terms of Quality Paving Blocks According to SNI

Mutu	Kuat Tekan (MPa)		Ketahanan Aus (mm/menit)		Penyerapan air rata-rata maks
	Rata-rata	min	Rata-rata	min	%
A	40	35	0.090	0.103	3
B	20	17.0	0.130	0.149	6
C	15	12.5	0.160	0.184	8
D	10	8.5	0.219	0.251	10

## 4. CONCLUSIONS And RECOMENDATIONS

### 4.1 Conclusions

In this study, RHA and CSW utilized to partially substitute cement and fine aggregate. Based on analysis from test. The following conclusions can be drawn:

- Using CSW as a Partially replace of fine aggregate in concrete, effect on the reduction in workability of fresh concrete is characterized by a decline in the value of slump, so it should be added to water at the time of stirring so the mixture does not dry quickly
- More used of CSW, more water to cement ratio resulting in a decreased value of compressive strength.
- The greater percentage using of CSW, that the unit weight of concrete it so small and so that the levels of air (voids) in the fresh concrete increases. Weight content of the smallest mixed it is in mixed code CHWC135 with percentage of 30% sand and 70% CSW in the amount of 2031 kg / m<sup>3</sup> with the air content of 7.28%. When compared with normal concrete is equal to 2174 kg / m<sup>3</sup> with the air content of 0.73%.
- The greater use of CSW, that the longer initial setting time occurring, so that process of cement hydration reaction had a long time. Caused CSW has a very high water absorption compared to the sand.
- At mixed code CHWC131 had a very high value of Compressive strength of 32,12 MPa at 28 days compare that another mixed code. So that CHWC131 with 92% cement, 8% RHA, 70% sand, and 30% CSW, it is a effective mixed for concrete Contain RHA and CSW.
- From modulus of elasticity test, the EC value acording SNI not applicable for concrete contain RHA and CSW, so that from test result value of EC be avowed by the formulation is  $EC = 5875 \sqrt{f_c}$ .
- The benefit of CSW can be used by industry as a material manufacture of paving block, according from SNI 03-0691-1996.
- Waste generated by batching plan can be recovered into a building material products can also be an environment that would minimize the environmental impact around the batching plan.

### 4.2 Recommendations

The following suggestions may be related to the research conducted are:

- Further research needs to be done on the use of CSW, in order to use the maximum percentage value of the mechanical properties of concrete.
- Use of CSW so great in the concrete mix, will decrease the compressive strength of concrete, so that further research is recommended to use must be adjusted to the amount of sand on the concrete.
- In this study the treatment of CSW proceed by manually, so that further research needs to be done on a good method to produce a CSW in standart.
- Need to use chemical ingredients added to the RHA and CSW mix concrete, in order to water cement ratio accordance with the composition of normal concrete.
- Use of CSW was able to be used as a complementary mixture of fine aggregate sand, it is necessary to do research on the economics of the use of CSW. So its use can be commercially exploited by the industry and can reduce the impact of pollution on the environment.
- Amount of concrete sludge waste from each batching plan it so variated in Indonesia, so further research is needed on how much the use of CSW can offer.

## REFERENCES

- [1] Anagyagos, Nigoskatis. Kuat Tekan, Density, Absorpsi Dan Modulus Elastisitas Mortar Campuran Semen, Abu Sekam Padi, Dan Precious Slag Ball Dengan Perbandingan 30%; 30%; 40%. Departemen Teknik Sipil, Universitas Indonesia, Depok : 2011.
- [2] ASTM C 127-01. *Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate*, ASTM International, 100 Barr Harbor Drive, United States : 2003.

- [3] ASTM C 128-01. *Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [4] ASTM C 29M-97. *Standard Test Method for Bulk Density (Unit Weight) and Voids in Aggregate*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [5] ASTM C 136-01. *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [6] ASTM C 117-03. *Standard Test Method for Materials Finer than 75- $\mu$ m (No. 200) Sieve in Mineral Aggregates by Washing*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [7] ASTM C 138M-01a. *Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [8] ASTM C 403M-99. *Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [9] ASTM C 642-97. *Standard Test Method for Density, Absorption, and Voids in Hardened Concrete*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [10] ASTM C 403M-99. *Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [11] ASTM C 469-02. *Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression*, ASTM International, 100 Barr Harbor Drive, United States : 2003.
- [12] CNS Farnell Limited, *Operating Instructions of PUNDIT Plus Model PC1006*, Elstree Way, England : 2006.
- [13] DIN 1048 Part 5. *Testing of Hardened Concrete (Water Permeability – Page 6)*, DIN-Normen-German Standards, Beuth Verlaag GmbH, Berlin : 1991.
- [14] Houston, D.F. *Rice Chemistry And Technology*, American Association Of Cereal Chemist, Inc. Minnesota : 1972.
- [15] Krishnarao R. V., Subrahmanyam J., Kumar, T. J. *Studies On The Formation Of Black In Rice Husk Silica Ash*, J. Ceramic Society : 2000
- [16] Kusumantara, Diah. *Pengaruh Faktor Air Semen Terhadap Campuran 50% Semen Dan 50% Abu Sekam Padi*, Departemen Teknik Sipil, Universitas Indonesia, Depok : 2009.
- [17] Kusumantara Diah, Basoenondo A. Essy., *Utilization of Waste From Concrete Mixer Truck To Create Low Grade Quality Concrete For Building Materials*, Departemen Teknik Sipil, Universitas Indonesia, Depok : 2009.
- [18] Laksono, Prasetyoko, Andhi. Didik. *Abu Sekam Padi Sebagai Sumber Silika Pada Sintesis Zeolit ZSM-5 Tanpa Menggunakan Templat Organik*, Laboratorium Kimia Anorganik Jurusan Kimia, Institut Teknologi Sepuluh Nopember. Surabaya : 2006.
- [19] Neville, A.M, *Properties of Concrete*, Fourth Edition, The English Language Book Society And Pitman Publishing, London, 2000.
- [20] Pasaribu, Ramos. *Analisa Kemampuan Beton Ringan Abu Sekam Padi*, Jurusan Arsitektur, Universitas Tarumanegara. Jakarta : 2007.
- [21] SNI 15-7064-2004. *Semen Portland Komposit*, Badan Standarisasi Nasional, Jakarta : 2004.
- [22] SNI 03-1971-1990. *Metode Pengujian Kadar Air Agregat*, Badan Standarisasi Nasional, Jakarta : 1990.
- [23] SNI 03-1972-1990. *Metode Pengujian Slump*, Badan Standarisasi Nasional, Jakarta : 1990.
- [24] SK SNI T-15-1990-03. *Pembuatan Benda Uji*, Badan Standarisasi Nasional, Jakarta : 1990.
- [25] SNI 03-1974-1990. *Pengujian Kuat Tekan Beton*, Badan Standarisasi Nasional, Jakarta : 1990.
- [26] SNI 03-0691-1996. *Bata Beton (Paving Block)*, Badan Standarisasi Nasional, Jakarta : 1996.
- [27] Tjokrodinuljo, K., *Teknologi Beton*, Nafiri, Yogyakarta, 1996.

# Adoption of Smartphones of Mobile Professionals in Indonesia and Its Implications on Travel Pattern using the concepts of Mobile Interaction-based Coordination: Preliminary Study

Gloriani Novita C<sup>a</sup>, Ofyar Z. Tamin<sup>b</sup>, Idwan Santosa<sup>c</sup>, Miming Miharja<sup>d</sup>

<sup>a</sup>School of Architecture, Planning and Policy Development  
 Institut Teknologi Bandung  
 Ganesha 10, Bandung 40132  
[glorinovi@yahoo.com](mailto:glorinovi@yahoo.com)

<sup>b</sup>Faculty of Civil and Environmental Engineering  
 Institut Teknologi Bandung  
 Ganesha 10, Bandung 40132 Indonesia  
[ofyar@trans.si.itb.ac.id](mailto:ofyar@trans.si.itb.ac.id)

<sup>c</sup>Faculty of Civil Engineering-  
 Institut Teknologi Bandung  
 Ganesha 10, Bandung 40132  
[idwan2003@yahoo.com](mailto:idwan2003@yahoo.com)

<sup>d</sup>School of Architecture, Planning and Policy Development  
 Institut Teknologi Bandung  
 Ganesha 10, Bandung 40132  
[mimiharja@yahoo.com](mailto:mimiharja@yahoo.com)

## ABSTRACT

*The adoption of smartphones, which is the result of the convergence of Information and Communication Technology (ICT), grow rapidly in mobile professionals, i.e. segment who spend 20 per cent or more of their total working time to work away from their office. The type of work of mobile professional, with the greater unpredictability and heterogeneity than fixed node-worker, need additional support in order to decrease the contextual constraints encountered while mobile, and smart phone may fulfil such needs. Smart phone potentially allow the restructuring of activity patterns of individual during work and in turn can influence their travel pattern. To understand it, this study theoretically discussed how individuals of mobile professionals adopt and use smartphones, and how its implications on the work activities and travel pattern by using a concept: mobile interaction based coordination. To provide the first insight, the results of the initial interview conducted on 20 mobile professionals in Indonesia are given. As the result, there are indications of change of the way of the coordination of mobile professionals and leads to changes in the dynamics of the mobile work-travel pattern. In aggregate, it will have large impacts on the use and configuration of urban transport network.*

**Keywords:** Smartphone, Professional Mobile, Mobile Interaction based Coordination, Work Activity, Travel Pattern

## → 1. INTRODUCTION

Information and Communication Technology (ICT) plays an increasingly important role in human life. For instance, as shown by the data at the end of 2011, which states that there are approximately six billion mobile phone subscribers in the world, with global penetration reaches 87%, and 79% in developing countries [1] and 89 per cent of users use it throughout the day [2]. Adoption is increasing due to the convergence of ICT has facilitated the transmission of large amounts of information with high speed and accuracy with a relatively low cost. It is then further strengthened with the advent of smartphones, which is a contemporary type of mobile phone that integrates a number of technologies for computing capabilities and advanced internet connectivity [3]. This phone is built in with applications and internet access, digital voice, text messaging, e-mail, browser (browsing) web, and multimedia devices, so users can do many things on the go, anytime, with direct access and multi-function. Technological and social characteristics of this device make them potential to change the behaviour of the users, more than the previous ICT.

Smartphone market started out in the business segment [4][5]. Especially so-called mobile professionals are important beneficiaries here. Mobile professionals could be characterized as individuals over age 20, employed full time in a professional occupation, who spend 20 per cent or more of their total working time away from their work environment [6][7]. The nature of work of mobile professional differs in many ways from desk work or fixed-node worker, because of the greater unpredictability and heterogeneity of the work caused by contextual constraints [8]. Mobile professional have less control over the configuration of their environment, therefore, they need additional support/information in order to decrease the uncertainty associated with the contextual constraints encountered while being mobile [9]. Thus, smartphone may fulfil such needs.

The issue of the interaction between the developments of ICT in individual travel behaviour is not a new thing. ICT-transport interaction is often expressed in function substitution, complementary, modification, and neutrality [10][11][12]. The main concern in many studies is whether ICT increase or decrease the amount of travel demand, and it seems that complementary concept (ICT increase transport demand) still dominates today, stronger than the interaction substitution [13]. Still in order to investigate the interaction, this study is a little different because it uses the 'activity system' as an intermediary interaction.

Because the interaction between ICT-transport is very complex, then to be more focused, objects are selected only one product technology (i.e. smart phone) and only the individual effects (i.e. the individual mobile professional), the purpose of the trip (i.e. travel to work) and then considering only one dimensional travel (i.e. use of smart phones in the coordination of activities performed while out of the office). This paper explores the impact of the use of smart phone technology on how the implications for the way individuals from mobile professionals organize activities and movement during work. Indonesia is used as a case, because the adoption of smart phones in Indonesia nearly 56 million and will continue to increase its penetration of the overall mobile phone subscribers in Indonesia, which has reached more than 240 million [4][14]. The rapid move towards the adoption and use of smart phone has provided people and organizations with the ability to work in novel and previously unpredictable ways. Thus, it is alleged that urban transport Indonesia will certainly dealing with the consequences of the transformation behaviour due to the use of smartphone.

This paper explores the use of smart phone mobile professionals and potential implications on the activities of their daily work, by reviewing relevant research that has been conducted before. To complete the review and obtain the first insight, it is given the results of a preliminary survey analysis of the semi-structured interviews with 20 smartphone users from mobile professionals in Indonesia. With this first insight, it is expected to gain a better understanding, and can be developed in subsequent phases of the study. The outline of the paper is as follows. The early part is an introduction, followed by a section that describes the theoretical background, which contains how smart phone technology, and the increasing number of mobile professional and nature of mobile work and how this use of ICT as well as the concept of the coordination of activities. In the section 3, the research methodology is presented which is contains the research design and expected outcomes, followed by section 4, the first insight as a result of the preliminary survey. The paper ends with a conclusion.

## → 2. THEORETICAL BACKGROUND AND HYPOTHESIS

### 2.1. Technology of Smartphone and Mobile Interaction

Recent Information and Communication Technology has the potential to transform everyday life: how to interact, privacy, social networking, economics, education, and urban transport [15]. Taking into account that smartphone is evolution of mobile phone, it is first necessary to review the research that has been done on the mobile phone. Over the past two decades, there are so many studies that focus on the use of mobile phones (e.g. [16][17][18][19]). Most of studies have tried to understand and explore how mobile adoption and potential changes in behaviour due to the use of mobile phones, from the perspective of sociology, for example [20] who focused at how mobile phones change the way a person interacts socially.

In the first phase of the development of mobile phones, users use the phone as a function of supplement, which is only for receiving and making calls or messages outside the home, office or other workplace. Mobile phone gives the possibility of new ways of doing activities and allows one to interact and carry out activities in a new way [21], and this results in (1) increasing the spatial and temporal flexibility, (2) the impact on travel behaviour and the decision to make the trip (3) to encourage users to spend their free time outside of the home, (4) the emergence of changes in the function and role of the existing nodes in the urban transport system, (5) a new mode of mobility that can improve accessibility to opportunities, services and social networks a person, even for individuals with limited physical mobility. After the convergence of ICT, the motive for adopting smartphones more powerful and causing consumers of mobile phones are quickly shifting to smart phones.

### 2.2. Mobile Professional and Mobile Work

Nature of work and location of work is undergoing a shift. Work is diversified, along with its increasingly mobile workers and the use of ICT equipment [22]. There is a tendency that the workforce has to deal with an increasingly complex job. With the expansion and globalization of business activities is rapidly increasing with higher consumer demand, the organization felt the need to better adapt the turbulent business environment. This trend led to a growing demand for highly skilled labour and a consequent increase in the number of mobile professional.

Technologies such as mobile phones and e-mail allows for workers and employers to keep in touch without the always present physically and led professional 'post-modern', the mobile nature, in the sense of operational, locational and interactional [22][23]. In operational terms, as a professional working in a flexible organizational structure, for example, in project teams, task forces, and virtual organizations, and in a different location and not always in the office. ICT helps them in organizing work in different locations, with continuous interaction with a large number of different people both inside and outside of formal organizations in a wide geographical area. List of tasks of a mobile professional work are planning, acquiring, searching, analysing, organizing, storing, organizing programs, distribute, and market information [24], . Mobile professional activities include creating, capturing, communicating, collaborating, seeking processes, and review the results and save them. With the advent of the function and connectivity to internet e.g. ability to send and receive email on a smart phone, which is not presented by earlier technology of mobile phone, the usage of smartphone during working is increasing. This is in line with statement that most interactions with mobile phones occur at working time/when a person is working [25].

Mobile work can be conceptualized in three types: travelling, visiting and wandering [8]. Travelling is essential for mobile work and it is important for transport study because it affects the performance of the transport network. Ref [26] call work related travelling as business trip, i.e. work related trip to a place that is not fixed, e.g., work to visit clients, participate in a conference or a meeting with business relations. Looking at the nature of their work, there are no strict boundaries whether inside or outside the office, because of where it could be their office, they penetrate the "regional" and "network." For mobile workers, work can be done not only in their formal office but at various locations such as home, a client's office, hotel, cafe, moving vehicles, and so on. Seeing the nature of their work, there is no rigid boundary between inside or outside the office, because of every place could be their office, they penetrate the "regional" and "network." In this sense, mobile work seems as working in the fluid mode.

### 2.3. Mobile Interaction based Coordination and Its Impact on Mobile Work

Coordination is a common everyday activity for mobile professionals. In practice, people often make an appointment, to arrange a visit, manage schedules and synchronize activities. The need to coordinate the activities is the basic social function, especially in contemporary society, which is characterized by distributed residential location, car-based transport, and complex activity patterns [27]. For mobile professionals, coordination means that the extension of the control [25]. He argued that interaction with mobile phones allow the coordination to do the movements, so that the meeting can be designed and people can be found. He calls a form of coordination that arise as a result of the use of mobile phones as a "coordination-based mobile interaction" and identifies three ways occurrence, namely (1) midcourse adjustment, which refers to the transfer of the journey has started and setting details of the meeting which had previously been agreed upon, (2) interactive coordination, which refers to the progressively setting of the meeting that is certain, (3) softening the schedule, which refers to the potential for increasing the flexibility of schedule compared to occurrence coordination based on fixed time [28].

It is undeniable that for mobile professionals working outside the office, smart phones useful in providing access to resources and result in improved efficiency and connectivity with the company. Smart phones are smaller in size than a laptop or notebook and easily grasped nature makes them ideal for mobile workers in mobile interaction. Allegedly providing mobile interactions change in the nature of the work itself, the time and place of work, as well as in the employment relationship. With the availability connectivity between the mobile workforce and its headquarters will mean greater efficiency for mobile workers, as well as they can be empowered and supported from a distance. Mobile professional still stay connected on holidays and they still work whereas they are travelling or relaxing.

Another aspect of the changes observed in the mobile work activities is the emergence of 'effects like jazz' to continue to align not only some of the activities, some of which are directly observable and some are not, but also to harmonize the activities planned improvisation activities. One view is that the basis of our research has been thorough mixing between planning and improvisation in everyday life, and especially in the middle of doing the movement [29]. Apparently terminology "mixture of planning and improvisation activities" is similar to "rescheduling of activities" [30].

Generally the activities rescheduled the agenda is at the core of many changes in travel behaviour. An agenda activity consists of a list of specific activities that would potentially be implemented, including a rare activity in spare time [31]. Activity schedule refers to a continuous pattern of activities and trips over time and space, including the observed choices of what activities to participate in, where, for how long, in what sequence, coupled with mode and route choices. The key components of this dynamic and continuous process include preplanning, impulsive and dynamic, and adaptive scheduling behaviours. Every activity on the agenda have unique attributes that affect scheduling, including the duration (min, max, average), the frequency, the time, the people involved, cost, location of people involved, the costs, the preferred location, and others. Process dynamic scheduling begins premises preplanning activities selected from the agenda, followed by re-planning and scheduling of continuous time, and ends with the pattern implementation of activities-travel schedule that can be observed. If it is true that mobile phones cause the mixing of planning the form of rescheduling, plus a shift towards coordinating with mobile interaction based coordination and potentially rescheduling, while rescheduling logically impact on aspects of space and time of movement through the space and sequence of events, it is alleged that mobile interaction based-coordination has the potential to have an impact on the travel behaviour through the concept of rescheduling. If mobile interaction based coordination using a mobile phone really has influence on one's behaviour in the conduct of activities and travelling, then issues related to how the attitude and the subjective role in it should be taken into account.

### 2.4. Hypothesis

Based on the literature review, it is developed the hypothesis that there are effects arising from the interaction using a mobile smart phone on travel pattern of mobile professionals through the change of activity pattern. Mobile interaction based coordination using smartphone increase the dynamic of activity scheduling. The dynamic of scheduling include adding/inserting, modification, and deleting activity on planned agenda. Decision to execute activity as a planned, or add, or modify and or delete is the respond of information received via smartphone. Types of information (content, from whom,

timing, service used) and situation (context of current activity performing and coming up activity, i.e. timing, urgency, flexibility activities) greatly affects the response given.

### 3. RESEARCH METHOD

The study consists of two stages, preliminary and main study. The current research is the initial part of the main study, thus this paper was not designed to provide a comprehensive study of mobile professional behaviour, but rather was intended to be interpretive. Thus we will not discuss statistics data here, but we will explore experience use-practices of mobile work from mobile professional.

Preliminary survey was conducted first to get the first insight about the phenomena. Considering that there is great diversity in the nature of work of mobile professional and their characteristic of technology use. Therefore, it is important to recruit the interviewees: 20 mobile professionals from Jakarta Great Area, Indonesia from a range of different professions, who were representative of those differences. Participant were also pre-screened to represent various level of mobility in term of frequency of mobile, the flexibility of time, flexibility of place of work. Occupation includes a variety professional from a range of consultant, project management, lawyer, veterinarian, obstetric-gynaecologic, marketing, sales, customer service, managing partner, real estate developer, government officer.

Semi-structured interviews conducted in this stage with the aim of obtaining information on the context surrounding the mobile professional activities, why they travel, with whom they visit, what will they do with them, what they do with their mobile phones while travelling, and at a third location, how they use their phones, especially for work purposes, what has changed in their mobile work, as the implications of the use of smart phones. Semi-structured interviews helped to inform us about the context surrounding the mobile professional activities. We wanted to understand the variety of ways they used their Smartphone, especially for work purposes, why they make a trip, who they would visit and what they would do with them, what they do with the smartphone during the trip and at the third location, how they plan and make an activity-travel schedule, and how they execute the agenda (include how they reschedule the agenda).

Surveys consist mostly of free response questions. In the free response surveys we found typical day of nature work, purpose of usage, characteristic of usage and what have been changed in their mobile work as implication of their smartphone usage. All of interviews are conducted in Indonesian, and the quotes have been translated to English. Interviews were transcribed and analyzed for the identification and sorting of themes and core concepts at several levels of specificity. (We translated the quotes used here from Indonesian into English). Data obtained from an initial interview indications are used as a basis to create the next step of the study.

The main survey, which is the next stage of this study, will be conducted using questionnaire with a larger number of mobile professionals, representing proportional pursued gender, profession proportion grouped by similar properties of mobile work (e.g. mobile based field work includes project consultants, city planners, contractors, distinguished group with mobile work which its location cannot be predicted, e.g. journalists, lawyers, sales, account representative, veterinarian). Clustering should be done in a more detailed classification. Participant were provided with a specific scenario to know the respond if they face the specific situation during the execution of activity-travel agenda. The study applies situational approach to understand the phenomena. Ideally we have to observed all of detailed information received from interaction using smartphone (e.g. forms, type of service, content, with whom, timing of interaction) and the attribute of activity at that moment (e.g. people involved, fixity, temporal attribute, spatial attribute, characteristic of joint the activity). Considering that every mobile professional have a unique agenda and have abroad spectrum, situational approach is chosen. The purpose of this approach is a simplification to compose the basic patterns of activity change due to the interaction using smartphones. In this approach, it is generated some scenario of situation on the storyboard that contain with “most probably information gained” from smartphone, that require immediate attention for re-scheduling decision (impulsion), as shown at figure 1.

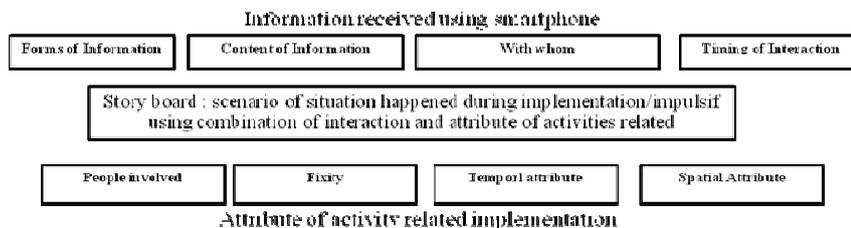


Figure. 1. Storyboard with scenario

The behavioural response to such a situation is recorded (whether addition/inserting, modification, deletion) and the basic pattern of activity execution is then analyzed. Agenda of mobile professional is assumed consist of two mandatory activity, one optional activity and one repertoire activity, with time window. During implementation, some situations might be happened, dealing with smartphone usage (access to real time information via interaction using smartphone) and it is assumed that a mobile professional make a decision whether reschedule his/her agenda or not, and what respond he/he will choose. Storyboards are prepared based on the experience of mobile professionals as told in the initial survey, i.e. results of the preliminary interviews. As the consequence of the chose, it will be noticed the pattern of activity executed and it is compared with the pre-planned activity pattern of agenda. This is accomplished also to the trip that attached to them. With the addition, subtraction or modification of activities conducted, it is logically viewed the impact on the travel pattern, whether it will potentially increase the number of trip, reducing the amount of trip, or change the destination and timing of the trip. Thus, the better understanding of phenomena of smartphone usage effect, by compare with and without using smartphone could be gained.

#### 4. RESULT OF PRELIMINARY SURVEY AND DISCUSSION

##### 4.1. Profile of Respondents

The survey was conducted on 20 respondents from professional mobile-smart phone users in the Greater Jakarta Area, with a variety of professions. Profession selected based on pre-screening that respondents actually is the target of research, i.e. more than 20% of the working time is out of the office (e.g. consultants, city planners, contractors, journalists, lawyers, sales, account representative, veterinarian, CEO). Profile of the respondents is given in Table 1.

Table 1. Profile of Respondents

Item	Profile Respondent
Number of hours working outside the office	> 20% of working hours
Age range	35-55 years
Type of smartphones user	Early adopter of smart phone users and use it all the time
Income range	3 million IDR - >25 million IDR
Gender	Male and Female
Education	Bachelor (minimum)
Managerial Position	Middle – CEO
Expenditure for smartphone operation	300,000 IDR – 3.5 million / month
Type of working time	8-4; 9-5; flexible (24 hrs)
Transport Mode	Public transport, motor cycle, private car
Travel distance range	30 – 100 km, (not include the flight)

Generally, the activities which carried out by the mobile professionals in the office are internal management functions (such as planning and organizing) and administrative work. The typical daily activities outside the office are very diverse. For example, for the CEO and GM, activities outside the office consists mainly of planning meetings, attending meetings and making decisions at the meeting. Mobile professionals from professional lawyer, insurance agent, sales agent, and account representative engaged extensively to meet with their clients, both existing and which are prospective/potential clients. Similar to them, veterinarians and obstetricians work mobile mainly to visit and treat patients, and they are often faced with an emergency situation. Consultants and Contractors, not only need mobile work to visit their client's office to present their plans and explain the progress of their work, but also need to meet with colleagues involved in the project at different locations such as members of the project from construction companies, architects, government offices, administrative, and others. From the interview, CEO, GM, Sales Agent, and journalist are highly mobile.

The utility of their smart phones is high averagely, characterized by high monthly expenses (ranged from IDR 300 thousand to IDR 3.5 million) and a higher frequency of daily use, such as the size of the calls made, emails sent/received/read, messages sent and received, with five of the most commonly used features are the instant messaging, voice calls (dialler), short message (SMS), electronic mail (e-mail) and browser.

Because of its multi-function, all respondents said that they always turn on their smartphones throughout the day and anywhere. Some reasons why they always turn on their phones throughout the day are: (1) to avoid the frustration of the people who contacted him (HD, urban planner), (2) to avoid accusations of 'irresponsible', and to provide security to something urgent and need immediate response (EMD, IT Programmer). During the trip, all of the respondents admitted that this was the most important moment they can always be connected. "Feeling more secure" and "feel comfortable" are other reasons they need to use smartphone during activity out of office. It is because when they were in the office, an alternative device of communication is still possible (e.g. landlines phone, computer).

#### 4.2. Mobile Interaction using Smartphone during Mobile

During planning a business meeting, the smart phone is used to make an appointment and determine whether or not the meeting is done, if the interaction is not too complicated, then communication with a smart phone can replace face-to-face, according to the role of a smart phone as a function of equivalent. The most frequently mentioned word, often repeated by all respondents was the word "coordination" as the intended use of smart phones, both internal and external coordination. Before a business trip, smart phones serve as verification of pre-trip. During a trip for business, mobile phones are used for traffic conditions investigate travel and to monitor the work and often also useful for gathering rearrangement, in the third and during the visit, most respondents use smart phones to coordinate, collect information about work and monitor the work of subordinates in the office during the time of waiting and also use it for personal gain, in order to balance personal life and work.

#### 4.3. Implications of Mobile Interaction using Smartphone on Work Related Movement

Some respondents felt the direct impact in the form of a reduction in the number of trips, such as NKL (GM mining company, 40). Equality interaction functions cause the occurrence of substitution. Some respondents claimed a relationship between cell phone use and the way it works is an indirect relationship, such as (EMD, IT Programmers, 40). For PJR (journalist, 44), the use of cell phones impact changes on the way to work and this then affects to the number of trips he can subtract to achieve the target word. EDP (CEO, 40) is quite different with him, who saw a more dominant complementary interaction with said, "The total trip seems to increase. Because the more information, the opportunity is also more and more. If the opportunity was taken, it appears the addition of new activities, and the edges are increasing the number of my daily trip."

According to the DHD (account representative, 39), "Smartphones really a coordination support, usually if there is an immediately change, then I use a smartphone to match the client's agenda and my activities. Activities and trips can be adjusted". It is shows that the smart phone is a coordination tool that helps in modifying travel in the event of a change of activities and design adjustments in the form of rescheduling. This is consistent with the concept that will be revealed through this research that the phenomenon of mobile interaction based coordination from Ling (2002).

One case for example is Experience of ARD (Lawyer, 55) i.e. "For the plan of the house in the morning I first went to the office, arriving at the office at 8:30, I monitor all the activities of my men, and it was much interrupted by communication with clients, my office 1.5 hours from home, as I monitor the entire work of my taskforce, where he was, who to an extent, then I check whether there is a need administrative approval, again I see my smartphone, whether there are another appointments. I have made schedule for tomorrow. Take a lunch at 12. I have a lunch date with Bank (A) directors at Pacific Place, after I finished my lunch there external meetings around Kelapa Gading, related to business clients in Cargo. I also have appointments with existing clients and he wants me to meet him in his house. I have already known where I will do my activities tomorrow, I already consider travel time". During implementation of his agenda, he use smartphone and make a conversation while mobile with another client. "On the way there was an impromptu incident, "Sir, the man was arrested today". He is a new client. We cannot say "tomorrow", it is not allowed to delay, we cannot delay it. It has to be done at the same day".

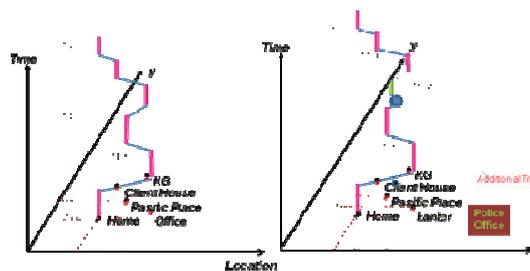


Figure 2. Case for example: adjustment of agenda as implication of mobile interaction and its impact to the total number of trip and travel distance

Based on the experience of the respondents can be described spatial-temporal graph agenda the day's activities and the implementation of the agenda, after the mobile interaction using a smartphone, as presented in Figure 2. It shows that, the number of trip is increasing as well as travel distance, because he inserted an unplanned activity to his agenda during execution, at once he receive the information via smartphone. In this case, indirect effect of smartphone effect to trip is complementary.

Another case is shown from RTP (Lecturer, Consultant, 49), “Yesterday afternoon I was not able to lunch out, because there were so many guests. I had to delay 13-hr meeting appointment to 14.30. They agree. I can leave the office at 14.20, and can conduct meetings with business partners from other company. We're so easy to adjust for any changes. I cannot imagine if I do not use smartphone”. In this case, she did not delete or insert an activity, but modified the attribute of activity, i.e. duration of prior activity and changed the start time of the next activity. Implication of those change, she had to modify timing of trip execution to the second activity. In this situation, smartphone indirectly modify her travel pattern.

Based on the results of the initial survey, although done on a very limited number of samples and a variety of professions, can still reflect a step forward in examining the relationship between the smart phone and the movement, which is an indication that there are more indirect influence, through the process of change in the pattern activities first. Taking into account the results of the interviews it was a real experience mobile professionals, developed situations that may occur and potentially to coordinate-based mobile interaction and how the responses will be analysed. This would then invoke a scheduling respond and subsequent changes in activity and travel pattern. Research paradigm is shown in figure 3.

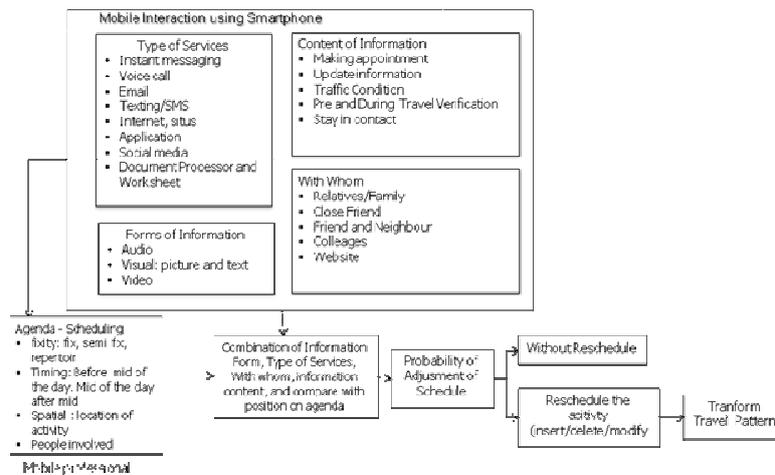


Figure 3. Research Paradigm

Probability of adjustment of schedule (rescheduling) due to mobile interaction based coordination is shown by the respond of combination type of services used, content of Information, Information form, and with whom, to evaluate whether they need to adjust or not by consider position of activity on agenda (fixity, people involved, temporal attribute, and spatial attribute). It need to be examined using main survey (the next stage of research), how the mechanism and when adjustment tend to be done (in what extent of information, which combination of information and activity), how significant the changing to number of trip, travel distance and travel time, and how the change in accessibility that will lead to make addition, modification or deletion of activity, and in turn will affect the increasing, reducing trip number or modification on destination and timing of trip execution.

The next step is to configure the basic pattern changes that occur in the activities as well as on the travel pattern. Illustrations can be made using space-time graph, or by using the comparison between the pattern of pre-planned activities with execution. Using data from a variety of responses to various scenarios situation developed, it is expected to be compiled basic typology of the phenomenon of changes in activity-travel pattern, as the impact when a mobile professional intensively uses smartphone.

## 5. CONCLUSION

This paper is a part of on-going research and will continue to evolve to the next research steps. First insight gained from the preliminary survey shows that: there is a change in the nature of professional work as an implication of the use of mobile smart phones. Smart phones fulfil to meet their needs for support information in order to reduce the uncertainty associated with the contextual constraints faced while being mobile. Smartphone influence when planning activities, before the trip, during the trip and upon arrival at the third location. Mobile Interaction based coordination using smart phone changes in the way of coordination, and potentially led to rescheduling agenda of mobile professional and in turn changes the trip pattern (e.g. travel distance, number of trip). Agenda of mobile professional is more dynamic and flexible. Some professionals feel the direct impact on the reduction or increase in the movement, and on the other have a look at the impact of indirect impact, through their impact on work activities in advance, especially through mobile interaction in nature is coordination.

For the next step, which is to stage collecting of main data to uncover patterns of communication and work practices of mobile professionals to answer questions include: how the patterns of usage of smart phones on a variety of different mobile professional group? How interaction patterns formed by mobile professionals to use a smart phone? How mobile professionals can work positively influenced and how these mechanisms affect their decision to adjust the schedule and changing their attribute business trip? These questions can be answered through an analysis by completion of the next step of this study.

## REFERENCES

- [1] ITU Telecom World, *The World in 2011. ICT Fact and Figure*, ICT Data and Statistics Division Telecommunication Development Bureau International Telecommunication Union. Switzerland, 2011
- [2] Google/IPSOS OTX Media CT, *The Mobile Movement, Understanding Smartphone Users*, U.S., 2011
- [3] A. Charlesworth, "The ascent of Smart Phone", in *Engineering and Technology*, 2009
- [4] Nielsen, *Smartphone Ownership on the Rise in Asia Pacific, Whilst Advertisers Struggle To Engage With Consumers via Mobile Ads.*, 2012
- [5] RIM, *Blackberry Target Market. Overview*. Research in Motion Limited. U.S., 2003
- [6] W. Ablondi, T. Elliot, *Mobile Professional Market Segmentation Study*. BIS, 1992
- [7] D. Frohlich, "Requirements for interpersonal information management", in P.J. Thomas (Ed.) *Personal information systems: Business applications*. Stanley Thornes in association with Unicom Seminars, 1995
- [8] S. Kristoffersen and F. Ljungberg, "Making Place to Make IT Work: Empirical Explorations of HCI for Mobile CSCW" in *GROUP'99: Proceedings of the international ACM SIGGROUP conference on supporting group work*, November 14-17, Phoenix, AZ, New York: ACM Press, 1999
- [9] M. Perry, K. O'Hara, A. Sellen, R. Harper, B.A.T. Brown, "Dealing with Mobility: Understanding Access Anytime, Anywhere", *ACM Transactions on Human-Computer Interaction*, 8 (4), 2001.
- [10] P. L. Mokhtarian and I. Salomon, "Emerging travel patterns: Do telecommunications make a difference?" In *In perpetual motion: Travel behavior research opportunities and application challenges*, edited by H. S. Mahmassani. Oxford, UK: Pergamon Press/Elsevier, 2002.
- [11] J. Niles, *Beyond telecommuting: A new paradigm for the effect of telecommunications on travel*. Report DOE/ER-0626, September. Washington, DC: National Technical Information Service (NTIS), 1994 [www.lbl.gov/ICSD/Niles](http://www.lbl.gov/ICSD/Niles)
- [12] I. Salomon, "Telecommunications and travel relationships: A review" in *Transportation Research A20A(3)*: 223–238
- [13] P. Mokhtarian, "If Telecommunication is such a good substitute for travel, why does congestion continue to get worse?" in *Transportation Letter, Vol.1, No. 1*, pp. 1-17, 2009
- [14] Nugraha, F., *Jumlah Pelanggan Seluler di Indonesia hampir Mendekati Jumlah Penduduk Indonesia*, posted in *Teknojurnal* 18 January 2012, <http://www.teknojurnal.com/>
- [15] H. J. Miller, "What about people in geographic information science?" in *Re-Presenting Geographical Information Systems*. P. Fisher in D. Unwin.(editors), John Wiley, 2005
- [16] L. Palen, M. Salzman, E. Youngs, "Going Wireless: Behavior & Practice of New Mobile Phone Users" in *CSCW'00*. Philadelphia, 2000
- [17] L. Fortunati, "Italy: stereotypes, true and false". in Katz, J. and E. Aakhus eds., *Perpetual contact: mobile communication, private talk, public performance*. Cambridge: Cambridge University Press, 2002
- [18] J. E. Katz and M. A. Aarhus, "Making meaning of mobiles: A theory of apparatus". In J.E. Katz & M. Aarhus (Eds.), *Perpetual contact: Mobile communication, Private talk, Public Performance*, Cambridge, UK: Cambridge University Press, 2002
- [19] R. Ling, *The mobile connection (The cell phone's impact on society)*, Morgan Kaufman publishers (Elsevier), 2004
- [20] H. Geser, "Towards a sociological theory of the mobile phone" in *Sociology in Switzerland: Sociology of the Mobile Phone*. 2002, Online Publications [http://socio.ch/mobile/t\\_geser1.htm](http://socio.ch/mobile/t_geser1.htm)
- [21] M.P. Kwan, "Mobile Communications, Social Networks, and Urban Travel: Hypertext as a New Metaphor for Conceptualizing Spatial Interaction", in *The Professional Geographer*. 59:4, 434-446 Routledge. 2007 <http://www.tandfonline.com/loi/rtpg20>.
- [22] M. Kakihara, C. Sorensen, M. Wiberg, "Fluid interaction in mobile work practices" in *Proceeding of 1st Tokyo Mobile Roundtable, Mobile Innovation Research Program, Insitute of Innovation Research Hitotsubashi*, Tokyo (Japan), 2002.
- [23] A. Al-Taitoon, C. Sørensen, D. Gibson, *Modern professionals and their tools (ICT supporting organisational Flexibility and Control)*. London, London School of Economics and Political Science, 2002
- [24] N. Jones, *The Communicating, Connected, Real-Time Mobile Worker of 2015*, Portals, Content & Collaboration Summit. September 16, 2010.
- [25] R. Ling and L. Haddon, L., "Mobile Telephony, Mobility and the Coordination of Everyday Life", paper at the *Machines that become us - Conference*, Rutgers University., 2001
- [26] A. Aquilera, "Business travel and mobile workers" in *Transportation Research*. Part A, General 42, 8 , pp. 1109-1116, 2008
- [27] A. Townsend, "Life in the Real Time City: Mobile Telephones and the Urban Metabolism", *Journal of Urban Technology* 7 (2), 85–104, 2002
- [28] R. Ling, B. Yttri "Hyper-coordination via mobile phones in Norway." in *Perpetual contact: Mobile communication, private talk, public performance*, edited by Katz, J. E. and Aarhus, M. Cambridge: Cambridge University Press. 2002.
- [29] J. Sherry and T. Salvador, "Running and Grimacing: The Struggle for Balance in Mobile Work". in B. Brown, N. Green and R. Harper, *Wireless World - Social and Interactional Aspects of the Mobile World*. London, Springer-Verlag: 108 – 120, 2002
- [30] K. Axhausen and T. Gärling, "Activity-based approaches to travel analysis: conceptual frameworks, models, and research problems", *Transp. Rev.*, 12, 324–341, 1992.
- [31] S.T. Doherty., F.A. Clark F. A., "Examining the Nature and Extent of the Activity-Travel Preplanning Decision Process" in *Transportation Research Record: Journal of the Transportation Research Board, No. 2054*, Transportation Research Board of the National Academies, Washington, D.C., 2008, pp. 83–92.

## The Development of Monorail Design Based on Local Industrial Component as an Alternative Implementation Concept of MRT for the Growth of Indonesian Sustainable Transportation System

Danardono A.S<sup>a</sup>, Sugiharto<sup>a</sup>, GatotPrayogo<sup>a</sup>, Kusnan Nuryadi<sup>b</sup>, TeguhN<sup>b</sup>

<sup>a</sup>Mechanical Engineering Department, Faculty of Engineering  
 University of Indonesia, Kampus Baru UI Depok 16424, Jawa Barat, Indonesia  
 Telephone (021) 7270032, 7864233, Faximile (021) 7270033  
 E-mail : [danardon@eng.ui.ac.id](mailto:danardon@eng.ui.ac.id), [sugih.sugiharto@unpas.ac.id](mailto:sugih.sugiharto@unpas.ac.id)

<sup>b</sup> PT. Melu Bangun Wiweka  
 Jl. SimpangTigaSetu No. 39 TambunBekasi 17510, Jawa Barat, Indonesia  
 Telephone (021) 8830177-79 Faximile(021) 8830180  
 E-mail : [kusnan.n@mbwpt.com](mailto:kusnan.n@mbwpt.com), [teguh.nk@mbwpt.com](mailto:teguh.nk@mbwpt.com)

### ABSTRACT

*This paper discusses the selection of transportation modes which plays important role in the growth of economics, politics, social, culture, and defense and security. Urban mobility which has been more varied than the sustainable transport system, will be required to support their activities. MRT (Mass Rapid Transit) is the mass transportation system mode which is based on road or rail (subway/elevated) ranging locally. This mode is generally operated on dedicated lines or potential common pathway, which is used separately and exclusively on schedule and routes that have been designed for the destination of a particular station. MRT can be operated in a variety of traffic conditions, in particular; the MRT is designed to be able to move the large numbers of the people on the same time.*

*Monorail is one of the MRT modes based single rail; the rail/track function is a guide-way of trains, that is usually, installed at elevated more positions from the road surface. That only takes a small area in vertical and horizontal space. The track/rail width is merely as wide as the cabin supported by the several columns along with its track. The body of a train is made more "lightweight" than the conventional train, the elevated rail position that only covered up a small area of the road surface. The noise can be reduced, because the bogie uses rubber tire that runs over a concrete/steel track as its trajectories. The monorail has the uphill and downhill, and small turning radius capability with movement faster than the conventional trains. The designs of a monorail have a high safety level; the bogies have holding design of the rail, so that the risk of the tumble, is much smaller. The noise can be reduced, because the bogie use rubber tire that runs over a concrete/steel track as its trajectories. Risks of bumping against the crossing of rail are very impossible because the rail is positioned on the elevated position instead the road surface. From the funding and investing, selection of this mode will be more interesting and affordable, the construction and maintenance is much easier than the other types of train modes.*

*Constructions of monorail facilities are as an alternative of MRT in Indonesia, to be balanced with the development of another infrastructure, including the human resources development and strengthening of the local industry as its supporters. Involvement of the local industry in the provision of facilities of the monorail considering the costs, quality, capacity, efficiency, and technologies is expected to reduce the cost required and increases the independence of the technology in transportation technology. Since 2006, BPPT in cooperation with PT. INKA (PT. Industri Kereta Api) in Madiun, has begun the activity of design and manufacturing a monorail prototype. This activity is part of the process in strengthening the local industries for support of the design and manufacturing of the national monorail. PT. Pindad in Bandung has the ability in designing and manufacturing an electric motor drive for the train. For a long time, these products have been used by PT. KAI (PT. Kereta Api Indonesia Persero). Moreover, the active participation from the national private company such as PT. MBW in Bekasi, needs to get the support of government, because, they have developed a monorail design of the prototype phase which is ready to be tested (gamma prototype) for multiple projects planning in Indonesia.*

**Keywords:** Monorail, Sustainable Transportation Modes, Mass Rapid Transit

### 1. INTRODUCTION

In some major cities, public transport has become a primary requirement for its inhabitants, so are in Indonesia. Public transportations in Indonesia are very diverse, from such unofficial modes like Ojek, Becak, and Andong to licensed public transport, such as taxi, bus, busway, and train. All of them aimed to serve the needs of the mass public transport which should operate with safe, convenient and inexpensive. The typology of public transportation in Indonesia is grouped based on the mass transit and individual shuttles [1].

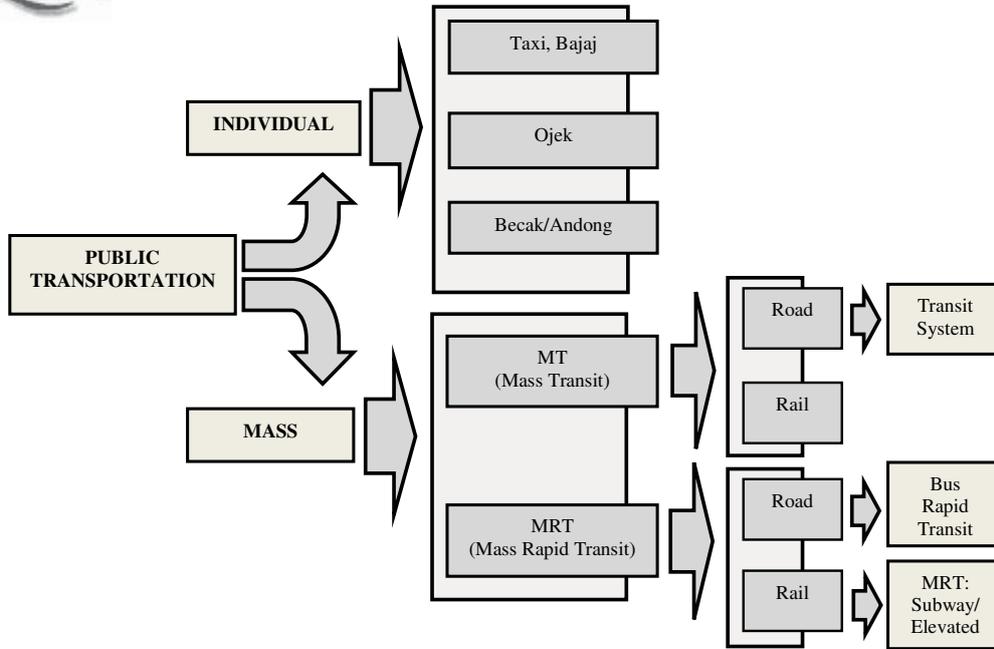


Figure 1: The typology urban public transportation in Indonesia [1]

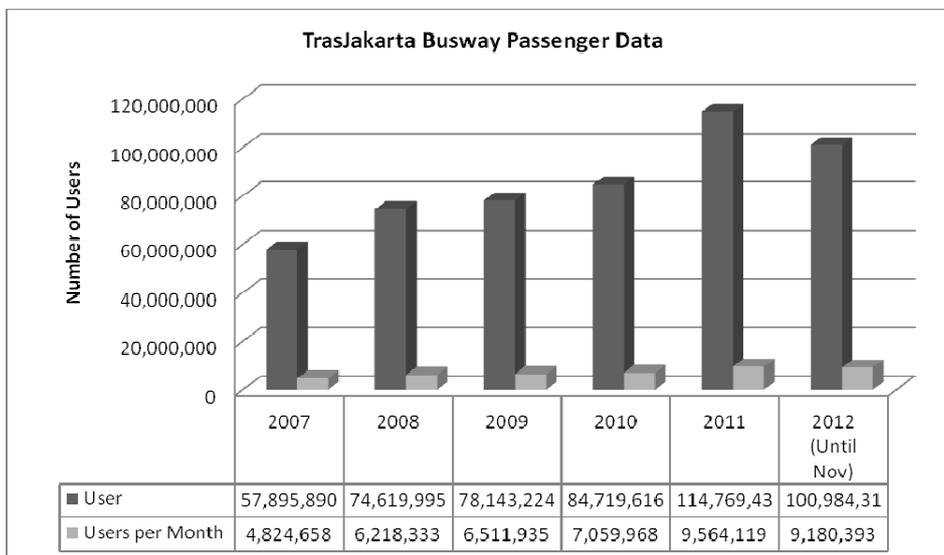
Currently, public transportation in Indonesia has not been able to address the demands of the public in terms of security, comfort, and timeliness to come and arrive on destination. As a result, the people prefer to use individual transportation modes, which have the impact in more increased traffic volume on the road. The survey result of “*The Study on Integrated Transportation Master Plan (SITRAMP)*” in 2004, shows that the economic losses due to congestion in Jabotabek traffic are Rp. 3,0 trillion for operating costs of vehicles; Rp. 2,5 trillion for a loss of time; Rp. 2,8 trillion for the loss of health impact. The same information from the Transportation Agency of Jakarta says that the losses due to congestion if assessed in monetary terms are equal to 12.8 trillion per annum [2].

The need for a safe, convenient, and inexpensive mass public transportation in several major cities in Indonesia is very reasonable, if seen from statistical data, the user of the means of that transportation in Jabodetabek area within last five years kept increasing both the based of roads and rail. Graph growth of the mass-transit users shown in figure 2 and 3.

To answer the problems above, the Jakarta regional government has made the breakthrough by offering to the private to build the mass-transit system in the capital within the package of developments the *Macro Transportation Programs (PTM)* in Jakarta. The pattern will integrate four public transportation system in Jakarta in the form bus priority includes *Bus-way*, *Light Rail Transit (LRT)*, *MRT* and the transportation of lake river and the crossing (in Indonesian: *ASDP/Angkutan Sungai Danau dan Penyeberangan*).

Monorail is one type a mass-transit system offered to the private in 2004. The project is divided into two paths, green line, circular route - *Casablanca - Kuningan - Semanggi* and blue line, the pathways connecting *Kampung Melayu - Casablanca - Tanah Abang - Roxy*. The implementation of this project has been offered into three stages, the first stage, Jakarta corridor with the length of  $\pm 27$  km, for the construction of the Green Line ( $\pm 14$  km) and the path of the blue line ( $\pm 13$  km), the second phase, Jakarta - Bekasi - Cikarang ( $\pm 18-30$  km), and the third phase Jakarta - Tangerang - Karawaci ( $\pm 16-25$  km). However, the project was eventually ended on 20 September 2011.

Figure

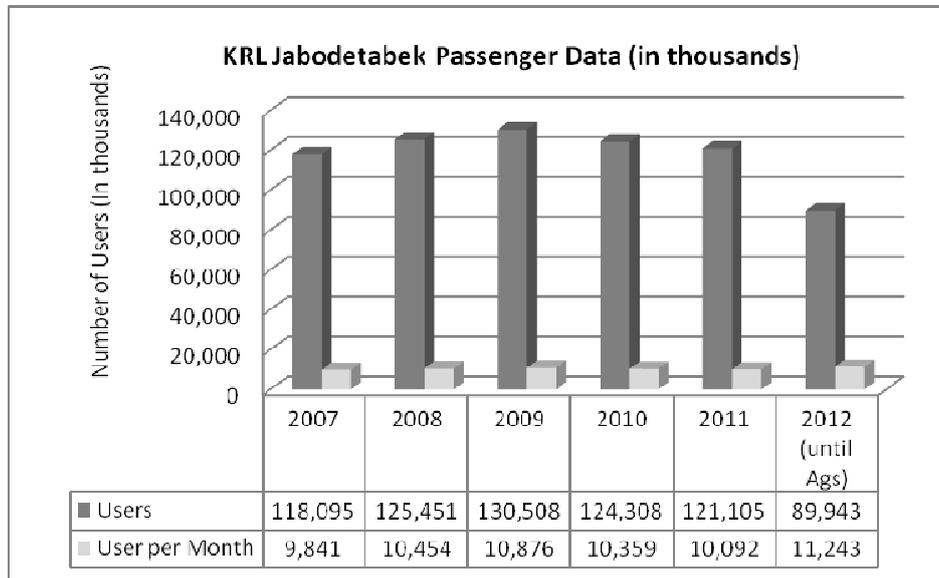


2: User

DataTransJakartaBusway(source: <http://www.transjakarta.co.id>)

Figure

3: User



DataKRLJabodetabek(Source: PT. KAICommuterJabodetabek)

The breakthrough conducted by Jakarta Government at that time was considered against the law Number 13 of 1992 regarding the railway as the bylaw does not enable the private sector as a train operator. The law of that was eventually repaired and replaced by Law Number 23,2007 which provides opportunities to the private entrance as the operator of a train [3].

The construction plan of monorail in Indonesia continues to run, on July 25, 2011, conducted by the signing of a memoranda of understanding among the Government of Makassar, Maros regency and Gowa regency with Kalla Group, to construct a mass transportation systems in Makassar. The construction implementation began in early 2012 and the completion is targeted to be finished no later than 2015. The monorail with more than 30 kilometers length of track will connect between the Hassanudin airport, Karebosi and Gowa.

Another issue was proposed by Kalla Group on August 5, 2011 in Bandung. They plan to build a monorail facility in Bandung with a +30km length path way, the rail will be operated inside and outside the city of Bandung, among the city of Bandung regency of Bandung and City of Cimahi.

Besides Kallagroup, The Mayorality of Surabaya has planned to construct a monorail facility with the +22 kilometers length, connecting the station Sidotopo, Gubeng, Wonokromo, Waru, Sedati and veered toward Juanda. The project is planned to be realized in 2015, in collaboration with the Societe Nationale des Chemins de Fer France (SNCF).

The plan of monorail construction for the mass transportation in Jakarta, was re-launched by the Governor of Jakarta at the beginning of 2013. The construction of the monorail facility will be continuing with the master plans that have been defined in the previous monorail project. This is to keep with the previous master plan for the development of the national railway network and train services the urban Jakarta year 2020 [3].

## 2. MONORAIL AS AN ALTERNATIVE MRT

The public transportation, classified by Joewono and Kubota (2005) [4] is shown in Table 1. The monorail itself is classified into rapid transit. The first application of a monorail for the mass rapid was proposed by Edward H. Anson (1954) [5], and Hermann (1957) [6], who made the feasibility study of monorail implementation as a mass rapid transport for community.

Table 1. Public Transportation Classification by Mode [4]

Public Transportation Class	Type of Mode
Paratransit Street Transit	Ojek, Bajaj, Becak, Angkutan Kota, Taxi Metromini, Reguler Bus, Rapid Bus, Trolleybus, Streetcar, Trem

Semirapid Transit	Light Rail Transit, Semirapid buses
Rapid Transit	Light Rail Rapid Transit, Rubber-tired Monorail, Rubber-tired rapid Transit, Rail Rapid Transit

MRT is a mode of transportation with the most efficient energy consumption in terms of the number of passengers which can be transported. When compared with other modes of land transportation, MRT energy consumption is only about 16% and 10% from the bus and private cars (Table 2).

Table 2: Comparison of energy consumption per km passenger [3]

Transportation Mode	Volume of Transport (persons)	Energy Consumption per km (litre)	Energy Usage (per km passenger)	Rates per Passenger Fuel Price Assumptions Rp 4500/litre (Rp)
MRT	1500	3	0,002	9,00
Bus	40	0,5	0,0125	56,25
Private Car	5	0,1	0,02	90,00

As a MRT, monorail has the following advantages as:

- generally constructed above the road, so it only needs small area to install the supported beam.
- more "lightweight," if compared to the conventional railway, with the elevated rail position, so that only the cover a small surface,
- reducing in total noise, because monorail uses rubber tire to run on the track concrete/steel (pathway),
- running on uphill, downhill, and turning with a radius smaller and faster than the conventional railway,
- more secure, because the train set that holds the rail is not a lot. Risks of bumping against the crossing of railway are very rarely,
- more reliable in construction investment and maintenance operation cost.

Meanwhile the disadvantages are:

- compared with the subway, monorail look take a greater space and hide the panoramic of the city because the monorail is usually built above the ground,
- the passengers could not be evacuated immediately in case of emergency, because they are only excluded at the station,
- the total capacity is still questionable due to the manufacturer design specification which is usually customized with the demand requirement.

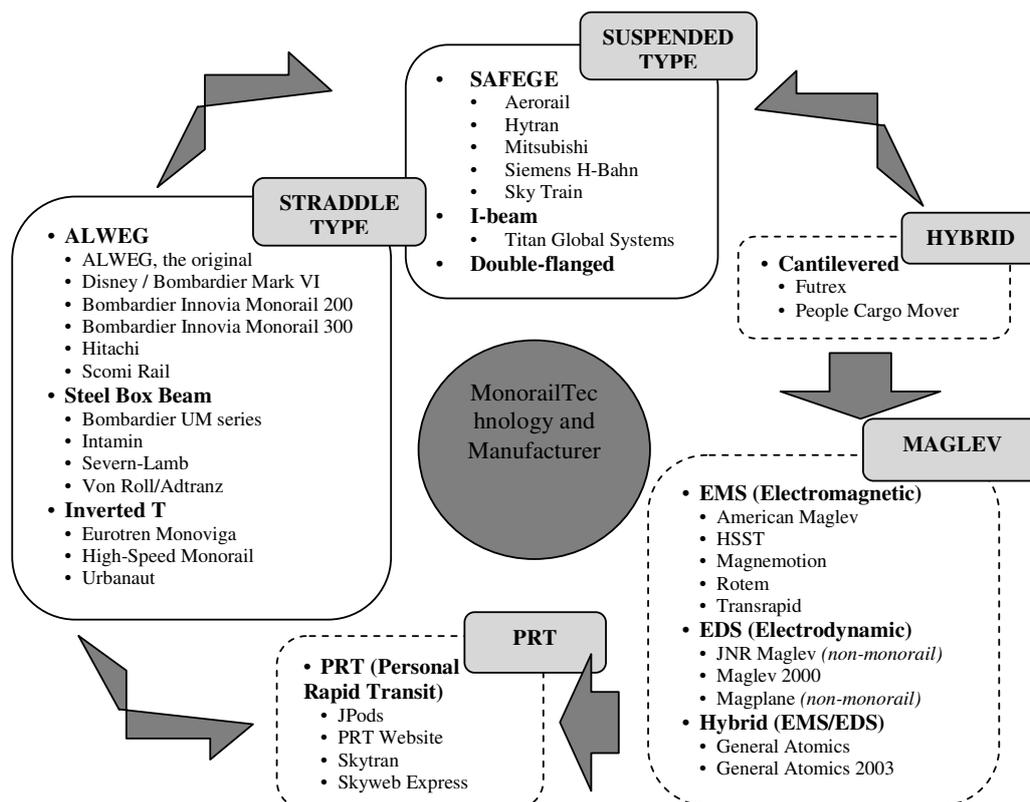


Figure 4: The blockclassificationof the monorailtechnology(source: <http://www.monorail.org>)

### 3. MONORAIL TECHNOLOGY

The monorail is a single rail-based transportation which serves as a pathway. This term is used to describe the system or vehicle that travels over a beam or pathway track. This term is derived from the combination of words mono and rails. The term has been used since 1897, and was often called monorail. The vehicles run on single track first patented by *Henry Robinson Palmer* in the UK with the number 4618 on 22 November 1821[6].

The monorail society defines as follow: "A single rail serving as a track for passenger or freight vehicles. Usually, rail is elevated, but monorails can also run at grade, below grade or in subway tunnels." This definition is somewhat confusing because it does not cover the whole development of the monorail technology. Monorail if classified according to the technology and its manufacturer can be seen in the schematic in Figure 4.

The straddle type of monorail is the most widely applied type because this type has more advantages than others. *Ishikawa* (1999) [7], has made a prediction with various considerations and reasons, that monorail system would lead the mass-transit system in the future. It is based on the possibility of this monorail type to be applied in various types of sizes, adjusted with their needs. This statement was confirmed by his partner, *Kubawara* (2001) [8], who proposed the straddle monorail type with small type for medium distance and for urban transport's solution, with the reasons and advantages in terms of environmental improvements. This concept has been reinforced by *Siu* (2007) [9]. He has proposed analysis of the light weight transit system innovations for the urban mobility in the perspective of the development and planning of sustainable transportation systems.

### 4. MONORAIL DESIGN AND MANUFACTUR, DOMESTIC TECHNOLOGY

The of Existence the plan to build a monorail as a facility system for mass transportation in several major cities in Indonesia must be balanced by the development of its infrastructure, including human resources development and strengthening of the local industry as its supports. Some of the important variables in the process of improving the ability local industries are:

- Cost of manufacturer.
- Quality of product.
- Capacity and productivity.
- Efficiency.
- Technology and skill.

With the involvement of local industries in the provision facility a monorail system which integrate the five variables above in the construction of the monorail system facilities, it is expected that the cost required can be reduced as low as possible, both in the construction and operation phase, especially in a procurement the spare parts supporters at the operation phase.



Figure5: The prototypemonorail bogie developed atBPPTandPT. INKA.



Figure6: The prototypemonorail bogie developed atPT. MBW.

The process of the reinforcement of local industries in upgrading design competency of the monorail system, has been running since 2006. BPPT in cooperation with PT. INKA in Madiun, has been pioneering in design activities of the monorail. The other national private company, PT. MBW has developed a monorail system design. Currently the prototype is ready for testing (unscaled prototyping test). This design will be used in Makassar, which will connect between the *Hasanuddin Airport, Karebosi, and Gowa*.

The design capabilities of local industries of Indonesia in the monorail system design, is the initial capital in the construction of a monorail system which is planned. This is a phase in supports the development of national sustainable transport systems. It is already shown by *PT. Pindad*, with its ability in design and manufacturing an electric motor. It has been currently a supplier of PT.KAI in the procurement of it's driving the electric train (in Indonesian; *KRL/Kereta Rel Listrik*).

The design of a monorail system which is done by the local industry should be accepted and usable by the public, without violating the design criterion, which will become the basis in proving of productfeasibility for a regulator to issue permits road worthy. Currently, these are fundamental problems faced by the local industry in defining that theirproduct design should be proven safe. To answer these problems faced by the local industries, it needs to do an academic study which strengthen its design safely and feasible to use. The results of those studies will be the basis for a regulator to provide the road worthy license for that product.

## 5. CONCLUSION

Construction of the monorail facility is expected to be able to answer problems of urban transport which has an important part of the driving force to the national economy.

Construction of the monorail facility which integrates with other modes of transport will improve efficiency of the national economy.

The Law Number 23 of 2007 on Railways has encouraged the participation of local governments in the implementation of railway transportation in the area. For that, the local government should be able to use this momentum to build transport facilities in the areas many as possible to accelerate the pace of economic growth in the region.

In the framework of encouraging participation of the local government in the administration of the mass transportation, a few things that need to be prepared are as follows:

- The involvement of the local government, in the planning process with the spatial structure plan and the availability of land.
- The involvement of the local government, in the investments, constructions, and operations, both of intercity and urban services.
- Strengthening the local industry as its supporter, in the form of technological support, regulations, which can strengthen its involvement.

## ACKNOWLEDGEMENTS

This research was fully supported financially by research grants from DRPM-UI (*Directorate of Research and Community Services, Universitas Indonesia*) and *PT. MeluBangunWiweka*. The authors also express sincere thanks to Mr. Didi for their kind assistance with the manuscript of this paper.

## REFERENCES

- [1] Ministry of Transportation Republic of Indonesia, "*Indonesia Urban Mobility-Grand Design*", Directorate of Urban Transportation System in cooperation with GIZ- Sustainable Urban Transport Improvement Project, Edition Draft VII, March 2011, D1-page 13 – 14. (in Indonesian).
- [2] Zulkifli Aboebakar, "*The challenges and Opportunities monorail As Macro Transportation Development Program (PTM) Jakarta*", *LexJurnalica* Vol. 5 No. 1 Desember 2007. (In Indonesian).
- [3] Ministry of Transportation Republic of Indonesia, "*National Railways Master Plan*", Directorate General of railway, April 2011. (In Indonesian).
- [4] Joewono, "*The Characteristics of Paratransit and Non-Motorized Transport in Bandung, Indonesia*" *Journal of the Eastern Asia Society for Transportation Studies*, Vol. 6, pp. 262 - 277, 2005.
- [5] Edward H. Anson, "*Monorail System for Mass Rapid Transit*", Gibb & Hill, Inc. Consulting Engineer, New-York, April 1954.

- [6] Hermann, "*The Feasibility of Monorail*", Master Theses Civil Engineering Department at Massachusetts Institute of Technology, September 1959.
- [7] Kosuke Ishikawa, "*Straddle-type Monorail as a Leading Urban Transport System for the 21st Century*", Hitachi Review Vol. 48, No. 3, 1999.
- [8] Takeo Kuwabara, "*New Solution for Urban Traffic: Small-type Monorail System*", Hitachi Review Vol. 50, No. 4, 2001.
- [9] Siu. L.K, "*Innovative Lightweight Transit Technologies for Sustainable Transportation*", Journal of Transportation System Engineering and Information Technology, 2007, 7(2), 63-71.

# TRAFFIC IMPACT OF HOUSING DEVELOPMENT TELUK – PURWOKERTO

Juanita<sup>1</sup>, Sulfah Anjarwati<sup>2</sup>

<sup>1</sup>Faculty of Engineering, University Muhammadiyah of Purwokerto, Purwokerto 53182  
Email: [nita\\_032003@yahoo.com](mailto:nita_032003@yahoo.com)

<sup>2</sup>Faculty of Engineering, University Muhammadiyah of Purwokerto, Purwokerto 53182  
Email: [mailesulfah@yahoo.com](mailto:mailesulfah@yahoo.com)

## ABSTRACT

*In RTRW Banyumas, Purwokerto develop as a strategic area for economic growth and urban development southerly direction to reduce pressure woke cultivation in the north Purwokerto. Teluk housing in South Purwokerto built in 1985 with changes of land use is residential to business units by 10.17%. Trip generation are light vehicle 149 vehicle, 1250 motorcycles and 87 slow vehicles and people 1710 occur at 6-7 Am. Classification of regional development are large-scale and the traffic impact analysis considered class III. Trip distributions from Perumnas Street to Sultan Agung Street are 69% and Suwatiao Street 31%. The purpose of travel is work by 10-20 km travel distance and the average travel time of 10-20 minutes. Mode used is 63% motorcycles, cars 27%, 8% public transport and "becak" 4%. Traffic assignment in 1984, housing road around have VCR very low. In 2012 VCR increased but Suwatiao Street up to 0.67. After housing in 2012 VCR are be increased but Suwatiao Street decreased. Teluk intersection VCR 0.74 with an average delay 55.17 second per smp with length of queue 57 meters at the Perumnas Street so as to reduce the impact of traffic need management and traffic engineering.*

**Key words:** *Traffic impact, Development, Housing*

## 1. INTRODUCTION

Easiness of investor in investment and the needs of livable homes are encouraging investors to invest in housing development. The change of land use is field into housing that will be increase the demand of trip in the fulfillment of their needs, such as work, school or campus, and into the shopping center to meet their needs. Varies trip generation housing will be affect the traffic assignment around the road especially with the fluctuation in peak hour that varies every day. This movement, if left to the rate of accumulation will be cause changes in the road performance. Besides that the high level of vehicle ownership and support facilities poor performance can be traffic jump. Based on research are use vehicle on the road in Purwokerto of motorcycles reaches 87.75%, light vehicles 11.99%, and medium weight vehicle of 0.25%. (Juanita, 2011).

Inconsistency in the development of land use on urban spatial system of the plan is not followed by changes in the transport network plan will result in the network is not able to accommodate the movement by the system activity, causing problems such as congestion, delays and queues of vehicles that safety and fluency traffic is reduced. Therefore, the development of land must be accompanied by an increase in good transport facilities so that land use changes are beneficial and efficient as optimal as possible. Under these conditions, the traffic impact analysis is required to save the conflicts of land use changes and transportation interests.

## 2. BASIC THEORY

### 2.1. Traffic Impact Analysis

Government Regulation No 32 in 2011 stated that traffic impact analysis is a series of studies on the traffic impact from the development center, residential, and infrastructure that aims to determine traffic impact that will be cause of security, safety, discipline and traffic fluency and road transport.

Department of Public Works stated that the development of criteria that must traffic impact analysis as follows: a) Development of the planned direct access to arterial road. b) If the planned development of the area does not have access to the arterial road, then apply the following criteria: 1) the scale of activities and / or planned effort is greater or equal than the minimum size of development set. 2) The development of area is expected to trip generation greater than or equal to 100

persons per hour trips. 3) There are some areas development plan that access to the road same, so the cumulative criteria in point a, b. 4) The development of area direct access to the road which has degree of saturation greater than or equal 0.75 and / or if the junction nearest to location of development area has degree of saturation greater than or equal 0.75. While of the expected trip generation caused of development area to classified four that are; 1) the development area of small scale, expected will result trip generation less than 500 trip persons per hour. 2) The development area of medium scale, expected will result trip generation between 500 to 1000 trip persons per hour. 3) The development area of big scale, expected will result trip generation greater than 1000 trip persons per hour. 4) The development area of medium or big scale, that done step by step with the implementation in a few years.

## 2.2. Transportation Planning

Transportation planning consist of four step are trip generation, trip distribution, modal choice and traffic assignment. Trip generation is step of expected some of generate and attraction to land use of zone. Trip generation is dependent of two aspects that is type of land use, amount of activity and intensity of land use. The higher of level of land use then will more higher traffic resulted. Trip distribution is the function of land use and transportation. The pattern of trip distribution between origin and destination of zone is from two aspect that occured simultaneously between location or intensity of land use that result of traffic and spatial separation. The interaction of two land use can be result movement persons and / or goods. Modal choice exist because of the interaction two land use then occur of traffic. For meet this conditions, there will be a step to determine whether modes using. The first of modal choice is walk or using car. If using car must be choice private or public transportation. Traffic assignment for people who use private transportation will be concern travel time and other factors such as security, safety and cost. But people use public transportation will be choose the shortest route and the consideration of cost, safety and security.

## 3. METHODOLOGY

The methodology of research is done assesment of literature to gain approaches and regulations concerning traffic impact analysis. The collection of data divided two data are secondary and primary data. Secondary data are map of land use study area, residential data is covering a land area and the number of housing units, The General Plan of City, road and traffic data and population. Primary data are through a direct survey that is road geometric data, traffic volume data of roads and intersections, trip geberation and attraction data. Than make an analysis trip generation, trip distribution, modal choice, traffic assignment and conduct traffic impact analysis before and after of housing.

## 4. RESULTS AND DISCUSSION

### 4.1. Characteristics of Study Area

Banyumas district is located direct border with four districts that are East with Purbalingga, Banjarnegara, and Kebumen District, West with Cilacap and Brebes Districts, North with Tegal and Pemalang Districts. The area study of research is Teluk Housing that located in South Purwokerto since 1985 which is intended for residential area of development area V. Regulation of Banyumas District in No 18 in 2005 about Spatial Plan of Banyumas is a guideline in utilization of space that stated Purwokerto into a strategic area of growth economical and Sub Regional Development I. In Spatial Central Java Province, Purwokerto will be plan to urban areas serving as provincial scale of activity or some cities / districts in southern and west part of Central Java. The reviewing of rapid population growth, then development policy of Purwokerto is southerly direction which aims to reduce the pressure in the wake cultivations in North Purwokerto which is a water catchment and conservation buffer of Slamet Mount. Besides that development of south is aim to distribution of urban development evenly.

### 4.2. Trip Generation Teluk Housing

Total of trip generation and trip attraction based on survey in 9-10 May 2012, the result of survey is Table1. From Table 1, the condition peak hour is 6 – 7 AM with total vehicle 1399 per hour and 1710 persons per hour. The resulting trip rate in peak hour is 6.995 vehicle per hour each 100 square meters total area.

### 4.3. Determination of Class Traffic Impact and Area Study

Total trip generation of 1710 persons per hour are classified the development area of big scale and traffic impact analysis class III. Then limitation of area study is minimal intersection between the collector to collector roads either signal or not, while the road is a road accessed by the development area within a radius of 2 km from the outer development site. Conclusion of intersection and road study is Teluk intersection that is a node of Sultan Agung Street, Suwatio Street and Perumnas Street, while roads surveyed are Sultan Agung Street and Suwatio Street are primary collector road functions; Lesanpura Street and Perumnas Street are primary local road functions.

Table 1 Total of trip generation Teluk Housing

Time	Heavy Vehicle	Light Vehicle	Motor Cycle	Total (vehicle/hour)	Vehicle Slow	Person
6-7 am	0	149	1250	1399	87	1710
7-8 am	4	158	1187	1349	117	1699
8-9 am	7	116	923	1046	80	1293
11-12 pm	21	95	598	714	25	861
12-1 pm	4	112	678	794	69	1027
1-2 pm	11	84	732	827	51	993
4-5 pm	6	128	905	1039	75	1300
5-6 pm	0	93	815	908	43	1091
6-7 pm	0	62	659	721	24	838

Source: Survey, 9 – 10 May 2012

#### 4.4. Trip Distribution

Trip distribution from Perumnas Street to Sultan Agung Street total is 69 % and to Suwatio Street is 31 %. The purpose routines are to work 55 %, business 25 %, to school or campus 12 % and to market 9 %. Travel distance to routine less than 10 km reaches 55%, between 11 km-20 km by 25%, between 21-30 km by 13% and more than 30 km by 9%. Travel time average is 10-20 minutes by 65%, between 20-30 minutes by 20% and between 30-40 minutes by 15%.

#### 4.5. Modal Choice

Modal choice based on survey using motorcycle 63 %, cars 27 %, public transport 8 % and rickshaw 4 %. The ownership of motorcycles one vehicle 46%, two vehicles 44%, more than three vehicles 2 % and do not have a motorcycle 3 %. While car ownership is 34 % one car, two cars by 14 %, more than two cars 2 % and 50% did not have a car.

#### 4.6. Traffic Impact Analysis

##### 4.6.1. Traffic condition before and after housing

Traffic condition before and after housing are based on primary and secondary survey presented in Table 2 which shows the VCR after the development is less than the critical VCR (Volume Capacity Ratio).

Table 2 Road VCR before and after housing

Access Road	Before Housing		After Housing 2012		VCR Critical
	1984	2012	Nothing trip generation	With trip generation	
Lesanpura	0.198	0.323	0.405	0.49	< 0.75
Sultan Agung	0.126	0.207	0.431	0.531	<0.75
Suwatio	0.409	0.667	0.395	0.443	<0.75
Perumnas	0.246	0.400	0.441	0.643	<0.75

Source: data analysis 2012

Teluk intersection have three phases, phase 1 and 2 are green time 14 second with inter green 2 second, while phase 3 is green time 11 second and inter green 8 second. Intersection performance in 2012 is shown in Table 3.

Table 3 Intersection performance in 2012

Access Road	Volume (pcu/hour)	Capacity (pcu/hour)	Degree of Saturation	Intersection Delay (second/pcu)	The Average Intersection Delay (second/pcu)
Suwatio (N)	206.1	277.61	0.74	53.26	55.17
Perumnas (S)	241.7	325.56	0.74	53.33	
Sultan Agung (E)	403.7	543.77	0.74	55.11	
Sultan Agung (W)	630.4	849.13	0.74	56.53	

Source: data analysis 2012

##### 4.6.2. Evaluation Traffic Impact Analysis

From Table 2, the traffic condition after the housing is still below the critical VCR. The category level of service B is Lesanpura Street, Sultan Agung Street and Suwatio Street, while Perumnas Street in category C. For Teluk intersection by VCR 0.74 is nearing the critical VCR 0.75 with the average intersection delay approaches one minute so need resetting time of traffic light to be a long queue from Perumnas Street and Sultan Agung Street. The resetting times are all phases in green time 14 second, with inter green 3 second but in the phase 3 by 5 second. So that performance intersection is shown Table 4.

Table 4 Intersection performance resetting

Access Road	Volume (pcu/hour)	Capacity (pcu/hour)	Degree of Saturation	Intersection Delay (second/pcu)	The Average Intersection Delay (second/pcu)
Suwatio (N)	206.1	317.65	0.65	20.79	21.89
Perumnas (S)	241.7	372.52	0.65	20.64	
Sultan Agung (E)	403.7	622.19	0.65	21.86	
Sultan Agung (W)	630.4	971.59	0.65	22.76	

Source: analysis 2012

## 5. CONCLUSIONS

Based on the analysis it can be concluded as follows:

1. Teluk Housing in view of urban spatial of land was appropriate functions.
2. Teluk Housing entry into the development area of large scale and traffic impact analysis class III.
3. The resulting of trip rate generation is 6.995 vehicles every 100 meter square at peak hour.
4. The impact of housing development will be increase on traffic assignment on the surrounding road network but still below the critical VCR. While the Teluk intersection required of resetting time of traffic light.

## 6. REFERENCES

- [1] Indonesian Government Regulation No.32 of 2011, "Management and Engineering, Impact Analysis, Requirements Management and Traffic".
- [2] District Government Banyumas Regulation No 18 of 2005, "Planning of Spatial Area District Banyumas", 2005.
- [3] District Government Purwokerto, "General Plans of Urban Spatial", 2002.
- [4] Department of Transportation Banyumas, "Performance of the Road Network in Banyumas", 2003.
- [5] Juanita, Iskahar, "Analysis Characteristics of Motorcycle Traffic Mixed in Purwokerto", Research, LPPM, UMP, May 2011.
- [6] Juanita, "Study of Traffic Impact SPBU Development", Proceeding of the National Seminar on Environment, Chemical Engineering UMP, Purwokerto, 2009.
- [7] Juanita, "Study of the Commercial Area to Transportation Problems", Proceedings of the International Seminar Results, LPPM UMP, Purwokerto, 2009.
- [8] Tamin O.Z., "Planning and Transport Modeling of Example and Application", 1<sup>st</sup> Edition, ITB, Bandung, 2003.
- [9] Tamin O.Z., Nahdalina, "Traffic Impact Analysis", Urban and Regional Planning Journal ITB, Vol. 9, no 3, pp. 22-40, September 1998.
- [10] Tamin O.Z., Russ Bona Frazila, "Interaction Concept Implementation of Land Use-Transportation Systems in Transport Network Planning System", Urban and Regional Planning Journal ITB, Vol.8, no 3, pp 34-52, July 1997.
- [11] Planning of Spatial Purwokerto in the Interactive Program of RRI Purwokerto, [www.penataruangbanyumas.com/2011/11/perencanaan-tata-ruang-perkotaan.html](http://www.penataruangbanyumas.com/2011/11/perencanaan-tata-ruang-perkotaan.html)

# The Mock Application of Greenroad Rating System for Design and Construction at Cemoro Sewu Road

Setyawan A<sup>a</sup>, Hidayat H<sup>b</sup>, Sarwono J<sup>c</sup>

<sup>f</sup>Faculty of Engineering, University of Sebelas Maret, Solo 57126  
E-mail : [cenase@yahoo.com](mailto:cenase@yahoo.com)

<sup>b</sup>Faculty of Engineering, University of Sebelas Maret, Solo 57126  
E-mail : [haaa\\_riiis@yahoo.com](mailto:haaa_riiis@yahoo.com)

<sup>c</sup>Faculty of Engineering, University of Sebelas Maret, Solo 57126  
E-mail : [sarwono60@yahoo.co.id](mailto:sarwono60@yahoo.co.id)

## ABSTRACT

*The development of environmental friendly road need to be considered at recent years, given the material used for the construction of a road largely derived from natural resources that can not be renewable. Sustainable practices can be used as the basis of assessment of environmental friendly road design and construction. Therefore, there should be a research that discussed the aspects of sustainability as an example case is Cemoro Sewu Road Construction Project. The research was carried out by conducting field studies at the location of case study, dissemination of technical questionnaire, the data collection and documents relating to the Cemoro Sewu Road Project. Data related to the road project, divided into a number of assessment criteria based on the categories that exist in Greenroads Rating System. The end result of this assessment in the form of mock certification from the Cemoro Sewu Road Project that can serve as input to the local government to plan a sustainable development. Based on the analysis of the assessment of each criterion, total earned credit for Cemoro Sewu Road Project by 36 points from 8 of the 11 criteria in the categories of Project Requirements that meets the criteria. This suggests that the non-fulfillment of all the requirements of existing projects on Project Requirements category, indicated that Cemoro Sewu Road Project can not be certified according to the provisions of Greenroads Rating. If all project requirements are met, then the Cemoro Sewu Road Project can obtain certification level that is "Certified".*

## Keywords

*Greenroads Rating System, Sustainability, Mock Certification*

## 1. INTRODUCTION

Sustainable development of the system becomes an important topic in the field of engineering and construction, road work being substantial part for further follow-up. Sustainable practices can be used as the basis of assessment of the environmentally friendly design and construction. Greenroads Rating System provides parameters that can be used to consider the sustainability of the design and construction of a road project. Greenroads first introduced in 2007 as an original concept in the form of credit linked to the six preliminary case study. Since then, the scoring system has undergone significant revisions in the opinion of professional stakeholders with empirical evidence on the field. Basically, this assessment system can be used to help people and agencies in making decisions on planning better sustainable way. Government as regulator that plays a role in the development and the construction industry must think of ways to reduce the consumption of materials used in construction projects. Cemoro Sewu. Road as the road connecting the region of Karanganyar and Magetan in Java Island, Indonesia selected on this research in order to give a little overview assessment of road projects in Indonesia by mock application of Greenroads Rating System v.1.5.

## 2. LITERATURE REVIEW

Clark [1], explaining that the design and construction of the road is a complex process that requires experienced professionals to work in it. Environmental assessment process is an important part of decision making in the construction of a road. Decisions will be made to describe the project as a whole with an effective way to determine the expectations and needs of decision-makers based on the limits of space and time. In addition, the feasibility of environmental impacts can also be made based on the most reasonable choice or based on the total cost of the necessary and meaningful and comprehensive benefits. According to Caldwell [2], road construction and maintenance activities get a tremendous demand on a national scope, especially financial resources. But in fact, the practice of design and construction of the current path is not always systematic or holistic manner to address the environmental impact or the quality of the environment occurs. The concept of environmental impacts or effects caused by road construction on the surrounding conditions are often ignored. It can be caused by three

common problems, namely: (i) Decision makers do not understand the complexities of ecosystems and how human-made highway context of sustainable roads. (ii) Decisions are often taken sometimes transcend conventional wisdom or existing traditional assumptions. (iii). Decision makers fail to understand that humans have limited control in the management of ecosystem resources [3]. Muench, et al. [4,5], defines Greenroads Rating System as an assessment system based road project award points system for approval as an option of sustainable practices and can be used to certify projects based on the total value of criteria that are certified.

### 3. RESEARCH METHOD

The method used in this research is to conduct a field study in the form of directly to the location of research survey, dissemination of technical questionnaire and the data collection and documents relating to the Cemoro Sewu Road Project. Distribution of questionnaires carried out to the two parties related to the Directorate General of Highways Central Java as Owner and PT. Pancadarma Puspawira as the General Contractor. All data related to the road project, divided into a number of assessment criteria based on the categories that exist in Greenroads Rating System. Based on the technical and data processing surveys and questionnaires, then the ranking will be obtained for mock certification from the Cemoro Sewu. If the results of research on the mock assessment of Greenroads Rating System at the Cemoro Sewu deemed applicable, the assessment results can be used as input to the government and the contractor to plan more sustainable road construction project.

### 4. ANALYSIS

#### 4.1 Criteria categorized by Greenroads

##### 4.1.1 Project Requirements

Based on the calculation and analysis on each of the criteria in this category, obtained 8 of 11 criteria that meet the requirements. 3 criteria that do not meet the requirements are:(i) Noise Mitigation Plan, (ii) Waste Management Plan, (iii) Educational Outreach. As an example, the calculation of energy requirements and CO<sub>2</sub> emissions in road construction projects of Cemoro Sewu using Software "Palate v.2-2" as listed in Table 1.

Table 1. Energy requirement and CO<sub>2</sub> emission of Cemoro Sewu Road

Palate V.2-2		Energy required [GJ]	CO <sub>2</sub> Emission [kg] = GWP
<b>Initial Construction</b>	Materials Production	267.096,5	18.297.543
	Materials Transportation	337.635,2	23.292.953
	Equipment	12.890,0	889.263
<b>Maintenance</b>	Materials Production	26,7	1.931
	Materials Transportation	7,0	482
	Equipment	0,3	18
<b>Total</b>	Materials Production	267.123,3	18.299.474
	Materials Transportation	337.642,2	23.293.435
	Equipment	12.890,3	889.280
<b>Total</b>		617.655,7	42.482.190

Figure 1 shown the need for energy consumption during construction activities, that is very high as calculated of 617,621.70 GJ compare to at the maintenance period which is only 34 GJ.

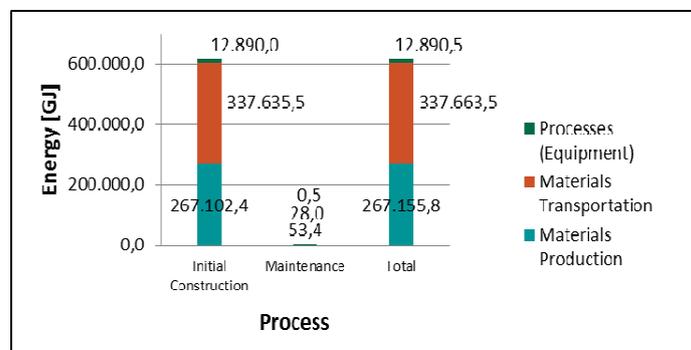


Figure 1. life Cycle Energy Consumption

Figure 2 indicated that the CO<sub>2</sub> emissions during the construction period is very high, that is 42,479,759.00 kg when compared to the maintenance period which is only 2,431.00 Kg.

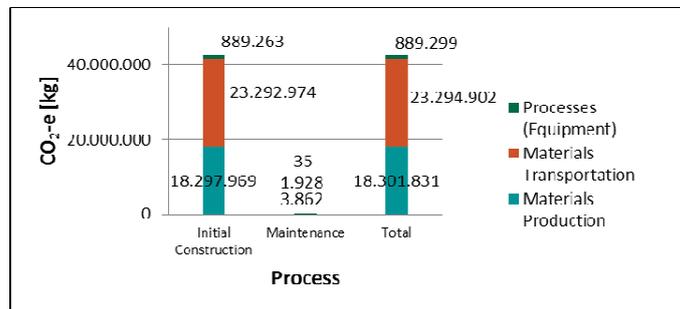


Figure 2. Life Cycle CO<sub>2</sub>-e Emissions

#### 4.1.2 Environment and Water

Based on calculations, Vegetation Site is only the criteria that can be processed for the assessment of the 8 criteria available on this category. A total of 3 points earned by Cemoro Sewu Road Project for this category. Cemoro Sewu Road Project has met the requirements for applying the criteria of site vegetation with 3 elements of the following requirements: (i) Using non-invasive plants as the site vegetation. (ii) Does not require additional irrigation water supply after the construction is completed. (iii) Using native plant species that previously existed in the project.

#### 4.1.3 Access and Equity

Fulfillment 5 of 9 criteria presented in this category, making Cemoro Sewu Road project gets big enough additional points which is 16 points. As an example the calculation of Pedestrian Access. The supporting infrastructure needs such as roads (sidewalks) and pedestrian bridges rated very important existence. It allows residents to enter and exit the area. Cemoro Sewu road project gives access to the pedestrian bridge located on Dawuhan Bridge I and II as well as in places such as at the Km. 1 +600, 1 +700, 2 +100, 2 +250, 2 +900, 3 +000, 3 +260, 3 +300 and some other places. The amount of the credit for this criterion is 2 points.



Figure 3. Site vegetation

#### 4.1.4 Construction Activities

There are three criteria from 8 criteria of construction activities category such as Quality Management System, Paving Emissions Reduction, and Warranty Contractor that meet the requirements. A total of 6 points to additional value for Cemoro Sewu Road Project of this category.. As an example the requirement of Quality Management System. PT. Pancadarma Puspawira as the General Contractor which is the respondent of this research has been certified for the Quality Management

System in accordance to the International Standards Organization (ISO) 9001:2008 with the following Standard: BS-EN-ISO 9001:2009 Certificate Number: AJA04/7859 Validity: August 3, 2011 to August 9, 2014. Based on the presence of ISO documentation, then the amount of credit for this category is 3 points.



Figure 4. Pedestrian Access

#### 4.1.5 Materials and Resources

Based on the calculation, only the category of Regional Material that can be processed for assessment. Total points earned is 5 for Cemoro Sewu Road Project for this category. Example for calculation of points from this criterion is for using regional materials. The crush stone material taken from the district of Sentolo at Yogyakarta province. The distance between project and material quarry sources is  $\pm 130$  km or about 81 miles from the project site, thus meeting the qualification requirements of 5 points.

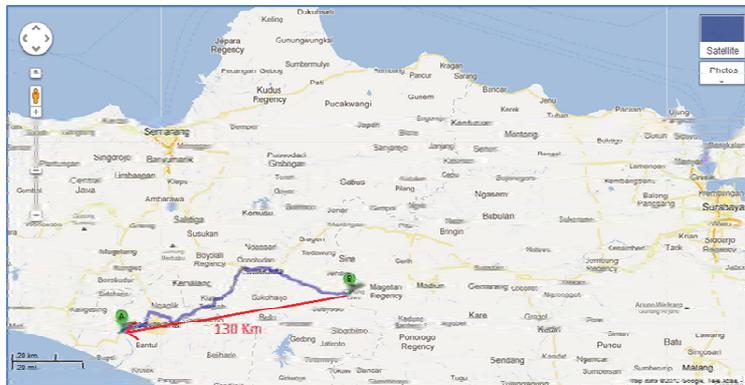


Figure 5. The location of materials quarry

#### 4.1.6 Pavement Technology

Based on the analysis and calculations, only the criteria of Long-Life Pavement and Pavement Performance Tracking are eligible. A total of 6 points to additional value for Cemoro Sewu Road Project of this category. The example of points determination for pavement Performance Tracking is the documentation manage by Directorate General of Highways as a service user Sewu Cemoro Road construction that has held the documentation about the performance of the road.. The documentation consist of documentation of the construction period, the maintenance period until the documentation of repairs of the road. One example of this form of documentation as indicated on the document Provisional Hand Over (PHO) No: 55/BA/BKGG/XII/2009.

Table 2. Total point of Greenroad Certification

No.	Criteria	Point
-----	----------	-------

EW-Site	Site Vegetation	3
AE-1	Safety Audit	2
AE-3	Context Sensitive Solutions	5
AE-4	Traffic Emissions Reduction	5
AE-5	Pedestrian Access	2
AE-8	Scenic Views	2
CA-1	Quality Management System	2
CA-6	Paving Emissions Reduction	1
CA-8	Contractor Warranty	3
MR-5	Regional Materials	5
PT-1	Long-Long life pavement Life Pavement	5
PT-6	Pavement Performance Tracking	1
Total		36

## 4.2 Certification

Based on the analysis they are only 8 of 11 criteria that meet the requirements. So it is concluded that Cemoro Sewu Road Project has not met the requirements to be certified. To obtain the real certification from Greenroads, Cemoro Sewu road projects should review and consider to met all the criteria based on the results of the assessment on each criterion. Table 2 shows the point of each criterion that met the requirements. However, if all the criteria met and based on the total points gain by Cemoro Sewu road project with a points total of 36 points, it could be categorized as "Certified".

## 5. CONCLUSION

1. Cemoro Sewu Road Project does not meet the requirements to be certified according to Greenroads rating system because there are only 8 of the 11 criteria that met the project requirements.
2. This project has fulfilled some criteria as follow:
  - a) Environment and Water: 3 Points
  - b) Access and Equity: 16 Points
  - c) Construction Activities: 6 Points
  - d) Materials and Resources: 5 Points
  - e) Pavement Technology: 6 Points

The total points earned by Cemoro Sewu Road project is 36 points. If all criteria in the category Project Requirement have been met, then the Road Cemoro Sewu entitled to certification standard as certified.

## REFERENCES

- [1] Clark, R. 1994. *Cumulative effects assessment: a tool for sustainable development. Impact Assessment*. 12(3):319-331.
- [2] Caldwell, L. K. (1999). *The National Environmental Policy Act: an agenda for the future*. Bloomington: Indiana Univ. Press. 209pp
- [3] Weinstein, N. 2010. *ODOT considers greenroads program*. (<http://djcoregon.com/news/2010/01/21/sustainable-roads-program-coming-to-oregon-ssby/>)
- [4] Muench, S.T., Anderson, J.L., Hatfield, J.P., Koester, J.R., & Söderlund, M.. 2011. *Greenroads Manual v1.5*.(J.L. Anderson, C.D. Weiland, and S.T. Muench, Eds.). Seattle, WA: University of Washington.
- [5] Muench S. T, Jeralee Anderson, Martina Söderlund. 2009. *Greenroads: Development of a Sustainability Rating System for Roadways*. Seattle: University of Washington.

## The Performance of Dynamic Stability and Roughness of Hot mixed Asphaltic Concrete with Superpave Aggregate Gradation

Eva Azhra Latifa<sup>a</sup>, Dify Rizky K<sup>b</sup>, Rhesty P Arishanty<sup>c</sup>

*a* Civil Engineering Department  
Jakarta State Polytechnic, Depok 16425  
Tel/ Fax (021) 7863532,

E mail : [evaall@yahoo.com](mailto:evaall@yahoo.com)

*b* Civil Engineering Department  
Jakarta State Polytechnic, Depok 16425  
Tel/ Fax (021) 7863532,

E mail : [difyrizkyk@gmail.com](mailto:difyrizkyk@gmail.com)

*c* Civil Engineering Department  
Jakarta State Polytechnic, Depok 16425  
Tel/ Fax (021) 7863532,

E mail : [rhesty.arishanty@gmail.com](mailto:rhesty.arishanty@gmail.com)

### ABSTRACT

*The material commonly used for flexible pavement surface layer is asphaltic concrete with various compositions and procedures. This research aim is to know Hot Mix Asphaltic Concrete behavior on surface pavement with compares the performance of both kinds of aggregate gradation, Superpave and Bina Marga fine gradation mixtures. Performance evaluation conducted on the characteristics of Marshall, dynamic stability using wheel tracking devices and roughness of mixture using British Pendulum Tester. Conclusions after analyzing data obtained that fine gradations of Bina Marga needs more asphalt to covered a whole surface because it has more fine grain. Flow smaller and stability is greater than the Superpave with a majority of coarse aggregate. However, this difference was not significant. Resistance to permanent deformation of asphalt concrete mixture with Superpave gradation is much larger, but the roughness is smaller, which means the Superpave surface rougher than Bina Marga. With the advantages of each mixture, it is recommended to choose the mixture that really fit with the field characteristics of the traffic and climate.*

**Keywords:** *Bina Marga, Marshall characteristic, permanent deformation, roughness, Superpave.*

### 1. INTRODUCTION

The commonly used method for flexible thick pavement design in Indonesia is based on design methods empirically developed by the AASHTO. The material commonly used for flexible pavement surface layer is asphaltic concrete with various compositions and procedures. In the case of asphalt concrete, road construction projects in Indonesia usually utilize specific asphalt concrete layer (*laston*) for AC-WC (Asphalt Concrete – Wearing Course) surface layer in accordance with the General Specifications of Bina Marga, Sixth Division, Asphalt Pavement, 2010.

On the other hand, the United States (through State Highway Research Program, SHRP) has developed specifications intended to fix the performance of pavement serving heavy traffic load, known as the **Superior Performing Asphalt Pavement** (Superpave). As it is focused on the enhancing of resistance, both the amount of fine aggregate and the use of asphalt decrease; consequently, it is more economical whereas in Indonesia, the Bina Marga provides two kinds of mixture for surface layer (Wearing Course) with both fine and coarse gradation. In comparison with the Superpave gradation, the amount of fine grain is higher, hence, the mixture is more dense and flexible; however it needs more asphalt.

Superpave is created in accordance with the performance of asphaltic mixture and the condition of the environment in order to improve the mixture's resistance to rutting, fatigue, thermal crack at low temperature, humidity, and material fatigue. The SHRP Program research on asphaltic Superpave carries three goals: investigating the reason why some kinds of pavements have good performance while some others don't; developing tests and specifications for superior material that is more durable than the current pavements there are; giving new alternative specifications (TRB Superpave Committee, 2005). Determining the resistance of superpave mixture comes from series of compaction that gives a more vibrating effect (gyratory) compared to compaction, so that it is closer to the conditions on the field as a representation of the vibration of vehicle wheels.

The design of the mixture is based on the Marshall Method, invented by Bruce Marshall in 1939 and standardized by both the ASTM and the AASHTO through various modifications; the ASTM D 6927-06 or the AASHTO T-245-90. The basic principle on the Marshall Method mixture design consists of choosing the optimal asphalt intensity that is in accordance with stability and flow testing with analyzing the density and pores of solid mixture that is form (Sukirman, 2003). The Marshall Test intends to measure the stability of asphaltic and aggregate mixture to plastic flow. The stability of the mixture is measured by the sample's resistance to a certain amount of compaction as a representation of traffic load planned to go through the pavement. Nowadays the Marshall Test is the most commonly used test in Indonesia. This is due to the simplicity of the equipment and the practicality of mobilization.

Finding the resistance of the mixture to permanent deformation is tested using Wheel Tracking Machine in laboratorium. This test is intended to measure the ability of asphalt concrete withstanding traffic load repetitions. Deformation values obtained from the depth of the specimen surface is formed due to load repetitions

This research aim is to know Hot Mix Asphaltic Concrete (HMA) behavior on surface pavement with compares the performance of both kinds of aggregate gradation, Superpave and Bina Marga fine gradation mixtures, which are made by the Marshall Method. Traditional compaction through the Marshall Method is more widely known compared to gyratory compaction; therefore, the availability of the equipment is more possible. After going through initial testing by the Marshall Test, it is then continued by measuring the values of deformation speed and dynamic stability using wheel tracking device and the roughness of the mixture using the British Pendulum Tester.

The research was carried out to the effort of designing an efficient, flexible pavement resistant to the effects of loading and climatic influences. The almost –always- jammed traffic conditions in Jakarta, coupled with the extreme heat as well as days-long floods submerging roads, and the overloading that always occurs on the main road, cause roads to be more easily deteriorated despite still being in its service life. It prompted the start of this research in an effort to contribute to the development of applied science and solutions to infrastructure problems.

## 2. METHODOLOGY

Research on the performance of two kinds of asphalt concrete aggregate gradation is done by using Marshall method as preliminary data. The values of deformation speed and stability are obtained with the wheel tracking as a destructive test and roughness value by British Pendulum Tester. In different ways, both initial tests simulate the resistance of mixtures to repeated loading. All of tests are performed in the laboratory. It is begins from Marshall test to obtain mechanical properties of two kinds of hot mix asphalt, which uses stone dust 7% with optimum asphalt percentage 5,90% for Bina Marga, and for Superpave 5,65%.

Samples are made according to the best mixture of asphalt optimum percentage with Marshall's method before. Wheel tracking test is done with 30 cm x 30 cm x 5 cm samples, which are passed repeatedly by the examiner wheel made of hard rubber that has a 20 cm diameter by wide wheel tread 5 cm ± 0.1 cm and loaded 20 N ± 5 N.

Measuring the value of roghness in the laboratory is done using the British Pendulum Tester (BPT) based on ISO 4427 (2008). With a simulated vehicle speed of 60 km/h, the skidding value is obtained from the result of friction between the rubber of the pendulum with the surface of the mixture. BPT will indicate the British Pendulum Number (BPN) that converted using the formula  $MuN = 1,017BPN - 20,9$  based on ISO 6748: 2008. The roughness values obtained by the unit μm.

## 3. DISCUSSION

### 3.1 The physical properties of aggregate

Table 1 and 2 shows the results of testing the physical properties of coarse and fine aggregate. Aggregate characteristics are in accordance with the requirements. Test results with specific gravity greater than 2.5 indicate that the aggregate can be used on roads with large volumes of traffic and high temperature.

*Table 1. Coarse Aggregate Testing tabulation*

No	Test	Results	Requirements
1	Apparent Relative density	2,596	Min 2,5
2	Bulking relative density	2,549	Min 2,5
3	Moisture content, %	1,812	Min 3
4	Unit weight without voids kg/m <sup>3</sup>	1508,52	Min 1200

5	Unit weight with voids kg/m <sup>3</sup>	1465,75	Min 1200
6	Material finer than 200 µm, %	1,75	-

*Table 2. Fine Aggregate Testing tabulation*

No	Test	Results	Requirements
1	Apparent Relative density	2,546	Min 2,5
2	Bulking relative density	2,518	Min 2,5
3	Moisture content, %	2,73	Min 3
4	Unit weight without voids kg/m <sup>3</sup>	1577,49	Min 1200
5	Unit weight with voids kg/m <sup>3</sup>	1503,10	Min 1200
6	Material finer than 200 µm, %	2,60	Min 8

The equation to obtain the percentage of each aggregate is done as follows:

$$Y = Y_a \frac{a}{100} + Y_b \frac{b}{100} + Y_c \frac{c}{100} \quad (1)$$

$$a + b + c = 100 \% \quad (2)$$

Where,

Y : percentage of each aggregate from the definitive hole of the curve that uses aggregate

Ya : ordinate of the curve aggregate A on the same hole with sieve Y

Yb : ordinate of the curve aggregate B on the same hole with sieve Y

a,b,c : percentage of each aggregate on the same hole with Y

Results from equation (1) and (2) listed in table 3, table 4, and figure 1 and figure 2 below

*Table 3. Blending Aggregate for Bina Marga Specification*

Sieve	filler content	fine content	coarse content	combined aggregate	spec	
	7%	27%	66%		max	min
19	7,00	27,00	66,00	100,00	100	100
12,5	7,00	27,00	65,06	99,06	90	100
9,5	7,00	27,00	46,72	80,72	72	90
4,75	7,00	27,00	8,82	42,82	43	63
2,36	7,00	27,00	0,27	34,27	28	39,1
1,18	7,00	13,92	0,00	20,92	19	25,6
0,6	7,00	5,80	0,00	12,80	13	19,1
0,3	7,00	2,96	0,00	9,96	9	15,5
0,15	7,00	2,06	0,00	9,06	6	13
0,075	7,00	0,98	0,00	7,98	4	10

*Table 4. Blending Aggregate for Superpave*

Sieve	filler content	fine content	coarse content	combined aggregate	spec	
	7%	27%	66%		max	min
19	7,00	27,00	66,00	100,00	100	100
12,5	7,00	27,00	65,06	99,06	90	100
9,5	7,00	27,00	46,72	80,72	72	90
4,75	7,00	27,00	8,82	42,82	43	63
2,36	7,00	27,00	0,27	34,27	28	39,1
1,18	7,00	13,92	0,00	20,92	19	25,6
0,6	7,00	5,80	0,00	12,80	13	19,1

0,3	7,00	2,96	0,00	9,96	9	15,5
0,15	7,00	2,06	0,00	9,06	6	13
0,075	7,00	0,98	0,00	7,98	4	10

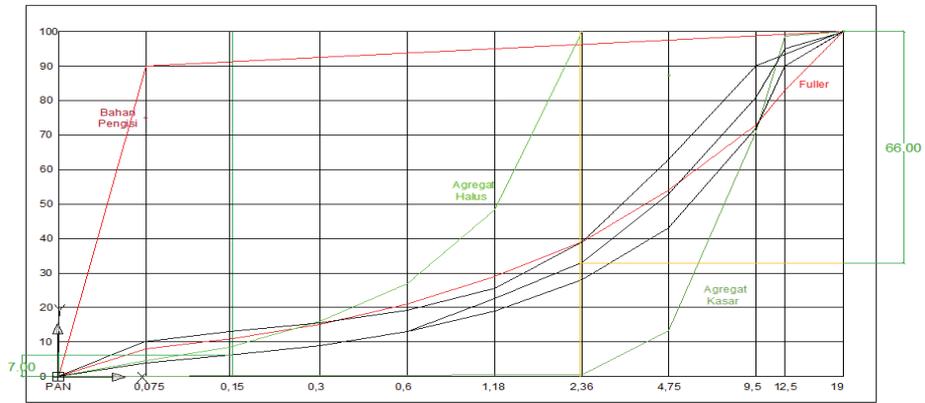


Fig.1 Blending Aggregate for Bina Marga Specification

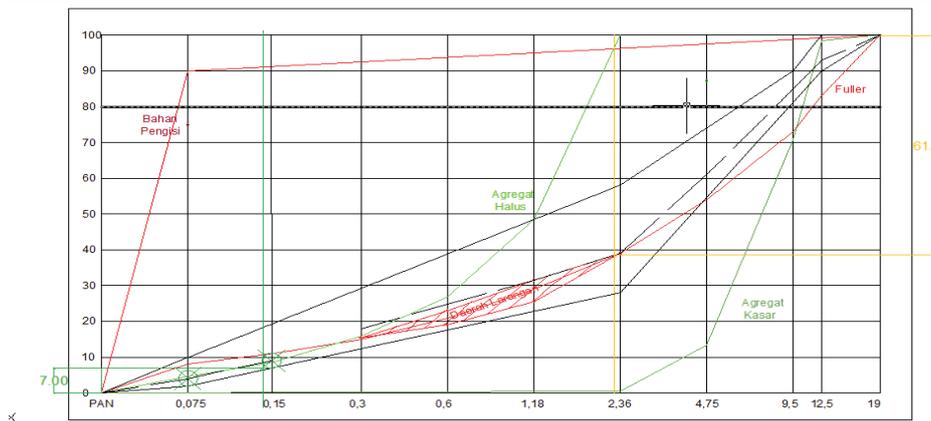


Fig.2 Blending Aggregate for Superpave Specification

### 3.2 The physical properties of asphalt

Tests on physical properties of asphalt are needed to determine whether the characteristics of asphalt match field conditions where the mixture will spread out, and as preliminary data for the design of asphalt concrete. Asphalt specific gravity, penetration, softening point, ductility and flash point value are a description of the asphaltene and maltene composition which determines its adhesiveness, generally tested at a temperature of 25<sup>0</sup>C, except for softening point at a temperature of 5<sup>0</sup>C and the flash point is obtained in accordance with its resistance when heated until it ignites and then burns. Table 5 shows the results of testing the physical properties of asphalt in accordance with the requirements of Highways Department of Public Works, 2010 Edition. According results of the testing, it is obtained that asphalt is included in the group with a 60/70 penetration and minimum 48<sup>0</sup> C softening point; suitable for roads with large traffic volumes and high temperature of road surface.

Table 5 Asphalt testing tabulation

No.	Laboratory Test	Specification		Result	Information
		Min	Max		

1	Penetration	60	70	64	Qualified
2	Specify Gravity	1	-	1	Qualified
3	Softening Point (°C)	48	58	49	Qualified
4	Burning Point (°C)	232	-	310	Qualified
5	Loss on Heating (TFOT) (%)	-	0,8	0,145	Qualified
6	Solubility (%)	99	-	99,59	Qualified
7	Ductility (cm)	100	-	130,5	Qualified

### 3.3. Designing mixture

From the aggregate blending data estimation, asphalt percentage is calculated. In preliminary tests to determine the characteristics of the mixture, the obtained optimum bitumen percentage is 5.9 % for Bina Marga Specification, and 5.65% for Superpave Specification, obtained through the following equation:

$$P_b = 0.035 (\%CA) + 0.045 (\%FA) + 0.13 (\%filler) + K \quad (3)$$

Where,

P<sub>b</sub> : percentage of binder

CA : % coarse of aggregate retained no 8

FA : % fine of aggregate passed no 8

K : constants from type of hot mixed asphalt

The same mixtures with various aggregate filler are then used on this test. Trial mix formula is applied to get a precise optimum asphalt percentage of asphaltic concrete mixture which is then determined based on a number of different asphalt percentages to certain aggregate graded by trial and error.

### 3.4. Marshall Stability Test

Figure 3 and 4 shows that Marshall Stability and Void In Mixture of Bina Marga are higher than Superpave's. However, Superpave's Void Filled with Binder, Flow and Marshall Quotient are higher than Bina Marga. Bina Marga has lower void filled explained that because of higher fine aggregate content. So, surface area covering with same amount of asphalt larger and affects higher asphalt void in mixture

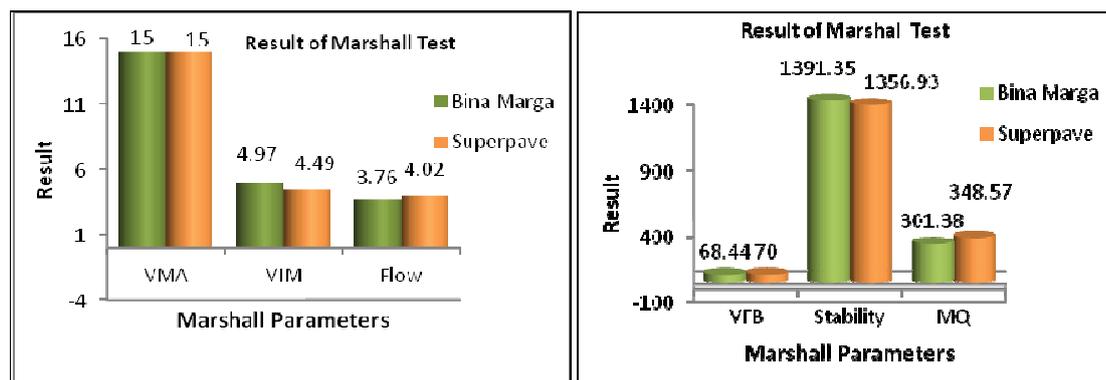


Figure 3 and 4 result of Marshall Test

### 3.4 Dynamic Stability Test

The results of this test, at two gradations, Bina Marga and Superpave, are presented in Figure 5. It is shown that the Dynamic Stability (DS) of Superpave gradation is higher than Bina Marga's. Hence it referred that the use of Superpave gradation would increase its resistance to permanent deformation.

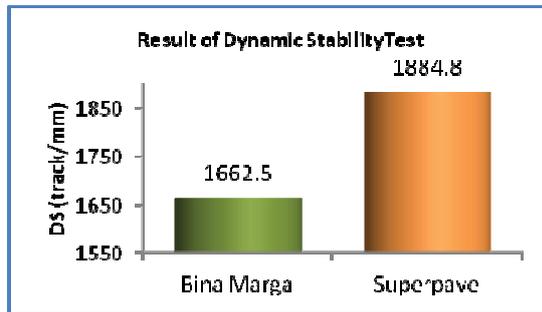


Figure 5 result of dynamic stability test

### 3.5 Roughness Test

Figure 6 is shown because of higher amount of fine aggregate, roughness value of Bina Marga is higher than Superpave but both are qualified the minimum specifications, which is 0.33  $\mu\text{m}$ . The more abrasive the surface of the pavement, it will reducing the accident rate more caused by the slippery road surface. However, it will also speed up the wear of vehicle tires. The values of roughness is obtained from the following formula:

$$MuN = 1,017BPN - 20,9 \quad (4)$$

Where,

MuN : *Mu Number*

BPN : *British Pendulum (Tester) Number*

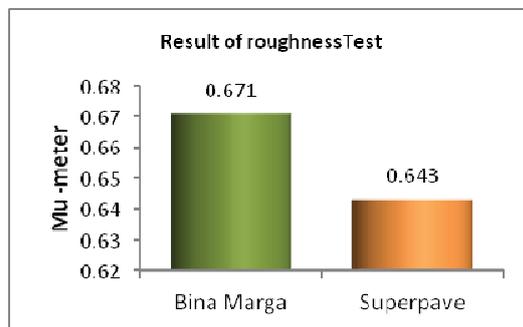


Figure 6. Result of roughness test

## 4. CONCLUSION

Based on research aim that comparing performance of both mixtures Superpave aggregate gradation and Bina Marga fine gradation, the conclusion are:

- Preliminary test with Marshall method, Bina marga mixture produce higher void in mixture and Marshall stability. The difference is not significant.
- Dynamic stability of the mixture obtained from the wheel tracking test shows enough significant difference. The ability of Bina Marga mixture to permanent deformation lower than the Superpave
- Bina Marga mixture has higher roughness value than superpave.
- The results of this research is expected to contribute to the efforts to find a solution of asphalt concrete mix design that meets the conditions the big cities of Indonesia, but remains economical. The results of this research are expected to contribute to the efforts to find a solution of asphalt concrete mix design that meets the conditions the existing in big cities in Indonesia, while remaining economical.

With the said advantages and disadvantages of each of the mixtures, they can be selected to be used in accordance with the actual condition in the field

## 5. ACKNOWLEDGMENT

Thanks for the help and attention given from the start until the end of this research to Syifa Mulyono, Waarid Mulyono, and Mutia Mulyono.

## 6. REFERENCES

- [1] Al-Khateeb, Ghazi and Basheer, Imad, 2009. *A Three-Stage Rutting Model Utilising Rutting Performance Data from The Hamburg Wheel-Tracking Device (WTD)*. J Road & Transport Research, Vol 18 No 3 September.
- [2] Bina Marga, 2010, *General Specification for Asphalt Pavement, Sixth Division (Spesifikasi Umum Divisi 6 Perkerasan Aspal)*. Jakarta: Departemen Pekerjaan Umum.
- [3] Dachlan, Tatang, A. 2007. *Refusal Density Test to Improve Appropriateness Quality of Flexible Road Pavement (Uji Kepadatan Membal) untuk Meningkatkan kesesuaian Mutu Perkerasan Jalan Beraspal*. Bandung.
- [4] FHWA, 1999, *Superpave Asphalt Mixture Design Workshop Workbook*. Washington: U.S Department of Transportation  
Masad, Eyad, dkk. 2009. *Predicting Asphalt Mixture Skid Resistance Based On Aggregate Characteristic*. Texas: Texas Department of Transportation.
- [5] Florida Department of Transportation, *Section 334 Superpave Hot Mix Asphalt for Local Agencies*, [www.dot.state.fl.us/specificationsoffice/.../LAP/.../d334\\_121903.doc](http://www.dot.state.fl.us/specificationsoffice/.../LAP/.../d334_121903.doc) (Accessed 26 Mar, 2013)
- [6] Sahar, Hanafi, 2008, *The Effect of Temperature on the Resilient Modulus of Flexible Road Pavement*, tesis, Universiti Teknologi Malaysia
- [7] Sukirman, Silvia. 2003. *Hot Mix Asphaltic Concrete (Beton Aspal Campuran Panas)*. Bandung: Nova
- [8] The Asphalt Institute, 2006. *Superpave Series No.2 (SP-2), 2006 Superpave Mix Design*, Kentucky, USA
- [9] Transport Research Board, 2005, *Superpave Performance by Design*, Final Report of The TRB Superpave Committee, USA
- [10] Wahyudi, Hemat; Prabadiyani, Sri; Purwanto, Djoko. 2003. *Evaluation of Structural Properties and Marshall Values of Asphalt Concrete Mixture Using Pertamina Pen Tie 60/70 and Esso Pen 60/70 (Evaluasi Sifat Marshall dan Nilai Struktural Campuran Beton Aspal yang Menggunakan Bahan Ikat Aspal Pertamina Pen 60/70 dan Aspal Esso Pen 60/70)*. Semarang: Universitas Diponegoro.
- [11] Wignall, Arthur; Kendrick, PS; Ancill, Roy; Copson, M. 2003. *Road Project Theory & Practice (Proyek Jalan Teori & Praktek), 4<sup>th</sup> Edition*. Jakarta: Erlangga

# Deformation Behaviour Of Soft Soils Railway Subgrade Reinforced By Wooden Pile

Fico Dio Agrensa<sup>a</sup>, Bambang Setiawan<sup>b</sup>, Ary Setyawan<sup>c</sup>

<sup>a</sup>Faculty of Engineering  
University of Sebelas Maret, Surakarta 57126  
Tel : (0271) 647069 ext 219. Fax : (0271) 634524  
E-mail : fico.agrensa@gmail.com

<sup>b</sup>Faculty of Engineering  
University of Sebelas Maret, Surakarta 57126  
Tel : (0271) 647069 ext 219. Fax : (0271) 634524  
E-mail : bbstw88@yahoo.com

<sup>c</sup>Faculty of Engineering  
University of Sebelas Maret, Surakarta 57126  
Tel : (0271) 647069 ext 219. Fax : (0271) 634524  
E-mail : cenase@yahoo.com

## ABSTRACT

*Over the recent years, many researches and experiments have been conducted in order to obtain a solution of soft soils problems. Soft soils can be commonly found in most of Indonesian regions. Basically, it provides small bearing capacity and can be extremely deformed due to massive and cyclic loads, especially on railway track. However, track sub-structure layer plays significant roles on railways performance. This paper provides an alternative of settlement problems in railway system lied on soft soils subgrade. By using reduced scale model of railway track with soft soils subgrade, this laboratory experiment was carried out to observe its settlements behaviour under repetitive loading with and without reinforcements. On this research, wooden pile was chosen as an alternative to settlement problems in laboratory model. The results showed that the wooden pile used in laboratory model subjected to cyclic load can significantly reduce settlement because of its friction capacity which could increase model bearing capacity on soft soils. According to this condition, applying wooden pile reinforcement would be necessary to overcome the problems.*

**Keywords :** bearing capacity, railway track, settlement, soft soils, wooden pile

## 1. INTRODUCTION

Several train accidents have been reported during year 2012 in Indonesia and mostly because of the track subgrade failures. It means that the track subgrade should be properly well-designed to keep the whole structure remains safe. However, there is an issue which is popularly known called soft soil. The existence of large soft soil deposits in railway subgrade can induce large settlements. Applying some reinforcement would be necessary in order to increase its bearing capacity to preserve the railway structure against the loading from passing train over the railway structure.

The main indicator that maintenance and improvement are needed are usually defects in geometry, as well as the deformation on the railway subgrade. Furthermore, as an integral part of railway structure, it is governed by two factors, strength and deformation. The strength itself refers to soils shear strength which governs bearing capacity and considered to be the general indicator of strength. Whereas the deformation refers to the subgrade settlement influenced by stiffness (soil modulus) [1].

Wooden pile was chosen to be an appropriate solution of this condition based on several consideration including economical one which needs less cost than replacing the existing subgrade. Assuming the wooden pile as a pile fondation, its resistance comes from two aspects, there are friction resistance and point resistance. But in this research, this pile will act as a friction pile because it doesn't reach the rock layer at the bottom so then it is called floating fondation.

Based on the case that has been described above, a reduced laboratory model of railway structure in soft soils subgrade with and without reinforcements are made to observe its behaviour during the loading phase. To obtain the effectiveness of using wooden pile reinforcements in terms of reducing the settlement caused by train loads, the deformation for both condition will be analysed and compared.

## 2. SOFT SOILS CHARACTERISTIC

Soft soil is one of problematic soils which is categorized as cohesive and high-compressibility soils. In fact, it will be harmful for the construction above. Under the load, large settlements will occur and damage the structure. Moreover, the deterioration caused by soft soil also needs high cost to overcome. These soils which generally comprise soft clay and peat, are widespread in Indonesia, specifically in area where so much infrastructures have to be constructed (Figure 1).

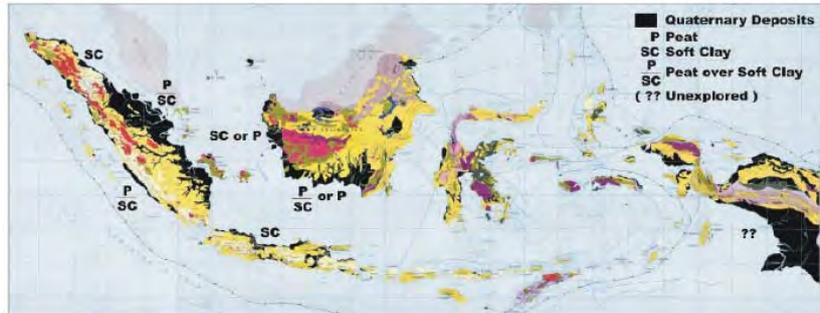


Figure 1: Soft soils deposit in Indonesia [2]

The identification of soft soils can be easily performed by either field test or laboratory test which have been developed by many experts. Firstly, simple field method that usually uses to identify the soft soils is by squeezing the soil. If it is formed easily using the fingers, then it is categorized as soft soil. In addition to this method, if the soil is suddenly came out between fingers when squeezed by hand, then it is very soft soil. Secondly, laboratory method takes into account high natural water content ( $\geq 40\%$ ), medium-high index of plasticity ( $>20\%$ ), and  $S_u$  value of  $<25$  kPa [3]. An additional indicator is described by table below.

Table 1: Shear strenght of soft clay [2].

Consistency	Shear Strenght (kN/m <sup>2</sup> )
Soft	12,5 – 25
Very Soft	< 12,5

## 3. SUBGRADE BEHAVIOUR APPROACHES

As a platform upon which the railway structure is lied above, the subgrade which is known as substructure must provide a stable condition. Literally, any other soil existing locally is uneconomical to use for the subgrade, besides it will be used without disturbance as much as possible. On the other hand, the substructure design needs better understanding of track forced that beared by railway structure. The classification of track forces that the structure must restrain involve mechanical (static and dynamic) and thermal. Figure 2 below describes load distribution from passing train into the subgrade layers [4].

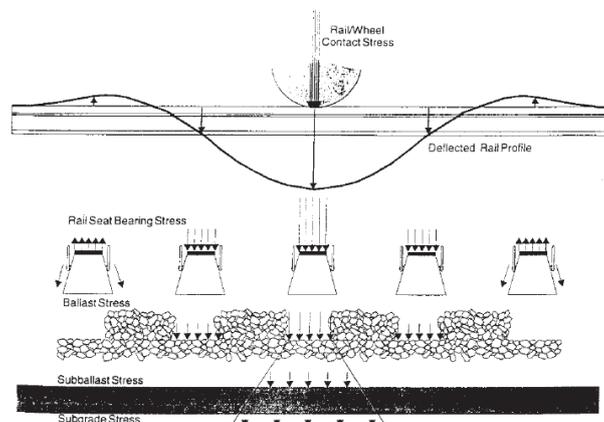


Figure 2: Typical wheel load distribution into the track structure [4].

On the both stable and unstable site test under axle load, the settlement which occurred in the test can be described through the figure 3. Each site has three settlement categories which are maximum, average, and minimum. According to the figure, unstable site definitely has bigger range of settlement than stable site which tend to retain track forces with its settlement below 10 mm. Since, there are so many factor that influences site condition, the charts below are only approaching result.

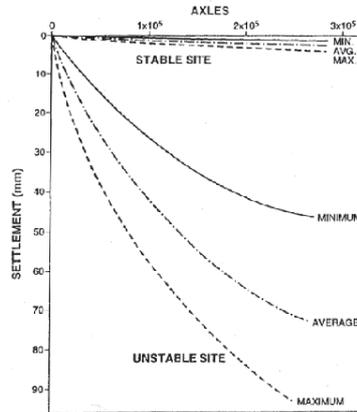


Figure 3: Comparison of settlement rates at stable and unstable sites [4].

#### 4. DESIGN OF LABORATORY MODEL

In this paper, reduced-scale model of railway structure (laboratory model) is proposed instead of field scale model. Although using field scale of railway structure gives real result, the cost will be very expensive and need long time. Thus, laboratory model is used to represent the real condition in the field. As a consequence, boundary condition is also carried out. Figure 4 shows the cross section of laboratory model reinforced by wooden pile.

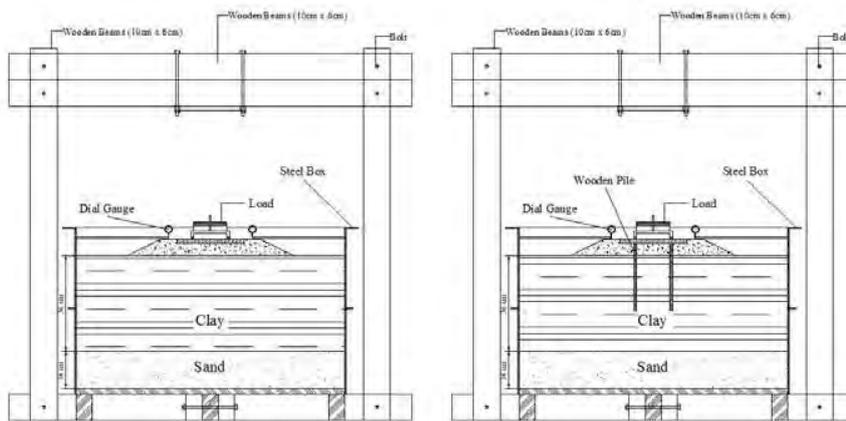


Figure 4: Cross section of laboratory model

Firstly, two different subgrades are sequentially used in this experiment, those are soft soil subgrade and soft soil subgrade with reinforcements embedded to the sleeper in both edges. The wooden pile which proposed as the reinforcement has 1 cm diameter and 25 cm length as shown in figure 3. Secondly, loading variations which comprise size, position, and cycle, are also applied to the reduced model. Size loading variations used to generate the settlement are 16 kg, 32 kg, 48 kg, 64 kg, and 80 kg. Similarly, the position and cycle variations with total loading cycles of 10 will be explained more by figure 6. With these variations, using the laboratory model is roughly assumed as a representation of real condition of railway structure.

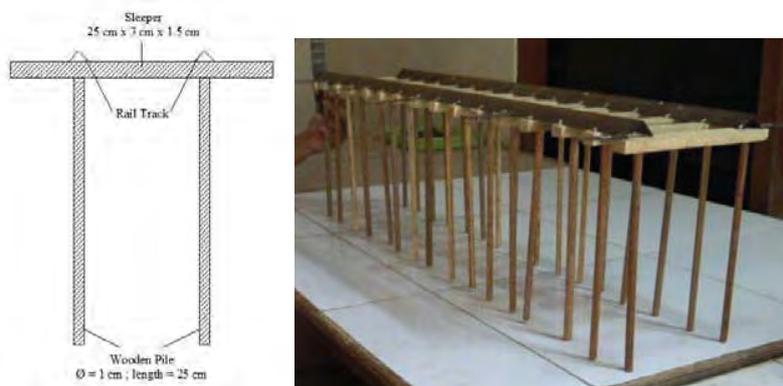


Figure 5: Wooden pile reinforcement

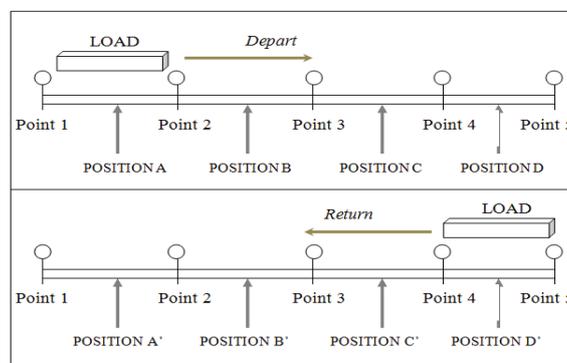


Figure 6: Variations of position and cycle loading

All of the reduced scale of railway structure and subgrade are set inside steel box. During the loading phase, the deformation of the railway structure are recorded by reading the dial gauge placed in the right and left side of railway track which only focused on position B and position C each cycle. The main reason is to approach the real condition in which as continuous structure, it has no end or rarely be found. The set-up of laboratory model is shown by figure 7.



Figure 7: Set up of laboratory model

## 5. RESULTS AND ANALYSIS

### 5.1. Soil Properties

As shown by table 2 below, laboratory test of soil subgrade is summarized. Several laboratory test subjected to soil sample cover moisture content test (ASTM D 2216) [5], direct shear test (ASTM D3080) [6], particle size analysis of soil (ASTM D422), hydrometer analysis of soil (ASTM D422) [7], unconfined compressive strength test (ASTM D2166) [8], liquid limit, plastic limit, and plasticity index of cohesive soil (ASTM D 4318) [9]. Compared to the parameter of soft soil identification which has been described in sections 2, soil subgrade that will be used as a platform of reduced model of railway structure can be categorized as soft soil. Two main consideration of this identification lied on both index properties and engineering properties.

Table 2: Soil Properties.

Parameter	Unit	Soil Sample
Moisture content	%	57,83
Cohesion (direct shear)	kg/cm <sup>2</sup>	0,081
Φ (direct shear)	...°	4,63
Cohesion (triaxial)	kg/cm <sup>2</sup>	0,133
Φ (triaxial)	...°	2,177
Gravel Proportion	%	0
Sand Proportion	%	16,93
Silt Proportion	%	36,72
Clay Proportion	%	46,35
Liquid Limit	%	41,32
Plastic Limit	%	12,45
Plasticity Index	%	28,87
Su	kPa	15,406

### 5.2. Deformation Behaviour

The vertical deformation were measured and plotted against cycle through figures below which is divided into two conditions of models subgrade. First part explains results of settlements recorded in soft soils subgrade without wooden pile reinforcement. This condition refers to unstable condition with excessive settlement occurred in it. Conversely, small settlements were recorded in soft soil with wooden pile reinforcement. However, to investigate the overall performance of reinforced laboratory model, comparison of both subgrade conditions must be considered.

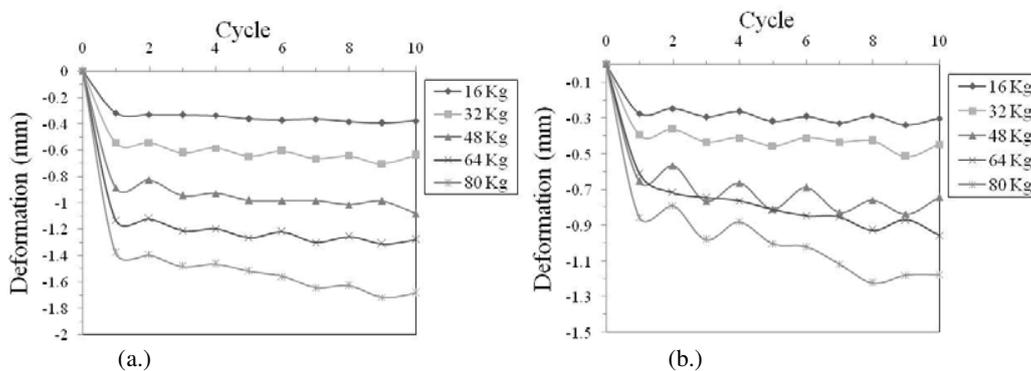


Figure 8: Measured deformation under loading variation in laboratory model without wooden pile reinforcement. (a.) Position B (b.) Position C.

Referring to the figure 8.a which represents deformation caused by cyclic loading, the minimum settlement was about -0.3 mm during the loading phase of 16 kg. The settlements kept rising through the increasing of load until reach about -1.7 mm of settlement which was assumed as the maximum settlement due to 80 kg loading. Similar to this condition, the loading phase of position C with 16 kg load induced minimum settlement of about -0.3 mm, while the maximum settlement of about -1.2 mm was measured due to 80 kg load. However, at the end of loading cycle, the deformation trends of 64 kg and 80 kg were still increasing while the other loads shows constant settlement values. Another result, as shown by figure 8.b, there are some oscillation of measured settlement, specifically caused by load 48 kg and 80 kg. This condition happened because the soil compaction did not evenly spread from one area to another within the steel box. Thus, for the next model of reinforced railway structure, the compaction process prior to the loading test were carefully carried out to avoid these condition.

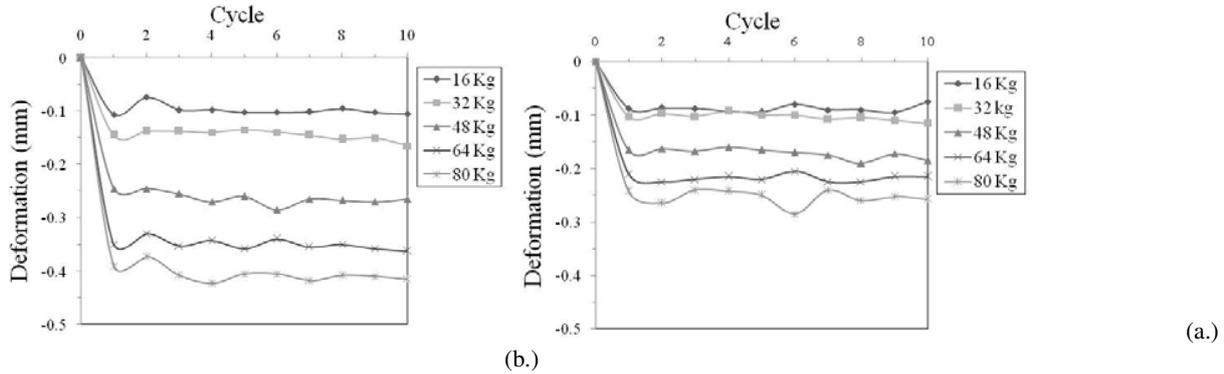


Figure 9: Measured deformation under loading variation in laboratory model with wooden pile reinforcement. (a.) Position B (b.) Position C.

For the reduced model of railway structure with wooden pile reinforcements, the settlement occurred in this model were much less than model without reinforcement. The measured settlement because of loading variation in position B was about -0.1 mm which is known as minimum settlement, then the maximum settlement was about -0.4 mm as shown in figure 9.a. The result of loading in position C was slightly different than position B, which measured minimum and maximum settlement were about -0.1 mm and -0.25 mm, respectively. Overall, the range of settlement each load was small and not exceed -0.5 mm. Furthermore, until the end of loading cycle, the settlement trends shown by figure 9 reach constant value.

### 5. FEM VALIDATION

Finite element method was used in this research to validate the laboratory results, particularly on its final settlement (last loading cycle). By using Plaxis 3D Foundation, a finite element software, the model was created similar to the laboratory model with their parameters including soils and structural parameters. Figure 10 and figure 11 illustrate the result comparison between laboratory model and FEM model which are focused on the induced settlement on the last cycle. It can be concluded that there are very small discrepancies from those two models. On the other hand, FEM models produce more conservative results than that of laboratory models.

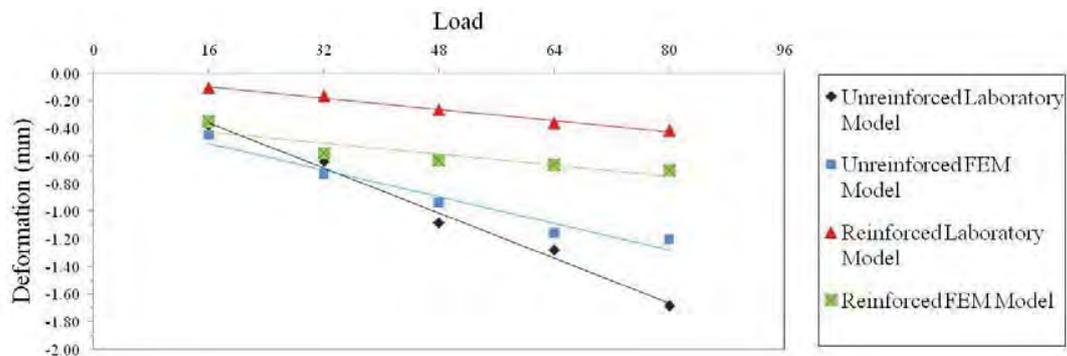


Figure 10: Settlement comparison between laboratory model and FEM model in position B.

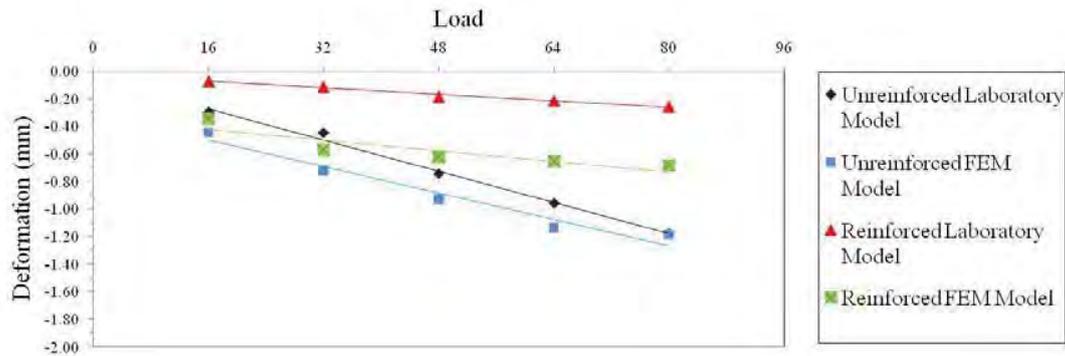


Figure 11: Settlement comparison between laboratory model and FEM model in position C

## 6. CONCLUSION

According to the results, the reinforced model tend to produce less settlements compared to the unreinforced model. Excessive settlement which occurred in both laboratory and FEM model without reinforcement generally was caused by small strength of soft soils which could not restrain the loading. In contrast, small settlement in reinforced model indicate that wooden pile used in the model provided support against the loading. This is due to capability of the reinforcement to reduce the excessive settlement into minimum through its friction which demonstrate the potential benefits of using wooden pile.

The effectiveness of applying wooden pile to reduce the settlement also has been calculated with consideration took into account the comparison of deformation between both models. The comparison of deformation was conducted each loads in each models. Therefore, it can be concluded that using wooden pile reinforcement can reduce the settlement with ranged from 70.09 % to 76.70 %.

## REFERENCES

- [1] M. T. McHenry and J.G. Rose, "Railroad Subgrade Support and Performance Indicators", Kentucky Transportation Center, College of Engineering, University of Kentucky, Feb. 2012.
- [2] Ministry of Public Work Indonesia, "Geotechnical Guide 1, Formation Process and Behaviour of Soft Soil" (in Indonesian), *Panduan Geoteknik 1, Proses Pembentukan dan Sifat-sifat Dasar Tanah Lunak*, WSP International, 2001.
- [3] N. M. Sasanti, "Engineering Knowledge for Contractor" (in Indonesian), *Pengetahuan Engineering untuk Kontraktor*, PT. PP, Jakarta, 2008.
- [4] E. T. Selig and J. M. Waters, "Track Geotechnology and Substructure Management", Thomas Telford, London, 1994.
- [5] ASTM D2216. "Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass", *Annual Book of Standards, Section 4*, vol. 04.08, Soil and Rock.
- [6] ASTM D3080. "Standard Test Method for Direct Shear Test of Soils Under Consolidated Drained Conditions", *Annual Book of Standards, Section 4*, vol. 04.08, Soil and Rock.
- [7] ASTM D422. "Standard Test Method for Particle-Size Analysis of Soils", *Annual Book of Standards, Section 4*, vol. 04.08, Soil and Rock.
- [8] ASTM D2166. "Standard Test Method for Unconfined Compressive Strength of Cohesive Soil", *Annual Book of Standards, Section 4*, vol. 04.08, Soil and Rock.
- [9] ASTM D4318. "Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils", *Annual Book of Standards, Section 4*, vol. 04.08, Soil and Rock.

## **Building Materials Composition Influence to Sound Transmission Loss (STL) Reduction**

**Erni Setyowati<sup>1,a</sup>, Anggana Fitri Sadwikasari<sup>2,b</sup>**

<sup>1</sup>*Building Science Laboratory, Engineering Faculty, UNDIP, Semarang, Indonesia*

<sup>2</sup>*Islamic University of Indonesia (UII), Yogyakarta, Indonesia*

<sup>a</sup>*ernisyahdu@gmail.com*, <sup>b</sup>*anggana@gmail.com*

### **ABSTRACT**

*The development of the airport always causes the noise impact to the surrounding environment.<sup>1</sup> Housing close to the airport will be annoyed by the aircraft noise, especially if the building is not added by absorber building materials. Housing lay out towards the runways as noise sources is also an aspect that should be considered. This research resulted building models equipped by simple material compositions that had capability in reducing the airport noise optimally. The decrease of the noise level found out from the research is caused by the value of Sound Transmission Loss (STL) of the building materials composition. The models of housing are laid out with a number of specific orientation angles towards the runway and resulted values of the highest noise level reduction.*

#### **Keywords:**

*Airport noise, building material composition, STL reduction.*

**This Paper is Published in Advanced Material Research**

## Safety Enhancement of Water-filled Composite Road Barriers

Thiyahuddin M.I<sup>a</sup>, Thambiratnam D.P<sup>b</sup>, Gu Y.T, Gover R.B

<sup>a</sup>School of Chemistry, Physics and Mechanical Engineering  
Queensland University of Technology, Brisbane, Queensland, Australia

\*email: [mohd.thiyahuddin@qut.edu.au](mailto:mohd.thiyahuddin@qut.edu.au)

<sup>b</sup>School of Civil Engineering and Built Environment  
Queensland University of Technology, Brisbane, Queensland, Australia

Email: [d.thambiratnam@qut.edu.au](mailto:d.thambiratnam@qut.edu.au)

### ABSTRACT

Road safety barriers are used to shield pedestrians and workers from oncoming traffic at roadsides. When filled with water, these barriers are able to withstand low to moderate impact speeds up to 50km/h. Despite this feature, Portable Water Filled Barriers (PWFBs) face challenges with large deflections, tear and breakage during impact, especially at higher speeds. This study explores the use of composite material to enhance the safety of these PWFBs and enable their use at higher speeds. Energy absorption capability of PWFBs is first investigated. Then, composite action of the PWFB with the introduction of foam and a steel frame is considered to evaluate its enhanced impact performance. Findings of the present study show that the initial height of the impact must be lower than the free surface level of water in a PWFB in order for the water to provide significant crash energy absorption. In general, an impact at 0.8 of the barrier height seems to be a good estimation. Furthermore, the addition of a composite structure greatly reduces the probability of tearing by decreasing the strain and impact energy transferred to the shell container. This allows the water to remain longer in the barrier to absorb energy via inertial and sloshing response. Information from this research will aid in the design of new generation roadside safety hardware that will cater to the modern roadways with enhanced safety to motorists and persons at roadsides.

### Keywords

Water Filled Road Barriers, Safety, Impact, Finite Element Methods, SPH, Composite, Foam

**This paper is published in International Journal of Technology (IJTech)**

## **Managed Motorways Research in Queensland, Australia**

**Jinwoo (Brian) Lee**

*Science and Engineering Faculty, Queensland University of Technology, Brisbane, Queensland, 4001, Australia  
E-mail: Brian.Lee@qut.edu.au*

### **ABSTRACT**

*This paper introduces the managed motorway research that was recently performed by the Smart Transport Research Centre at Queensland University of Technology, Brisbane, Australia. The aim of the managed motorways research is to develop smart motorway traffic control and management solutions to cost-effectively alleviate congestion pressure, and thereby to reduce its negative impacts on travel time reliability, traffic throughput, and safety. Research was conducted to develop enhanced algorithms for motorway ramp metering and variable speed limits. This paper introduces those two algorithms highlighting the fundamental concepts, control principles, and evaluation results.*

### **Keywords**

*Managed motorways, ramp metering, variable speed limits*

**This Paper is Published in International Journal of Technology (IJTech)**

# Modified Buton Granular Asphalt with SBS as binder of hot-mix asphalt

Heddy R Agah

Faculty of Engineering, University of Indonesia, Depok 16424  
 E-mail : agah@eng.ui.ac.id

## ABSTRACT

*Buton Asphalt (Butas) is naturally occurring bitumen and categorized as natural asphalt which is found in Buton Island – Indonesia. It contained of mineral and 10-30% bitumen of the total weight and can be used as materials for asphalt concrete mixture. Butas has shown it is function as materials for asphalt concrete both for hot mix and cold mix asphalt concrete. Number of researches aimed at improving Butas due to its relatively low bitumen content and low penetration. This paper assessed the empirical rheological properties of Butas in a form of Buton Granular Aggregate (BGA) as binder of hot-mix asphalt concrete. It is laboratory research work, and Marshall method of testing and preparation of sample is used. Two type of asphalts are use which are genuine asphalt of 60-70 pen and SBS polymer modified asphalt as binder, and BGA is treated as fine aggregate. Extraction of sample mixtures after Marshall test is undertaken to evaluate the physical characteristic of materials composition includes aggregate gradation and asphalt properties. The finding shows that BGA contributed to the increase of fine aggregate percentage and asphalt content. The optimum combination is 5% of BGA and with 2% of polymer modified asphalt.*

**Keywords:** *Buton asphalt, Marshall method, modules resilient, polymer modified asphalt, physical properties*

## 1. INTRODUCTION

Asphalt based materials for road construction remains the primary choice for pavement industries. Asphalt can be obtained as oil based materials, several natural bitumen with various content composition and mineral are also found. The types of natural asphalt in Buton-Sulawesi can be classified into two categories: hard asphalt found in the Kabungka area and soft asphalt mined in the Lawele area [1]. The area of the rock asphalt mine in Buton located at 5 longitude and 123 latitude, has an asphalt content that varies from 10% to 40%. Using a number of mined materials, the data suggests that the average level of asphalt ranges roughly 21.8%.

The deposit of this material is predicted at the amount of 62.5-350 million tonnes. This material is available at a the depth of about 1.5meter, spreading at approximately 70.000acres. Buton asphalt has been used as asphalt construction based materials as its quality improvise through extraction or division (splitting into parts) of its forming component, and as primary binding material or additive. Conventional Asbuton particle in the form of Asbuton aggregate with maximum size of 12.5mm distributed in the bulk is a type used in Indonesia [2]. Requirements for buton particles are presented in Table 1. Buton Granular Asphalt (BGA) is the research product of Asbuton which is broken by a suitable crusher to certain desirable size particle.

The usage of asbuton is expanded through raw material modification in order to be used both as an additive in the form of granular and also as modified asphalt. [3]. The nature of the aggregate asbuton agglomerates becomes altered during the process of storage due to the migration from hydrocarbon phase, from interion component to the granular surface [4]. The other negative result can occur because of Indonesian humidity which may cause result in more sticky material. The asphalt content varies from 20% to 30%, and the test result for penetration value varies significantly between 4 to 36. Penetration is higher for the Lawele area compared to the one mined at Kabungka. The softening point of the material at the two areas is around 59<sup>0</sup>C, and the flash point is 198<sup>0</sup>C. The test result of the softening point of BGA base material is 67.5C, (SNI 06-2432-1991 – Indonesia National Standard - standard is 60<sup>0</sup>C). The results implicate that this material is suitable to use with the weather condition of typical tropical areas.

Table 1 Asbuton specification

Parameter	Type *)			
	5/20	15/20	15/25	20/25
Bitumen content (%)	18-22	18-22	23-27	23-27
Aggregates passing sieve (%)				
No 4	100	100	100	100
No.8	100	100	100	95 Min.
No.16 (min)	95	95	95	75

Water content (%) max	2	2	2	2
Penetration (25°C, 100gr, 5sec, 0,1mm)	≤ 10	10-18	10-18	19-22

The usage of asbuton started (during 1929) with bitumen content of 18-22% max size 12,7mm, further, fine asbuton with 6.35 diameter was developed. In 1993 Asbuton Micro plus with maximum size of no.8 was developed, with bitumen content of 25%, water content less than 2%. Butonite Mastic Asphalt was developed in 1995 with bitumen content of 50%, in 1997 added by liquid asphalt and Extracted Buton asphalt resulted in Retona type. In this study, the BGA used was resulted in max size 1.16mm and <2% water content which was initially developed in 2003. In 1995 Issacson and Lu introduced polymer, along with the finding of various types and derivatives of polymer, which are elastomeric and thermoplastic types to modify asphalt. Polymer can be used both as admixture and binders [5], [6], [7], [8]. This research is conducted to assess the characteristics of gradation and the influence of asphalt content based on BGA composition. Polymer modified asphalt is introduced to strengthen binding influence for BGA mineral deposit

## 2. METHODOLOGY

The materials are asphalt cement, BGA, and asphalt modified polymer. The gradation composition conforms with Bina Marga continuous gradation specification, Indonesia. Asphalt mixtures are designed as a combination between BGA and polymer in each composition of 5-7% and 2-4% respectively. This results in one combination without additive and four type combinations with BGA and polymer asphalt..

The test is carried out using indirect tensile strength and Marshall methods. The indirect tensile strength test is used to determine the tensile properties of the asphalt concrete which can be related to the cracking properties of the pavement. [9]. After tested using indirect tensile strength and Marshall methods, the sample is extracted to analyse the aggregate gradation. Extraction test is aimed to evaluate the gradation resulted from BGA material.

## 3. MATERIAL AND TESTING

Based on the composition of aggregate and BGA, gradation is designed to comply with the percentage of BGA addition. (Table 2). BGA gradation is tested in two ways: before and after extraction. Table 3 and 4 shows test result of asphalt and aggregate.

Table 2 Gradation BGA before and after extraction

Sieve	Before	After
3/8"	100,00	100,00
4	88,19	100,00
8	68,77	99,75
30	42,94	98,24
50	15,42	85,53
100	3,10	60,38
200	0,20	39,87

Table 3 Test result of aggregate per fraction

Type	Coarse	Medium	Fine
Bulk SG gr/cm <sup>3</sup>	2,57	2,50	2,61
SSD gr/cm <sup>3</sup>	2,61	2,58	2,63
Apparent gr/cm <sup>3</sup>	2,68	2,70	2,67
Absorption %	1,65	2,85	1,01

Table 4 Test result of asphalt 60/70

Type of testing	Specs	Results
Penetration, 25°, 100 gram, 5sec, 0.1 mm	60-79	62,8
Softening point 5°C- °C	48-58	49
Flash point- °C	232-	320
Weight -loss -1%	0,4	0,19
Solubility in CCl <sub>4</sub> %	99-	99,5
Ductility Cm	100-	100

Penetration -loss %	75-	89,17
Unit weight Gr/Cc	1-	1,031

Specifications on gradation are aimed to assure that the designer chooses the best possible combination of materials to obtain desirable responses such as stability, flux, voids, Young modulus, rutting resistance, permeability [10]. Table 5 shows the design gradation of standard/normal gradation and gradation with the combination of BGA.

Table 5 Design aggregate gradation

Sieve	Normal	BGA 5%	BGA 7%
¾"	99.81	99.8	99.80
½"	94.98	95.1	94.85
3/8"	77.92	77.6	78.23
No 4	62.25	59.9	63.23
No 8	49.07	46.8	49.79
No 30	28.14	27.0	28.80
No 50	16.44	15.3	16.15
No 100	9.04	8.1	8.50
No 200	4.49	4.0	4.13

#### 4. ANALYSIS

##### 4.1 Mixture performance

BGA addition in the mixture is able to increase performance measured from the Marshall test. The result shows an increase of mixture with BGA of 1,45 and 1,63 times compared to the mixture without BGA. Stability increases significantly for the addition of 2% and 4% polymer to the mixture with 5% BGA. However, influence of combination of 7% BGA and polymer produced lesser value compared to 5% BGA. Marshall quotient varies between 320 to 385, in which the higher is reached at combination of 5%BGA and 2% polymer (B5P2) with 385kg/mm, showing that the mixture is relatively rigid. All combinations with 4% polymer seem more flexible with moderate high value of stability (Figure1).

##### 4.2 Modulus of Resilient

UMATTA set is used as a tool to analyse MR in two scenarios: (i) normal temperature, and (ii) preheating at 40°C for 24 hours with variation of rise time and pulse. Optimum value is reached for all combination of the mixture at asphalt content of 5.5%. BGA addition and BGA in combination with polymer increase MR value, each amounts to 1.33 and 0,99 times for BGA mixture of 5% BGA and 2,4% polymer; and 1.07 increase for concrete mixture with 7% BGA and 4% polymer compared to the mixture without polymer. (Figure 2 and 3)

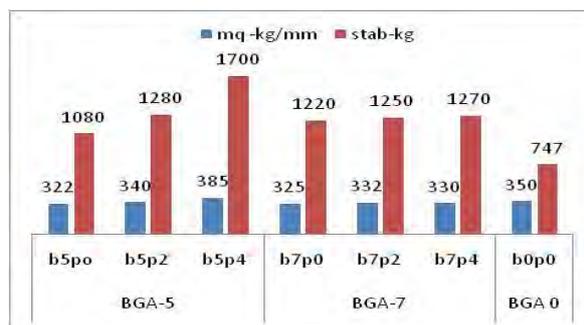


Figure 1 Stability and Marshall Quotient

The value of MR for 7% BGA mixture is higher than 5%BGA estimated from rise time and pulse variation of 80-3000 and 40-1000. However the mixture with polymer content, causes MR value to decrease, indicating impact of polymer to mixtures stiffness (see Figure 4).

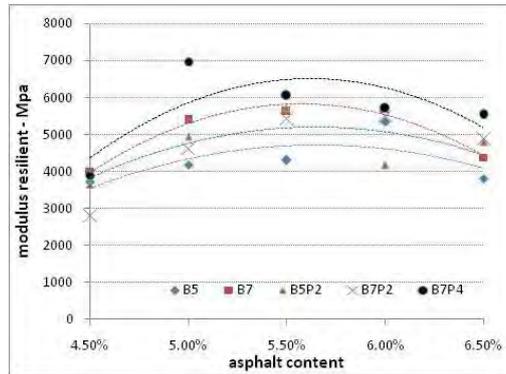


Figure 2 Modulus resilient for BGA 5%

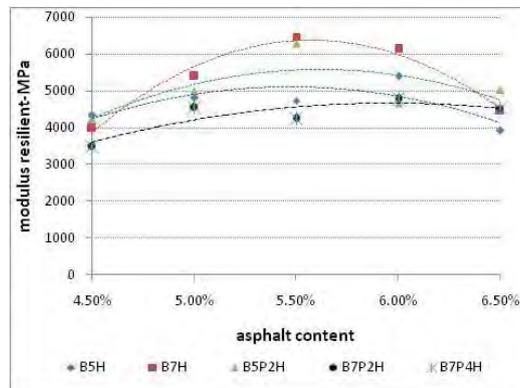


Figure 3 Modulus resilient for BGA 7%

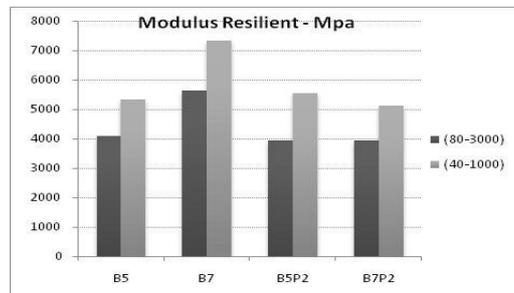


Figure 4 Modulus resilient for BGA 5% for different raise time and pulse

### 4.3 Gradation

It was found that [11] potential degradation or aggregate is caused by compaction, and Marshall compaction create more aggregate degradation. BGA addition changes initial gradation because a part of the fine fraction portion is substituted by BGA. BGA which comprised of mineral and asphalt will separate to its components during mixing time. The addition occurs for fine granule (no.50, 100 and 200), and it tends to reach maximum level, while the highest is at sieve no.100. Fine granule percentage is increase 21.02%, 71,89% and 105.74% respectively for sieve sizes of no. 50, 100 and 200 estimated from design and extracted gradation. The small fraction comprised of 7% BGA mixture is for the three aggregate sizes is 16.48, 67.8 and 107.9%. For the two types of BGA mixture, the addition of fine granule of no 200 almost doubles the initial percentage. The result is presented at Figure 5, 6, and Table 5. Polymer addition minimizes fine granule addition so that initial design gradation can be maintained.

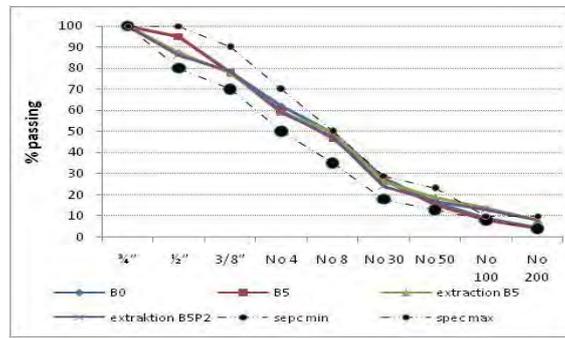


Figure 5 Comparison of aggregate gradation with BGA 5% polymer 2%, (B5P2) before and after extraction

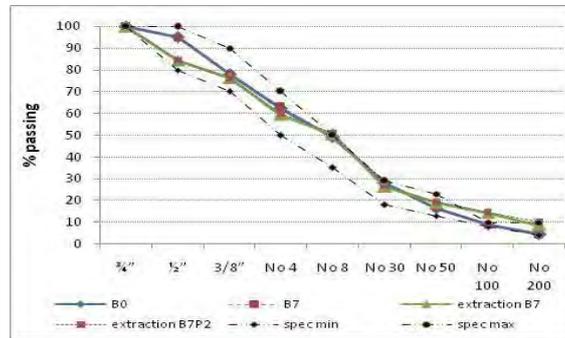


Figure 6 Comparison of aggregate gradation with BGA 7% polymer 2%, (B7P2) before and after extraction

Table 6 Aggregate gradation for various mix after extraction

Sieve size	Spec	Basic	B5P0	B5P2	B5P4	B7P0	B7P2	B7P4
3/4"	100	99.81	100	100.0	100.0	100	100	100
1/2"	80-100	94.98	87.3	86.1	85.7	84.4	85.0	84.2
3/8"	70-90	77.92	77.4	78.6	76.4	76.2	73.2	74.9
No 4	50-70	62.25	59.2	59.2	60.7	59.4	58.2	59.4
No 8	35-50	49.07	49.8	47.6	50.4	50.3	48.1	46.6
No 30	18-29	28.14	26.1	23.9	27.6	26.3	26.3	24.7
No 50	13-23	16.44	18.5	17.0	19.9	18.9	20.0	18.6
No 100	8-10	9.04	13.9	12.9	15.1	14.3	12.9	12.1
No 200	4-10	4.49	8.2	7.9	9.0	8.6	8.1	7.8

## 5. CONCLUSION

- 1) Buton asphalt has role in increasing the quality of concrete asphalt mixture and simultaneously utilizes great amount of natural asphalt avails in Sulawesi island. Mineral and asphalt content contributes to the composition of both aggregate and mixed concrete asphalt content
- 2) The use of BGA influences the composition and fine granular content, especially after mixing process, it increases at the mixing because mineral content changes to be finer sizes.
- 3) The amount of 5% BGA addition trends to better result compared to BGA high content. The mixture of Marshall properties increases with the addition of BGA. Polymer role gives better bond on fine granule addition as a result of BGA physical change and has improved the mixture performance.
- 4) UMATTA test proves that the mixture can overcome speed and load frequency for medium to high traffic amount.

## 6. REFERENCES

- [1] Siswosoebroto, B.I., Kusnianti, N, Tumewu, W (2005), Laboratory Evaluation of Lawele Buton Natural Asphalt in Asphalt Concrete Mixture, *Proc. of the Eastern Asia for Transportation Studies*, vol 5, pp 857-867.
- [2] Affandi, Furqon, (2008); Sifat Campuran Beraspal Panas dengan Asbuton Butir. *Jurnal Jalan dan Jembatan*, vol.26, No.2. in Bahasa Indonesia
- [3] Samadhi, T. W.; Putrawan I.D.G.A...Prabowo B.E, Dwintawidi, A (2011), Statistical Evaluation on Non-agglomeration Coating for Granulated Natural Asphalt, *Journal Engineering Science, ITB* vol 43no 1, 2011, p 41-56.
- [4] Balitbang Departemen Pekerjaan Umum (2009), Balitbang Departemen Pekerjaan Umum. *ASBUTON*, in Bahasa Indonesia.
- [5] Chen, J.S.; Liao, M.C.; Tsai, H.H. (2002), Evaluation and Optimization of the Engineering Properties of Polymer-Modified Asphalt. *Journal PFANF8* (2002) 3:75-83, Practical Failure Analysis Volume 2(3) June 2002 *National Cheng Kung University*, Taiwan.
- [6] Airey, G. D., (2004), Styrene Butadiene Styrene Polymer Modification of Road Bitumens. *Journal of Materials Science in Civil Engineering ASCE*, access: December 2010.
- [7] Awanti, S.S.; Amarnath, M.S.; Veeraragavan, A., (2008). Laboratory Evaluation of SBS Modified Bituminous Paving Mix., *Journal of Materials in Civil Engineering ASCE*.
- [8] Al-Hadidy, Al.,Tan Yi-qiuz, (2011), Effect of Styrene-Butadiene-Styrene on the Properties of Asphalt and Stone Matrix Asphalt Mixture, *Journal of Materials in Civil Engineering, ASCE*, April 2011.
- [9] Tabatabaie, S.A., Ziari, Khalili, H.,M., (2008). Modeling Temperature and Resilient Modulus of Asphalt Pavements for Tropic Zones of Iran. *Asian Journal of Scientific Research*,
- [10] Freddy J Sanchez-Leal, (2007), Gradation chart for Asphalt Mixes: Development, *Journal of Materials in Civil Engineering, ASCE*, February 2007.
- [11] Airey, GD., Hunter, AE., Collop, AC., (2007), The effect of asphalt mixture gradation and compaction energy on aggregate degradation, *Journal of Engineering Construction and Materials*, January 2007 (on-line).

# The Urban Transportation System and Fuel Consumption of Metropolitan and Large Cities In Java

Dr. Ir. Mudjiastuti Handajani, M.T

Civil Engineering, Semarang University, Semarang 50196  
E-mail : hmudjiastuti@yahoo.co.id

## ABSTRACT

*The urban transportation system includes the number of private passenger cars, private buses and motor cycles, public buses and public passenger cars, goods transportation vehicles, road length, and route length. The fuel consumption is greatly influenced by the city typology (land use management, population size, population density, RGDP). Both transportation and fuel consumption are very strategic because they are related with the local, national, and global-scale economy and environment.*

*The data were analyzed by using a multivariate-multivariable analysis, including a co-relational analysis, Biplot and a multivariable regression analysis. Metropolitan and large cities in Java have the following characteristic: city typology, transportation system, bigger fuel consumption than medium cities. The effect of the population on the fuel consumption is very great.*

*The urban transportation that can make efficient fuel consumption: small percentage and number of vehicles (private and goods vehicles), route efficiency, the public transportation services with a large capacity, grid road network, land use management (compact). The fuel consumption is influenced by the urban transportation system and city typology. All integrated influential variables can reduce fuel consumption, can reduce subsidy on the fuel consumption, can increase health, and increase state economy.*

### Keywords:

*city typology, fuel consumption, Java, transportation system, urban transportation.*

## 1. INTRODUCTION

State that the concept of sustainable transportation becomes both a foundation and challenge for effective development and implementation [18]. One of the challenges of *sustainable transportation* is the *urban resource conserving mobility* [4], [5] or by developing a transportation mobility strategy in the country [24].

Improving the city transportation system, especially that is triggered by the increase of private vehicle ownership and usage negatively has some impacts on the city, like traffic jams and accidents, space usage, environmental preservation (exhaust gas emission, air pollution, energy resource exploitation, etc.). This occurs in large cities of both developed and developing countries, like Rio de Janeiro, Mexico City, Jakarta, New Delhi, and Bangkok.

States that sustainable transportation is related to collective and integrated management of fossil fuel consumption, vehicle exhaust gas emission, safety, traffic jams and social economy towards future sustainability without causing problems for future generations around the world [23]. Therefore, an environment-based transportation is needed by taking potential environmental implications and impacts into consideration, especially air pollution, noise pollution and energy consumption. These impacts trigger the *sustainable urban city transportation system*, which is a concept involving several systems and is cross-disciplinary and requires a holistic analysis.

Biplot is a *multivariate multivariable* statistics technique which can be displayed visually to simultaneously demonstrate the  $n$  observed object and the  $p$  variable on a two dimensional space for the variable and observed object characteristics and the relative position between observed objects with the analyzable variable. So, the Biplot can show the relationship between variables, the relative similarities between observed objects, as well as the relative position between the observed object and the variable [13].

The objective of this study is to investigate the effect of city typologi and urban transportation system on the fuel consumption of Metro and Large Cities in Java.

## 2. LITERATURE REVIEW

According to [6], with respect to fossil fuel consumption in the United States, 80% of the transportation sector is taken up by land transportation, 20-30 % uses truck and buses. [9] Considers trucks carrying goods consume up to 30-40% of the transportation fossil fuel consumption. In Indonesia, the national economy growth has increased the number of private vehicle ownership and usage in the city area. Private vehicle ownership has increased significantly compared to public transportation, therefore also increasing fossil fuel consumption. According to [12], to reduce fossil fuel consumption, we need to reduce the number of private vehicles. In reality, the number of private vehicles in Indonesia actually rises each year. The number of vehicles and fossil fuel consumption in Indonesia during 1983-2003 can be seen in Figure 1[8].

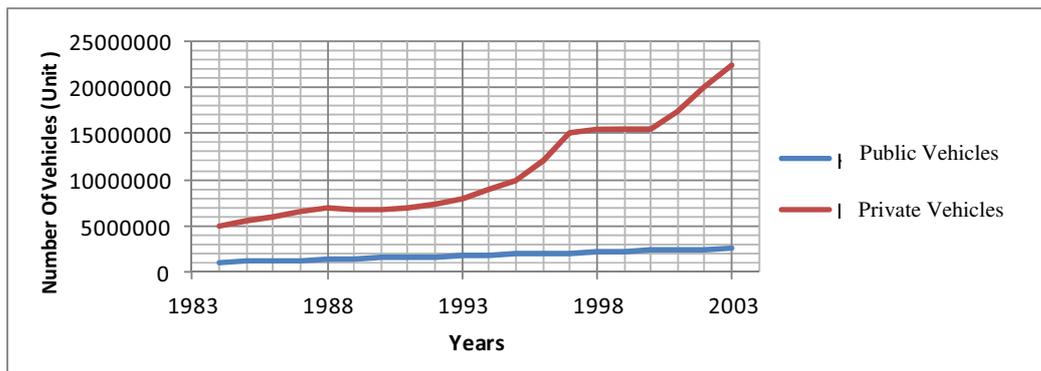


Figure 1. Number of Vehicles in Indonesia 1983-2003

In the United States, between 1970 and 1995, there was a large gap between the supply or production of fossil fuel and the need for fossil fuel for transportation. This fact is considered worrying because the transportation sector is currently heavily reliant on unrenrenewable fossil fuel that is rare and decreasing. Declining supplies affect the rising price of fossil fuel, impacting the creation of wide external factors towards the national social-economy condition. In Indonesia, the growth of fossil fuel need is bigger than the government's capability in providing subsidies [21]. Some developing country governments are forced to provide subsidies for the people to be able to access the rising prices of fossil fuels. Figure 2 shows energy consumption in Indonesia based on their resources [8].

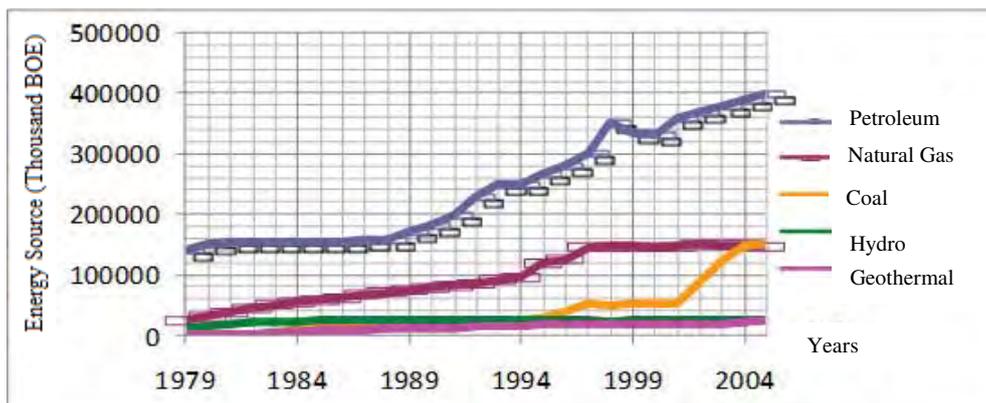


Figure 2. Energy Consumption in Indonesia Based on Resources

Because road transportation consumes fossil fuel the most, reaching 70 % (for developing countries) [15], and even in Australia energy needs for transportation reaches 80% [17], this transportation sub-sector requires attention in several policies, planning and research. According to [1], the fossil fuel consumption for each vehicle's transportation needs is different. The calculation for each vehicle's fossil fuel consumption can be seen in Table 1.

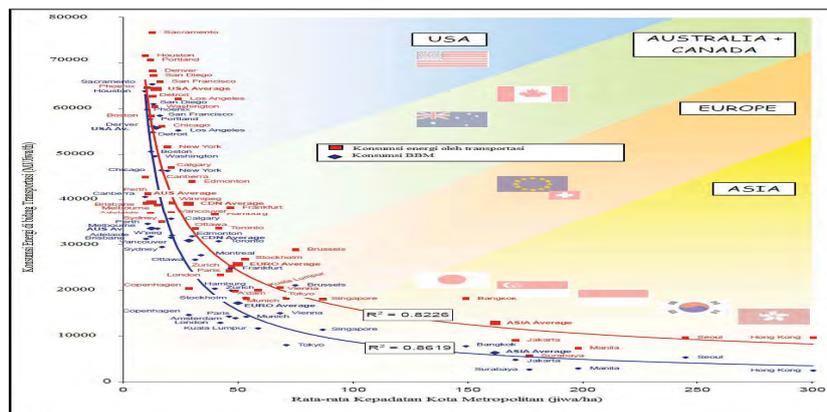
Table 1. Fossil Fuel Consumption Intensity Calculation

Type of Vehicle	energy intensity				
	km / l	liters / km	km / day	liters / day	liters / year
<b>Gasoline</b>					
sedan	9,0	0,111	17,50	1,94	700
carriage	9,0	0,111	17,50	1,94	700
mid / light truck	11,0	0,091	150	13,64	4909
pick up	11,0	0,091	30	2,73	982
microbus	11,0	0,091	183,33	16,67	6000
jitney	11,0	0,091	152,78	13,89	5000
ambulance	9,0	0,111	10	1,11	400
jeep	5,0	0,200	13,89	2,78	1000
Bentor	20,0	0,050	88,17	4,41	1587
motorcycle	30,0	0,033	35	1,17	420
<b>diesel oil</b>					
carriage	7,0	0,143	18,06	2,58	929
mid / light truck	6,0	0,167	158,33	26,39	9500
tanker	6,0	0,167	158,33	26,39	9500
heavy equipment	0	4,000	6,61	26,44	9520
pick up	11,0	0,091	107,77	9,80	3527
mid / macro bus	8,0	0,125	214,80	26,85	9666
mini / light bus	9,0	0,111	244,50	27,17	9780

### The Impact of Land Use (LU)

According to [10], the effect of city growth developing through a concentric typology or a single city center saves fossil fuel consumption more than a city typology with several city centers. This is in accordance with [12], and [11], the city form influences energy use. There is a conservative view stating that the current land use will not change much even if there is a change in the public transportation system. According to [22], the empirical reality always proves that land use has a strong correlation to city transportation because the land use determines the size and distribution of movement, influencing travel movement, transportation modes used and fossil fuel consumption.

The impact of land use on fossil fuel consumption is not only caused by the type of land use, but also the influence of the intensity in using the land of which can be demonstrated through population density. Rising population density allows higher possibility for *mixed use* to happen. Areas with lower population density have higher per capita fossil fuel use, on the contrary, areas with high population density have lower per capita fossil fuel use. The land use and transportation cycle can be seen in Figure 3.



Source: [16]

Figure 3. The Relation between Per Capita Energy Use and Density in Cities

Figure 3 shows the relation between fossil fuel/capita and population density in cities, by sampling 84 cities in the world [16]. The study conducted by [2],[3], shows that rising population density in West Europe does not always lower vehicle ownership which would lower fossil fuel consumption, but the people or population's travel route in the city is more determining. Likewise, according to [7], studying cities in Asia (including Indonesia), fossil fuel consumption has a low correlation with population density. Research in Indonesia shows that fossil fuel consumption is influenced by travel patterns, meanwhile travel patterns are influenced by the location of activity centers (residences, shopping centers, offices, schools, hospitals, etc.) [20].

### 3. METHODOLOGY RESEARCH

Fuel consumption data is taken from the gas station to purchase Pertamina 2007-2008. The data analysis will involve many variables and indicators, so a multivariate multivariable analysis, that is an application method that deals with large number of measurement (more than one independent variable and one dependent variable) of the objects simultaneously conducted. Analysis of the characteristics of the fuel consumption, the typology of cities and the transport system using biplot The proposed analysis of the relationship between transportation system and fuel consumption of the cities in Java is made in accordance with the theoretical framework as illustrated in Figure 4.

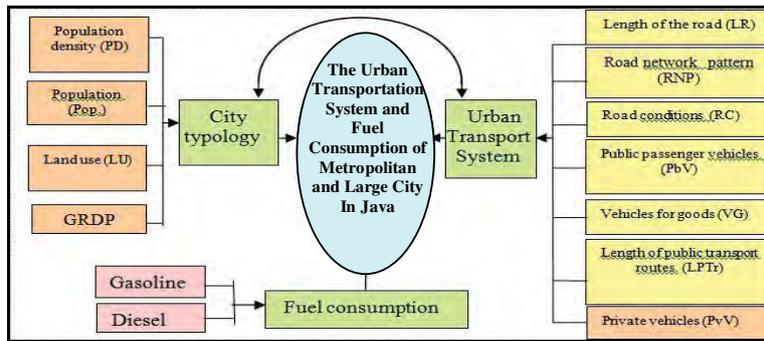


Figure 4. Theoretical Framework for Urban Transportation Model System and Fuel Consumption Of Metropolitan and Large City In Java

### 4. ANALYSIS

#### 4.1. Fossil Fuel Consumption Characteristics in Cities in Java

The analysis results show that large and medium-sized cities can be grouped together and are positioned opposite of the direction of the line, meaning that large and medium-sized cities share similarities in fossil fuel consumption (petrol, diesel oil and both), in that they have low consumption of petrol fuel, diesel oil and both, whereas metropolitan cities (Semarang, Tangerang, Surabaya, Bekasi and Bandung) are spread out, meaning that each city is different in its fossil fuel consumption. Bandung has the highest petrol fuel consumption. Tangerang and Semarang has the highest diesel fuel consumption, the highest two types of fuel consumption is Surabaya, with almost equal percentages of petrol and diesel fuel consumption. The Biplot fossil fuel consumption analysis results can be seen in Figure 5 below.

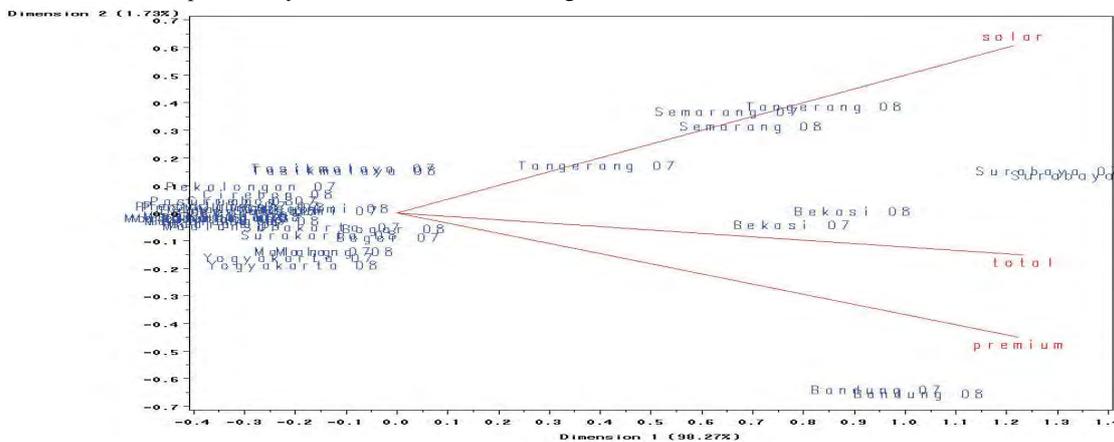
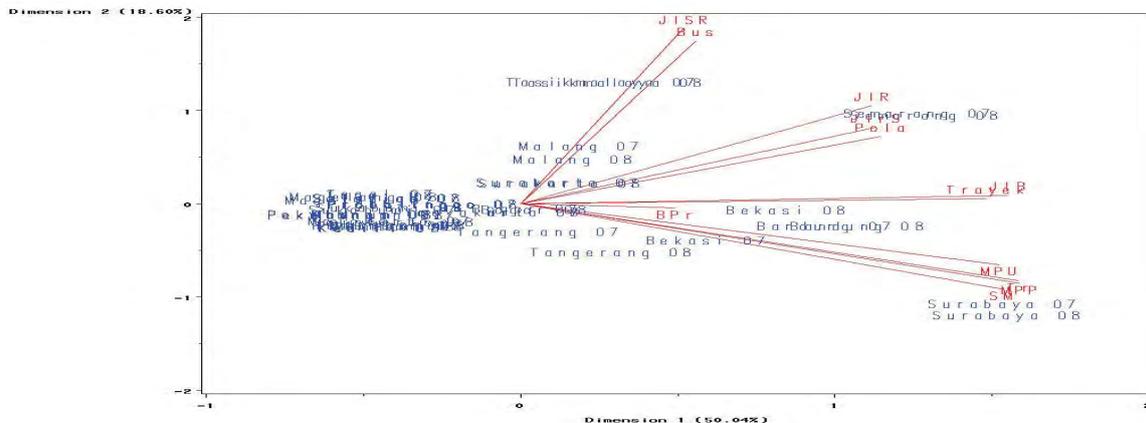


Figure 5. Biplot Fossil Fuel Consumption Analysis Results

#### 4.2. City Transportation System Characteristics in Java

Large cities are within the middle group. This shows that large cities have the following transportation system characteristics: a) road length, b) road condition (good, fair, damaged, very damaged), c) goods vehicles (trucks), d) public transportation vehicles (buses and public passenger cars), e) route length of public transportations, f) personal vehicles (buses, passenger cars, motorcycles) are not too apparent when compared to metropolitan cities. The Biplot city transportation system analysis results can be seen in Figure 6 below. Metropolitan cities consisting of: Semarang, Surabaya, Bandung, Bekasi and Tangerang have different prominent transportation system characteristics. This is evident from their spread out positions. Semarang has the

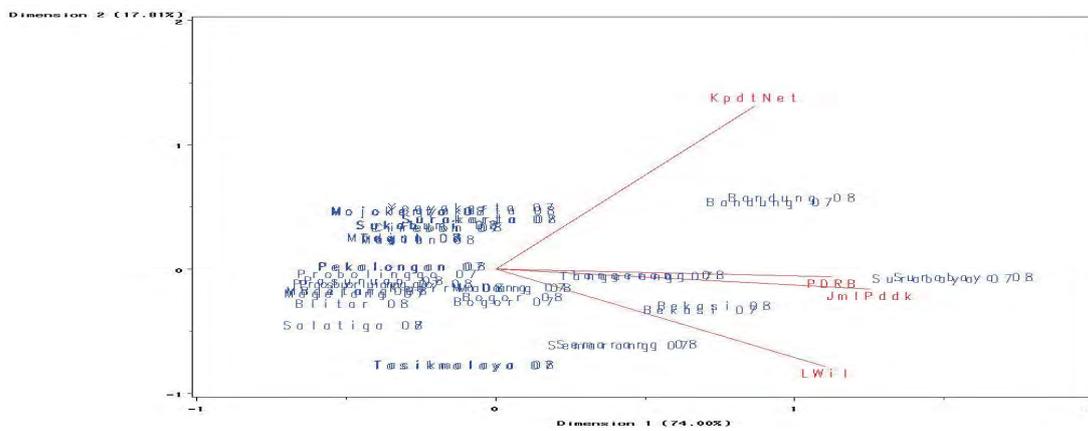
longest road length. Surabaya has the largest number of public passenger cars, motorcycles and trucks. Bekasi has a prominent number of private passenger cars. Bandung has prominent public passenger cars, truck and motorcycles.



Source: [14], 2010  
 Figure 6 Biplot City Transportation System Analysis Results, All Cities

### 4.3. City Typology Characteristics in Java

The variables of city typology consists of the number of population, the nett area (area based on the width of developed areas), population density (based on developed areas), and RGDP (based on current prices). Analysis results show that there is grouping of the position and proximity between objects of city typology in Java. This shows that there are resemblances or similarities, meaning the cities have a relatively similar city typology. Cities grouped together are medium-sized and large cities. These cities have similar city typology, which is a low population number, low population density, low PRDB and low developed area. Metropolitan cities are widely spread or not grouped together, meaning each city has a different prominent city typology. Bandung has a high population density nett, Surabaya has the highest number of population and RGDP, and Semarang has the largest area. The Biplot city typology analysis results can be seen in Figure 7 below.



Source: [15], 2010  
 Figure 7 Biplot City Typology Analysis Results

### 4.4. Fossil Fuel Consumption Model of Metropolitan and Large Cities in Java

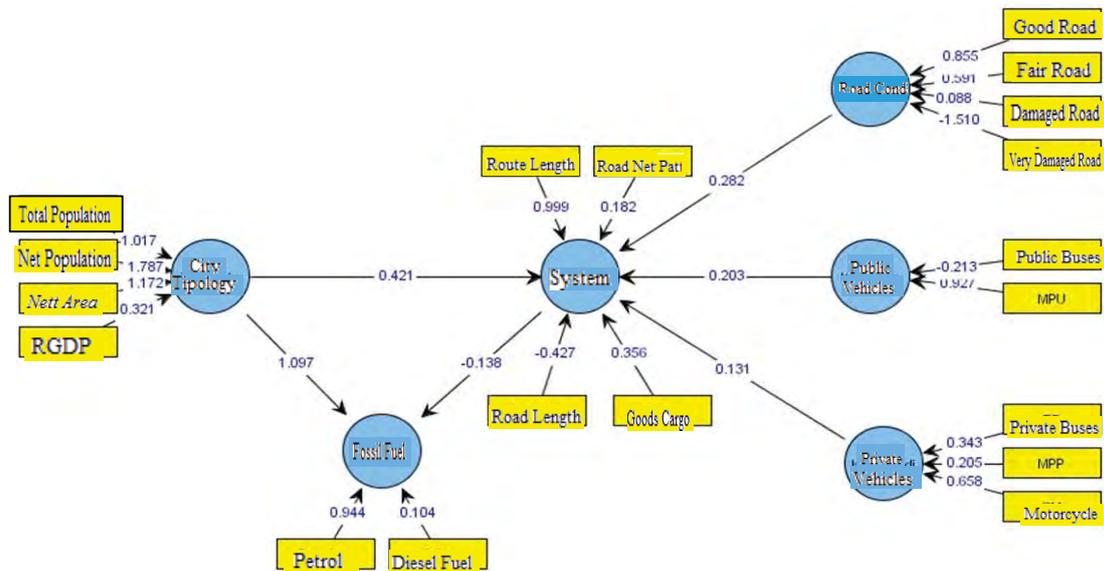
Petrol fuel consumption highly influences total fuel consumption, yet not so for diesel fuel. Diesel fuel has a low and negative effect on total fossil fuel consumption. The higher the petrol fuel consumption, the higher the total fossil fuel consumption, but the higher the value of diesel fuel, the lower the value of fossil fuel consumption. City typology influences the city transportation system. The effect of the city typology on fossil fuel consumption for metropolitan cities are far bigger compared to the effect of the city transportation system on fossil fuel consumption. The higher the value of city typology is, the higher the fossil fuel consumption will be. The higher the value of the city transportation system is, the lower the fossil fuel consumption will be. The metropolitan city population density nett and developed areas variables have the biggest impact on

city typology. The same applies for the transportation system variable: route length, good condition of roads, public passenger cars and motorcycles have a big impact on the city transportation system.

The population size in metropolitan cities is much higher than large and medium-sized cities, so fossil fuel consumption in metropolitan cities is much higher compared to large cities and medium-sized cities. Rising fossil fuel consumption in metropolitan cities is influenced more by the rise of RGDP rather than the rise of population. The higher the population, the higher the value of city typology, and this will raise fossil fuel consumption. The same applies for a rise in RGDP in metropolitan cities, where the higher the RGDP is, the higher the fossil fuel consumption will be. Population density in metropolitan cities has a big effect on city typology, so the higher the population density is, the higher the fossil fuel consumption will be.

The rise of the value of city typology is influenced more by the population number, population density nett and developed area as well as RGDP. So if the population size, population density nett and developed area as well as RGDP rise, the value of city typology also rises, therefore increasing fossil fuel consumption. In reality on the field, metropolitan cities have a higher population density nett, a wider developed area and a higher RGDP compared to large cities and medium-sized cities. Metropolitan cities generally have a wider administrative area than other cities but also a higher population density, so fossil fuel consumption, if viewed from the number of vehicles by the length of the road and population density nett divided by the city's branches, has a smaller angle. The longer the roads is, the lower the value of the transportation system will be. This will increase fossil fuel consumption.

The number of motorcycles in metropolitan cities is higher than any other private vehicles. Although the fossil fuel consumption, especially petrol fuel, per motorcycle is smaller than for passenger cars, but the impact of motorcycles toward private vehicles is high, therefore, increasing petrol fuel consumption with the increasing number of motorcycles. The number of private passenger cars vehicles greatly affect private vehicles, meaning the higher the MPP vehicles are, the higher the value of private vehicles and the higher the value of the transportation system will be, which will eventually reduce fossil fuel consumption. The data analysis using Structural Equation Modelling PLS (Partial Least Square) has produced *Bootstrapping*, and has produced an impact model of the city transportation system on fossil fuel consumption which can be seen in Figure 8 below.



Source: [14] 2011

Figure 8. Metropolitan and Large Cities Fossil Fuel Consumption Model

The metropolitan cities in Java fossil fuel consumption model can be explained as below:

If the length of the road increases in value by 1 unit, the system's value will decrease 0.427. If trucks increase in value by 1 unit, the system's value will increase 0.356. If the route length increases in value by 1 unit, the system's value will increase 0.999. If the road network patten increases in value by 1 unit, the system's value will increase 0.182.

The road condition is classified into good roads, fair roads, damaged roads and non-damaged roads. If the road condition increases in value by 1 unit, the system's value will increase by 0.282. If the good road condition increases in value by 1 unit, the road condition value will increase by 0.855. If the fair road condition increases in value by 1 unit, the road condition value will increase by 0.591. If the damaged road condition increases in value by 1 unit, the road condition value will increase by 0.088. If the very damaged road condition increases in value by 1 unit, the road condition value will decrease by 1.510.

will increase by 0.591. If the damaged road condition increases in value by 1 unit, the road condition value will increase by 0.088. If the very damaged road condition increases in value by 1 unit, the road condition value will decrease by 1.510. A good road condition greatly impacts the road condition value.

The public vehicle value is formed from public buses and public passenger cars. If public buses increase by 1 unit, the public vehicle value will decrease by 0.213. If public passenger cars increase by 1 unit, the public vehicle value will increase by 0.927. The private vehicle value is formed from private buses, private passenger cars and motorcycles. If private buses increase by 1 unit, the private vehicle value will increase 0.343. If private passenger cars increases by 1 unit, the private vehicle value will increase by 0.205. If motorcycles increase by 1 unit, the private vehicle value will increase by 0.658.

If the population increases by 1 unit, the typology value will increase by 1.017. If the population density increases by 1 unit, the typology value will increase by 1.787. If developed area increase by 1 unit, the typology value will increase by 1.172. If RGDP increases by 1 unit, the typology value will increase by 0.321.

Fossil fuel consumption in cities in Java can be explained as follows: if the typology increases by 1 unit, fossil fuel consumption will rise up to 1.097 kilo liters per year, but if the system increases by 1 unit, fossil fuel consumption will decrease 0.138 kilo liters per year. So the above explanation can be put into the following equation:

$$\text{Road Condition} = 0,855*\text{Good Road} + 0,591*\text{Fair Road} + 0,088*\text{Damaged Road} - 1,510*\text{Very Damaged Road} \quad (1)$$

$$\text{Public Vehicles} = -0,213*\text{Public Buses} + 0,927*\text{MPU} \quad (2)$$

$$\text{Private Vehicles} = 0,343*\text{Private Buses} + 0,205*\text{MPP} + 0,658 * \text{Motorcycles} \quad (3)$$

$$\begin{aligned} \text{System} = & -0,427*\text{Road Length} + 0,182*\text{Road Network Pattern} + 0,282* \text{Road Condition} \\ & + 0,203*\text{Public Vehicles} - 0,131* \text{Private Vehicles} + 0,999* \text{Route Length} + 0,356 * \text{Goods Cargo} \\ & + 0,421 * \text{City Typology} \end{aligned} \quad (4)$$

$$\text{City Typology} = 1,017*\text{Population} + 3,378* \text{Net Population Density} + 1,172* \text{Nett Area} + 0,321*\text{RGDP} \quad (5)$$

$$\text{Fossil Fuel (outer)} = 0,944*\text{Petrol} + 0,104*\text{Diesel Fuel} \quad (6)$$

$$\text{Fossil Fuel (inner)} = 1,097*\text{City Typlogy} - 0,944*\text{System} \quad (7)$$

The number of public passenger cars strongly influences public vehicles, the more public passenger cars are, the higher the value of public vehicles and the higher the value of the transportation system will be. This will eventually lower fossil fuel consumption. Public transport buses have a relative (negative) effect on the metropolitan cities transportation system. The more buses are, the lower the value of public vehicles will be, and also the lower the transportation system value is, therefore increasing fossil fuel consumption. This is caused by the number of public transport buses that is lower than the required amount.

The route length in metropolitan cities greatly affects the city's transportation system. The longer the route length of city public transportation (wider service area of public transportation) is, the higher the transportation system value will be, which will lower the fossil fuel consumption. Good road conditions in metropolitan cities greatly affects the city transportation system, the longer the good road condition is, the higher the transportation system value will be, which will lower fossil fuel consumption. Goods transportation has a fair effect on the city transportation system.

The dependent variable is fossil fuel consumption (petrol and diesel oil) and the independent variables are city typology (population size, nett area, population density nett, RGDP) and transportation system (road length, road network pattern, number of public vehicles, number of private vehicles, number of goods vehicles, road length based on road condition (good, fair, damaged, and very damaged).

## 5. CONCLUSION

The city transportation system and city typology have reciprocal effects. Fossil fuel consumption in metropolitan cities are more influenced by the city typology (population size, nett area, nett population density, RGDP) than by the city transportation system. This is because the currently available transportation system has not been provided well and the management of land use has not been implemented well.

The city transportation system consuming fossil fuel efficiently is a city transportation system with public transportation services using large capacity vehicles, efficient routes, low percentage and number of vehicles (private and goods), road network pattern using *grid*, and a compact *land use*. The transportation system consuming a lot of fossil fuel is the city transportation system providing small capacity public transportation services, inefficient routes, high percentage and number of vehicles (private and goods), a radial road network pattern, and a *land use* that is not compact (for example: Semarang, Bandung, Tangerang).

## REFERENCES

- [1] Boedoyo Sidik, 2007, *Analisis Kebutuhan and Penyediaan Bahan Bakar Minyak di Sektor Transportasi di Propinsi Gorontalo*, Perencanaan Energi Propinsi Gorontalo 2000-2015, Gorontalo.
- [2] Bertraud A. and Richardson, W., 2004, *a. Transit and Density: Atlanta, The United States and Western Europe*, in *Urban Sprawl in Western Europe and The United States*, Urban Planning and Environment, Ashgate.
- [3] Bertraud, A. and Richardson. W., 2004, *b. the United States and Western Europe*, in *Urban Sprawl in western Europe and United States*, Urban Planning and Environment, Ashgate.
- [4] Carrol, T.A., 1977, *Calculating Community Energy Demand*. In *Energ and the Community*, edited by R.J. Burby and A. Flemming Bell. Cambridge, MA: Ballinger.
- [5] Cheng-Min F., and Cheng-Hsien H., 2007, *The Implicaion of Transort Diversity for Sustainable Urban Transportation*, Journal of The Eastern Asia Society for Transportation Studies, Vol. 7, 1236-1249.
- [6] Davis, SC., 1994, *Transportation Energy Data Book: Edition 14 ORNL-6798*. Center for Transportation Analysis. Energy Division, Oak Ridge National Laboratory.
- [7] Departemen ESDM, 2004.
- [8] Doi Naoko, 2007, *Urban Transport Energy Use in the APEC Region Trend and Option*, Asia Pacific Energy Research Centre.
- [9] Duleep KG, 1995, *Emission and Energy Characteristic of Heavy Duty Diesel- Powered Truck and Buses*, Energy and Environmental Analysis, Inc.
- [10] Goro O. M., 2003, *The Indicators of Minority Transportation Equity (TE)*, Sacramento Transportation & Air Quality Collaborative Community Development Institute.
- [11] Kanaroglou, PS and Robert South, 1999, *Energy Studies Review Can Urban Form Affect Transportation Energy Use and Emissions?* Vol 9 Issue 2 article 5, Barkeley Electronic Press. <http://digitalcommons.mcmaster.ca/esr>.
- [12] Kanaroglou, PS and W.P Anderson, 1997, *Emission Form Mobile Source In Urban Areas: An Integrated and Transportation and Landused Approach*, Proceedings, Fifth Conference of Environmental Science and Technology, Molyvos, Lisvos, Greece.
- [13] Kurnia A., 2002, *Analisis Biplot and Rantai Markov untuk Menelaah Perilaku Konsumen Majalah Berita Mingguan*. Forum Statistika and Komputasi. Jurnal Publikasi.
- [14] Mudjiastuti Handajani, 2010, *Analisis Struktur Kota di Jawa Terhadap Konsumsi BBM Dengan Menggunakan BIPLLOT*, Media Komunikasi Teknik Sipil Terakreditasi:23a/Dikti/Kep/2004, MKTS No.1 Tahun 18.
- [15] Mudjiastuti Handajani, Pinardi, Bambang Riyanto, 2010, *Analisis Hubungan Karakteristik Sistem Transportasi Kota-Kota di Jawa Terhadap Konsumsi BBM Dengan Menggunakan BIPLLOT*, Prosiding Simposium FSTPT 13, ISBN 979-95721-2-13.
- [16] Newman, P.W.G and Kenworthy J., 1999, *Sustainability and Cities: Overcoming Automobile Dependence Washington DC*: Island Press.
- [17] Official Nebraska Government Website, 2003, *Energy Consumption Transportation Sector*, Nebraska.
- [18] Pearce and Warford, 1996, *World Without End*, World Bank, Oxford University Press pp 43-44.
- [19] Repogle Michael, 2006, *SAFETEA–Transportation Reuthorization : Environmental Scorecard*, update Edition, Environmental Defense Finding The Way That Work.
- [20] Sukarto Haryono, 2006, *Transportasi Perkotaan and Lingkungan*, Jurnal Teknik Sipil vol.3 no 2.
- [21] Tim Pemantau and Evaluasi Kinerja Transportasi nasional (TPEKTN), 2008, *Urgensi Kebijakan and Program Komprehensif Dalam Penghematan BBM Transportasi*.
- [22] Wegener Michael, 2003, *A Land Use – Transportation Perspective of Urban Processes*.
- [23] Williams K., 2005, *Spatial Planning, Urban Form and Sustainable Transport: An Introduction*.
- [24] World Bank, 2006, *A Panorama of Urban Mobility Strategies in Developing Countries*, Hubert Metge, Aurelie Jehanno, Systra.

# The Influence of Grout Containing Fly Ash on The Tensile Strength of Grouted Macadam

Setyawan A.<sup>a</sup>, Zoorob, S.E.<sup>b</sup>, Nalarsih R.T.<sup>c</sup>

<sup>a</sup>Faculty of Engineering, University of Isebelas Maret, Surakarta 57126  
E-mail : [cenase@yahoo.com](mailto:cenase@yahoo.com)

<sup>b</sup>Faculty of Engineering, University of Leeds, Leeds LS2 9JT, UK  
E-mail : [s.e.zoorob@yahoo.com](mailto:s.e.zoorob@yahoo.com)

<sup>c</sup>Faculty of Engineering University of Bangun Nusantara, Sukoharjo 57551  
E-mail : [auronesia@yahoo.com](mailto:auronesia@yahoo.com)

## ABSTRACT

*Grouted Macadam*s are manufactured by producing a very open porous asphalt skeleton and filling the voids with selected cementitious grouts, the final product is combination of the flexibility of the bituminous component with the strength and rigidity of the cementitious component. A range of cementitious grouts was formulated using a variety of binders including ordinary Portland cement, silica fume and fly ash. The grouts were designed to provide improved strength and performance characteristics with reduced water/binder ratios, whilst maintaining high workability. This was achieved with the aid of chemical admixtures that allowed the grouts to penetrate the porous asphalt skeleton by gravitational. The formulated cementitious grouts attained high strength characteristics (90-120 MPa at 28days), with the pozzolanic materials silica fume and fly ash, providing improved permeability and shrinkage properties. This paper is discussing the influence of grout properties containing fly ash especially on the indirect tensile properties of grouted macadam. It is concluded that the indirect tensile strength of grouted macadam were greatly affected by the cementitious grout type, in general the higher the compressive strength of the cementitious grout, the higher the tensile properties of the hydrated grouted macadam.

## Keywords

*Grouted macadam, fly ash, indirect tensile strength*

## 1. INTRODUCTION

The tensile properties of materials govern the cracking behaviour and affect other properties such as stiffness and fatigue behaviour of the materials. Tensile strength can be determined either by direct tensile tests or by indirect tensile tests such as flexural or split cylinder tests. Due to the difficulty in testing, only limited and often conflicting data are available on direct tensile tests. It is often assumed that the direct tensile strength of concrete is about 10% of its compressive strength [1].

The indirect tensile test was introduced to measure the tensile properties of pavement materials due to its many practical advantages as summarised by Kennedy [2]:

- (1) the test is relatively simple to carry out,
- (2) the type of specimen and the equipment are the same as those used for other testing, for instance using cylindrical specimens,
- (3) failure is not seriously affected by surface conditions and is initiated in a region of relatively uniform tensile stress,
- (4) the test can be conducted under static or repeated loading conditions, and provides information on:
  - a. the tensile strength, modulus of elasticity, and Poisson's ratio for both static and repeated loads,
  - b. fatigue characteristics,
  - c. permanent deformation characteristics of pavement materials.

The indirect tensile test is carried out on a cylindrical specimen by loading it with a single or repeated compressive load which acts parallel to and along the vertical diametrical plane of the specimen. This loading system develops a relatively uniform stress perpendicular to the direction of the applied load and along the vertical diametrical plane, thus ultimately causing failure of the specimen by splitting along the vertical diameter. The stress state in the surroundings of the centre of the circular face of an indirect tension specimen is similar to the stress state that occurs at the underside of a bituminous road layers.

Grouted macadam have visco-elastic properties similar to flexible pavements. The tensile properties of grouted macadam covered in this investigation were mainly the indirect tensile strength (ITS), the indirect tensile stiffness modulus (ITSM) and the indirect tensile fatigue test (ITFT) [4]. These tests were conducted at several temperatures and at a range of curing ages. Flexural strength testing was additionally carried out to enable a direct comparison to be carried out between the flexural

strength of grouted macadams and those of a typical concrete at 28 days curing. Grouted macadam test results were thus compared to the properties of bituminous mixtures and concrete.

## 2. RESEARCH METHOD

### 2.1 Materials preparation

#### 2.1.1. Materials for cementitious grouts

The cement used through out this investigation was ordinary Portland cement (OPC) supplied by Castle Cement Limited. The OPC complied with requirements of BS 12 (BS 1996). The properties of OPC are presented in Table 3.7. Quartzitic sand obtained from Tyhram Hall Quarry supplied by Tarmac Northern Ltd. was sieved, and the material passing 300µm was used as fine sand for the cementitious mortar. The water used in this investigation was tap drinking water from Yorkshire Water. The fly ash used in this investigation was produced at Drax Power Station and supplied by National Power plc. U.K. The ash conforms to BS 3892: Part 1 (BSI 1997). Table 3.6 gives the chemical composition of the Fly Ash use. Powdered silica fume was supplied by Elkem Chemical. The chemical composition is also presented in Table 1.

Table 1: Chemical composition of OPC, fly ash (FA) and silica fume (SF).

	<i>Ordinary Portland cement %</i>	<i>Fly ash %</i>	<i>Silica fume %</i>
SiO <sub>2</sub>	21.03	49.9	90.0
Al <sub>2</sub> O <sub>3</sub>	4.73	26.5	1.21
Fe <sub>2</sub> O <sub>3</sub>	2.93	8.1	3.87
CaO	63.63	1.7	0.34
MgO	2.67	1.3	1.43
SO <sub>3</sub>	3.00	0.9	0.31
K <sub>2</sub> O	0.65	3.6	1.49
Na <sub>2</sub> O	0.30	1.5	0.46
Loss on Ignition	0.97	3.8	2.17

#### 2.1.2 Superplasticizer

The use of chemical admixtures is an essential requirement for the production of flowable high performance slurries. A superplasticiser (SP) based on modified polycarboxylic ether was used with all the cementitious mixes, which complied with BS 5075: Part 3 (BSI 1985). This chemical admixture was supplied by Feb MBT Ltd. in liquid form. Technical data as supplied by supplier is presented in Table 2.

Table 2: Properties of superplasticiser

Appearance	Viscous liquid
Colour	brown
Specific gravity	1.1
pH	6
Alkali content (as Na <sub>2</sub> equivalent)	< 5g/l
Chloride Ion content	< 0.1% w/v
Hazardous ingredients	none

## 2.2 Cementitious grout mixture design

### 2.2.1 Binder compositions and fresh properties of the grouts

It is now generally accepted that mineral and chemical admixtures are essential requirements for the production of concrete. In addition to their dramatic effect of on the reduction of mortar porosity, they improve the packing capacity at the interface with the aggregates and thus create a tighter pore structure of the composite [5].

Three main cementitious binders were used in this investigation with the composition and binder/cement ratios as shown in Table 3. The first type was used as a control mixture by incorporating 100% ordinary Portland cement (OPC). The second type

was formulated by adding 5% of silica fume (SF) and the third cementitious binder was formulated by adding 30% of fly ash (FA).

Table 3: Composition and fresh grout properties of the different grouts used in this investigation

Grout	Composition	Super-plasticiser	W/B*	Workability index (seconds)	Setting time	
					initial	final
OPC	OPC 100	1%	0.28	9.50	3h. 05min.	4h. 10min.
SF	OPC: SF 95: 5	1%	0.28	9.10	3h. 35min.	4h. 30min
FA/SF	OPC: FA: SF 65: 30: 5	1%	0.28	10.32	3h. 50min	4h. 55min

W/B\* = water/binder ratio, binder is defined as blend of OPC or OPC and mineral admixtures

The proportions of mineral admixtures as cement replacement can vary from 5% to 80% by mass of cement. In normal structural concrete containing 5% silica fume addition, the water demand is normally increased to maintain the desired workability otherwise a superplasticiser is added [6]. In this investigation, the water/binder ratio was selected to produce grout flow times between 8-11 seconds as measured using the Leeds flow cone. Several initial trials indicated that by adding 1% superplasticiser by mass of binder to a grout with a water/binder ratio of 0.28 produced grouts that had satisfactory workability. Ease of impregnation was also assessed using dummy porous asphalt samples to ensure full depth penetration of the grout into the porous asphalt.

### 2.2.2. Strength properties

Both silica fume and fly ash are industrial waste by products and are very well known as mineral admixtures or supplementary cementing materials. In many cases these mineral admixtures react more slowly than OPC, giving increased strength and improved impermeability to the hardened cement paste at later ages.

The strength property of various cementitious grouts, at various curing ages is presented in Table 4. and graphically shown in Figure 1.

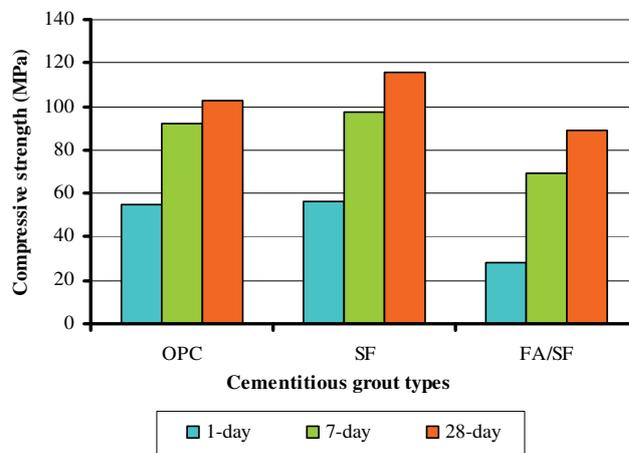


Figure 1: Compressive strength of three main types cementitious grouts

Table 4: Compressive strength of the cementitious grouts

Grout	Compressive strength (MPa)		
	1 day	7 days	28 days
OPC	55	96	102
SF	56	97	108
FA/SF	28	69	90

All the hydrated grout mixes showed little variation in bulk density (density values ranging from 1.85 to 2 g/cm<sup>3</sup>). However, the compressive strengths varied widely depending on the grout composition. As shown in Figure 1 the highest compressive strength values were found with the SF grout mixture. The 1-day compressive strength was 56 MPa, which increased to about 108 MPa at 28-days. The OPC showed similar strength to that of SF whereas fly ash grouts (FA/SF) resulted in a lower compressive strength at 1-day, but achieved a reasonably high value at 28-days. Both SF and FA are pozzolanic materials, which provide additional hydration products through their pozzolanic reaction to densify the cementitious matrix and improve the micro-structural properties [7]. Whilst Fly Ash adversely affects the strength gain at early ages, it contributes more to the strength development in the long term [8].

### 2.2.3 Performance properties

The performance properties of cementitious grouts at 28 days are presented in Table 5. Drying shrinkage results of the cementitious grouts up to 180 days are presented in Figure 2. The results, as shown in Table 5, indicate little variation within the calculated porosity values for the different cementitious binders, overall the results ranged between 29 and 31%. The effect of SF and FA replacement can be seen more clearly from the permeability and shrinkage results. Both replacement types are known to refine the pore structure of the cementitious composites and hence improve the performance properties. The pore refinement effect was reflected in the results, as both grout mixtures exhibited lower permeability and shrinkage than the OPC grout. The reduction in permeability was about 60% for the SF and 35% for the FA/SF, when compared to the OPC mix. SF and FA also reduced the drying shrinkage values by about 12-15%.

Table 5: Performance properties of the cementitious grouts measured at 28 days.

Grout	Porosity (%)	Oxygen permeability ( $10^{-17} m^2$ )	Shrinkage (micro-strain)
OPC	29.4	3.05	1803
SF	29.8	1.17	1518
FA/SF	30.9	1.95	1578

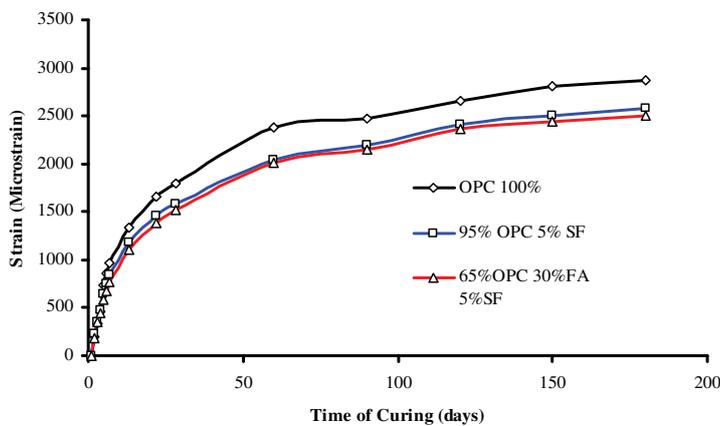


Figure 2: Drying shrinkage of the main type of cementitious grout up to 180 days

### 2.3 Indirect Tensile Strength Test

The indirect tensile strength test was conducted according to BS:99/108553 BS EN 12697-23 “Determination of the indirect tensile strength of Bituminous Specimens” (BSI 1999). The test was carried out using a Marshall loading frame fitted with a 12.5mm wide concave surface loading strip. The cylindrical specimens are subjected to compressive loads, which act parallel to and along the vertical diametrical plane. This creates uniform tensile stresses perpendicular to the direction of applied load and along the vertical diametrical plane, which ultimately causes the specimen to fail by splitting along the vertical diameter. Based upon the maximum load carried by a specimen at failure, the ITS is calculated from the following equation:

$$ITS = \frac{2 \times P_{max}}{\pi \times t \times d} \quad (1)$$

where: *ITS* = indirect tensile strength (kPa), *P<sub>max</sub>* = maximum applied load (kN),

$t$  = average height of specimen (m),  $d$  = diameter of specimen (m).

The tests were conducted at three temperatures (5, 20 and 60°C) to simulate various pavement conditions. To investigate the early strength development, the tests were also carried out at three curing ages (1, 7 and 28 days).

### 3. RESULTS AND DISCUSSION

Grouted macadam specimens produced using the same hot mix limestone porous asphalt skeleton with three types of cementitious grouts were subjected to the ITS test at three different temperatures. The tests were conducted after 28 days of curing. The results are presented in Table 6. and graphically displayed in Figure 3.

Table 6: The effect of cementitious grouts on ITS at different test temperatures

Material	Indirect tensile strength at 28 days (kPa)		
	5°C	20°C	60°C
HL/OPC-GM	1027	957	219
HL/SF-GM	1152	1050	220
HL/FA&SF-GM	943	935	206

At a test temperature of 5°C, the ITS values were approximately 110% higher than the ITS at 20°C. Increasing the test temperature from 20°C to 60°C, reduced the ITS of the specimens by approximately 80%. It was clear that the mechanical properties of grouted macadams, similar to conventional bituminous mixtures, were highly dependent on the test temperature. The visco-elastic nature of the binder in the porous asphalt skeleton was clearly reflected in the performance of the grouted macadams.

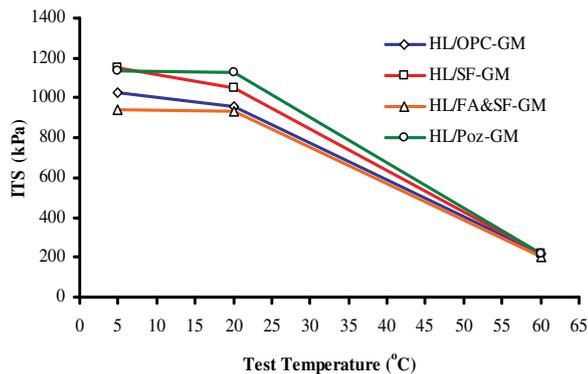


Figure 3: Effect of cementitious grout on the indirect tensile strength of grouted macadam at different test temperatures. Since all the results shown in Table 6. were of identical porous asphalt skeletons, it was clear that the properties of cementitious grouts also had a marked influence on the properties of grouted macadams. The relation between compressive strength of cementitious grouts and ITS of grouted macadam are presented in Table 7 and graphically displayed in Figure 4.

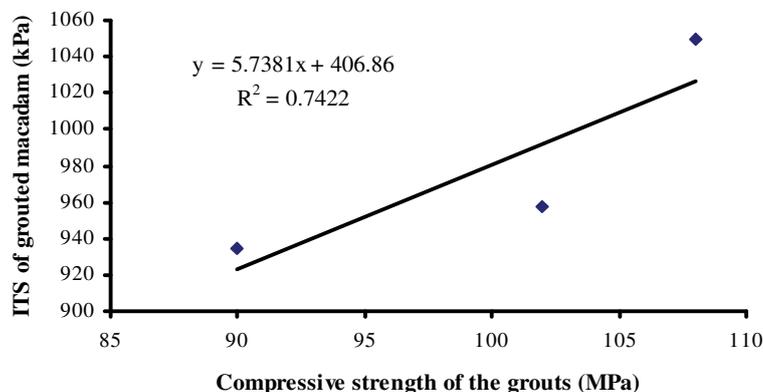


Figure 4: Relation between indirect tensile strength of grouted macadam and compressive strength of the grouts

In terms of ranking, it was clear that the strength of the hydrated cementitious grouts had a direct influence on the tensile strength of the respective grouted macadam.

Table 7: Relation between ITS and Compressive strength of cementitious grout

<i>Material</i>	<i>Compressive strength of cementitious grouts (MPa)</i>	<i>ITS of grouted macadam (kPa)</i>
HL/OPC-GM	102	957
HL/SF-GM	108	1050
HL/FA&SF-GM	90	935

#### 4. CONCLUSION

1. High workability cementitious grouts that can rapidly penetrate a porous asphalt skeleton by gravitational flow and provide adequate hydrated strength and performance properties were also successfully produced using combinations of readily available cementitious binders (including silica fume and fly ash) and chemical admixtures (superplasticizer).
2. The use of silica fume and fly ash were shown to enhance the porosity, permeability and shrinkage characteristics of the hydrated cementitious grouts
3. The indirect tensile strength of grouted macadam were greatly affected by the cementitious grout type, in general the higher the compressive strength of the cementitious grout, the higher the tensile properties of the hydrated grouted macadam.

#### REFERENCES

- [1] Zia, P., Leming, M.L. and Ahmed, S.H., 1994, High Performance Concrete: A State of the Art Report, Strategic Highway Research Program, National Research Council, Washington, D.C.
- [2] Kennedy, T.W., 1977, *Characterization of asphalt pavement matrilas using the indirect tensile test*, Proceeding of the Association of Asphalt Paving Technologist, vol. 46, pp. 133-150.
- [3] Rogue, R. and Buttlar, W.G., 1995, The development of measurement and analysis system to accurately determine asphalt concrete properties using the indirect tensile mode, Journal of the Association of Asphalt Paving Technologist, Vol.61, pp.304-332, Bookcrafters, Inc., Chelsea, MI.
- [4] Oliveira, J., Thom, N., and Zoorob, S. (2012). "Design of Pavements Incorporating Grouted Macadam." *J. Transp. Eng.*, 134(1), 7-14.
- [5] Hassan K.E., Cabrera J.G. & Head M.K. 1998, The influence of aggregate characteristics on the properties of high performance high strength concrete. In B.V. Rangan & A.K. Patnaik (eds), *Proceedings International Conference: High Performance High Strength Concrete*: 441-455, Perth-Australia.
- [6] Lohtia R.P. & Joshi R.M. 1995, Mineral Admixture, In Ramachandran (ed), *Concrete Admixture Handbook Properties Science and Technology*, Noyes Publication, USA, pp. 657-739
- [7] Mehta P.K. 1990, Durability of high strength concrete, In D Whiting (ed) *Proceeding of the Paul Klieger Symposium*: 19-27, ACI SP-122
- [8] Hassan, K.E.; Setyawan, A. & Zoorob, S.E., 2002, Non-Proprietary Cementitious Slurries for the Production of Semi-Flexible Bituminous Pavements, paper presented at 4<sup>th</sup> *European Symposium on Performance of Bituminous and Hydraulic Materials in Pavements*, University of Nottingham, 11/12<sup>th</sup> April 2002.

## **EVALUATION OF PRECAST SYSTEM STRUCTURE FOR A HISTORICAL BUILDING REHABILITATION**

**Kusno Adi Sambowo<sup>1</sup>), Agus Setiya Budi<sup>1</sup>), Budi Waluyo<sup>1</sup>) & Retno Susilorini<sup>2</sup>)**

*<sup>1</sup>Department of Civil Engineering, Faculty of Engineering, Sebelas Maret University  
Jalan Ir. Sutami 36a, Surakarta, Central Java, Indonesia, 57126*

*<sup>2</sup>Departement of Civil Engineering, Soegijapranata Catholic University, Semarang, Indonesia  
email: kusno@uns.ac.id, setya\_budi\_99@yahoo.co.id, waluyo.z.budi@gmail.com, retno\_susilorini@yahoo.com*

### **ABSTRACT**

*This paper presents an evaluation of precast system structure implementation for the rehabilitation of a historical colonial building in Surakarta dated back from year 1880 hereafter called Ex Mabrigif 6 Building Block B. Due to lack of maintenance and care, one corner has collapsed and material deformation happened in some places. Rehabilitation is necessary to be done to strengthen and ensure that the building can be used again.*

*Analysis and experimental methods has been used in this research to determine the structre of the building's strength. Analysis has been done by conducting studies to existing condition of the building and precast structural system by using SAP2000 program. The step consists of field investigations, building damage assessment, evaluation and determining the solution. Experimental method is done by simulating structural model and making of concrete beam models. Structural model simulation provides some alternative for precast structural system. The deflection test has been done to 5 pieces of concrete beams with 250 mm x 350 mm x 3500 mm in size and 40 MPa compressive strength to provide the best beam model.*

*The laboratory test results showed that beam with sugar-based additive composition and confinement has the highest rupture value. The use of precast system model 2 and beam with sugar-based additive composition and confinement is the recommended for the rehabilitation of the building.*

**Keywords** : confinement, evaluation, inspection, precast, recommendation, rehabilitation.

### **I. INTRODUCTION**

Building rehabilitation is an effort to restore a building to a better condition to be used for its purpose. Building rehabilitation includes all building components that suffered damage or degradation. Quality degradation can occur because of material disorientation caused by environmental factors such as weather and aging. Failure of each sub and or super structures may cause damage to the building. Material deterioration due to aging of old buildings has a big influence in deteriorating buildings strength and structural stiffness. Similarly, structural damage might also occur during the service life of a building. Rehabilitation of each case of damage are specific and need accurate in identification of the main cause of damage.

The buildings of the former Markas Brigade Infanteri 6 (ex Mabrigif 6) building complex is a heritage building which was built during the Dutch colonial era in XVIII-XIX century as a complementary facility to Vastenburg Fort (Beteng Vastenburg). It is located at the intersection of Mayor Katamso Road and Kapten Mulyadi Road. It is an integrated part of Beteng Vastenburg which has a great historical value for Surakarta City. According to information submitted by Executive Daily Branch of "Angkatan 45" (DHC 45), the buildings in the complex were built in 1880. Building used as a Dutch internaat office until 1942. During different stages in Indonesian history, buildings in ex Mabrigif 6 complex experienced the transition of ownership and function. I was functioned as an educational facilities in 1945-1949, and then used as military base in 1949. Currently some buildings in ex Mabrigif 6 complex are used as the DHC 45 office. Presently the buildings are the property of the Department of Defence of Republic of Indonea. The building rehabilitation effort has been initiated by the government of Surakarta City and Department of Defence. However due to some administration problems this plan has not been realised. There are three mass buildings in this complex and not all are in good conditions. One mass bulding at the east side (block B) suffered from structural damage with the collapse of one of its corner.

Principles and conservation measures on historical building in Indonesia as the basic reference to the treatment of historical buildings have been set in the State Law No. 5 tahun 1992 regarding cultural and historical building preservation area, government law No. 10 year 1992 on the operationalization of State Law (UU) No. 5 year 1992, and the Cultural and Tourism Law No PM.49/UM.001/MKP/2009 on Guideline of Cultural Tangible Heritage and Sites. The Basic technical handling is stated in the State Law No. 28 year 2002 on Buildings and government law No. 36 year 2005 on the operationalisation of state law on building. Considering that most part of the Beteng Vastenburg area has a historical value, buildings of ex Mabrigif 6 complex can be categorized into cultural heritage building in accordance with the State Law No. 5 year 1992 in terms of age. The rehabilitation of ex Mabrigif 6 block B bulding is a promising step in saving the historical asset of Surakarta city which are in the verge of extinction and started to be replace by new buildings. Rehabilitation has also been done to extend the service life of buildings by increasing its strength.



Figure 1: Condition of Block B building corners.

Precast system structure is known as a method that use concrete into part of building's structural and non structural component with more practise and carefull material control quality. It is well known that precast concrete product can be installed quickly and will lead to a good quality work result. It is not only superior in terms of structure, strength and shear, but also in architectural form on exterior view. The benefits of precast concrete technology include speed of construction time, flexibility in the planning process, more simple on site job, carefully accounted concrete quality, dimensional accuracy and better quality building.

## II. STRUCTURAL ANALYSIS

Structural analysis is based on the following rules and procedures:

- SNI 03-2847-2002 on the procedure to calculate concrete structure for buildings.
- SNI 03-1726-2002 on the procedure to plan the resilience of a building towards earthquake.
- Regulation on the weighting for Indonesian building year 1983.
- Analysis and structural calculation using SAP2000.

According to article 8 of SNI 03-1726-2002 about structural performance of building, building structure must comply with the performance requirements for serviceability limit ( $\Delta s$ ) and ultimate limit ( $\Delta m$ ).

### 1. Serviceability limit performance ( $\Delta s$ )

Serviceability limit performance ( $\Delta s$ ) is determined by storey drift under seismic design. It is intended to maintain users comfortability, prevent non structural damage, limit the steel elasticity and over cracking concrete. Therefore  $\Delta s$  storey drift must not be larger than:

$$\Delta s = \frac{0.03}{R} \times h_i \quad \text{or } 30 \text{ mm} \quad (1)$$

(whichever smaller)

in which :

$h_i$  is number of storey,  $R$  is seismic reduction factor.

To calculate the serviceability limit, the performance of the inter level should consider structural deviation output based on the earth quake load.

### 2. Ultimate limit performance ( $\Delta m$ )

Ultimate limit performance ( $\Delta m$ ) is determined by the deviation and maximum storey drift due to seismic design on the verge of the collapse building condition. According to article 8.2 in SNI 03-1726-2002, deviation and storey drift should be calculate from structural deviation due to nominal quake load, multiplied by a multiplier factor  $\xi$ .

$$\Delta m = \xi \times \Delta s \quad (2)$$

Rate of multiplier factor  $\xi$  : For regular building  $\xi = 0.7 \times R$ , For irregular building  $\xi = R$ , with  $R$  is seismic reduction factor and regular building type.

## III. RESEARCH METHOD

Activities of this research are as follows:

### 1. Investigation and assessment of damage level

The first step in the on site investigation to see the existing building condition. The result of the assessment of the damage level found in the existing building leads toward a recommendation for further action towards the building rehabilitation methods. Investigation and damage level assessment step should be implemented.

An examination to determine the building status, to be used as a basic determination for the classification of the building's damage has been implemented. Subsequently further necessary actions should be evaluated to solve the problems.

### 2. Experimental Test

Planned alternative models have tested using SAP 2000 program to determine the strength level of the building. If the results are less than the standard requirements for earth quake resistant building, then we remodel the step to get the optimal result. After we obtained the optimal system structure result, we need a concrete beam models test as part of precast system structure. The quality of material used in this test is in accordance with the assumptions of material quality in structural model plan to obtain the alignment of research settings.

### 3. Laboratory Experiments

Laboratory model experiment is done by making and testing concrete beam models with aim to obtain the best composition beam model. Bending test done to 5 beam with 25 cm x 35 cm x 350 cm in dimension. Its variation is as follows:

- a. 1 (one) model of normal composition beam.
- b. 1 (one) model of sugar based additive composition beam.
- c. 2 (two) models of normal composition with confinement beam.
- d. 1 (one) model of sugar based additive composition with confinement beam.

## 4. RESULT AND DISCUSSION

### 4.1 Preliminary Building Damage Assessment Result

Result of building damage assessment of ex Mabrigif 6 blok B building shows that the wall structure of the 1st floor outer walls had a Rangk-IV damage of 42,3 m (> 20%) and Rangk-V damage of 10,65 m (> 10%). The 1st floor inner walls have no damage. Structure wall of 2nd floor outer walls had a Rangk-IV damage of 0 m (< 10%) and Rangk-V damage of 16,05 m (> 10%). Building components that have risk overturned and classified with risk level B (be careful) are the windows, stairs and ceilings. Overturned risk can be classified with risk level C (danger) on coating components, roof and walls. Recommended decision and advice on emergency inspection on ex Mabrigif 6 blok B building as follows:

- a. Building included in category of **“Danger”**.
- b. For activities around the building is categorized in **“Be careful”**.

Result of classification damage building assessment and follow-up determination, damage evaluation 1st floor shows that building suffer the damage level of **“medium”** with D (damage ratio) of 22,1589. 2nd floor structure suffered the damage level **“medium”** with D by 34,4103. Based on both conditions, identification of overall damage level the building include damage category **“medium”**. Advice given in the building damage classification assessment and follow up determination can be determined the possibility act as **“repairing or strengthening (for further investigation)”**.

### 4.2. Building Component Testing Result

Test carried out on wall component to get mass weight and compressive strength (f'c). Thus then fill into SAP 2000 program to analyse building strength. Test done in two ways: with rebound hammer test and compressive strenght test to building sample on laboratory. Average value of compressive strength result using rebound hammer test shown in Table 2. and average value building sample material test, as shown in Table 2.

Table 1. Value of Concrete Compressive Strength Testing Result in Field by Rebound Hammer Test

No.	Average Compressive Strength (MPa)	No.	Average Compressive Strength (MPa)
1	12,66	14	8,50
2	8,50	15	8,50
3	10,58	16	8,86
4	8,50	17	14,45
5	15,21	18	9,92
6	15,96	19	8,99
7	8,50	20	10,09
8	17,94	21	10,39
9	8,50	22	8,69
10	13,60	23	9,73
11	15,96	24	12,28
12	12,96	25	9,35
13	15,68	26	9,92

Table 2. Value of Concrete Compressive Strength testing Result by Universal Testing Machine.

No.	Compressive Strength (MPa)	No.	Compressive Strength (MPa)
1	3,88	8	6,49
2	3,08	9	4,31
3	3,25	10	7,19
4	3,76	11	6,30
5	4,17	12	4,45
6	3,17	13	3,36
7	3,56		

Result of average compressive strength with two ways testing showed significant differences. From testing with rebound hammer test obtained average value of 11,32 MPa, while testing with Universal Testing Machine (UTM) on cube samples found average value of 4,38 MPa. Calculation will be done is the calculation of building strength, compressive strength value set to smallest value to give calculation with greatest risk of 4,38 MPa.

Mass weight obtained by measure volume and weight of material is sample. Based on the measurement resul, we obtain average mass weight value of 1586,56 kg/m<sup>3</sup>.

### 4.3. Calculation of Building Strength

Deformation diagram as analysis result due to load combination 3 can be seen in Figure 4. Deformation diagram in Figure 4 explains that almost all joint deformed vertical and horizontal directions. That condition indicates wall structure is vulnerable to loads when less of structural stiffness. Vertical direction deformation with largest value were on upper beams that support roof truss and ceiling. Joint component in vicinity collapse corner, showed large deformation value.

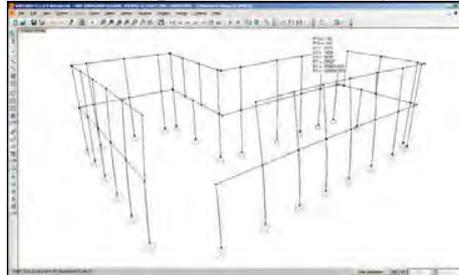


Figure 4: Deformation Diagram due to Load Combination 3 in SAP2000 program

The largest vertical deformation of Z direction were on joint number 188 at the coordinates cc, 6', 881 at 0,10961 cm due to load combination 1. The largest horizontal deformation of X direction were on joint number 140 at coordinates i, 1, 881 at 0,16945 cm due to load combination 4. The largest horizontal deformation of Y direction were on joint number 121 at coordinates i, 1, 881 at 0,075836 due to load combination 3.

The large value of vertical and horizontal deformation indicated that the wall structure critically support the dead load of 50 kg/m<sup>2</sup> live load assumption. The building's existing concrete compressive strength does not fill the quality requirement for the construction of 28 MPa. As a precaution we reduced the load of the wall, so that wall only support its own weight. The structural load and another planned load will be supported by a new system structure to be placed in the building.

Views of transferred load from wall (a) to new system structure (b) can be seen in Figure 5.

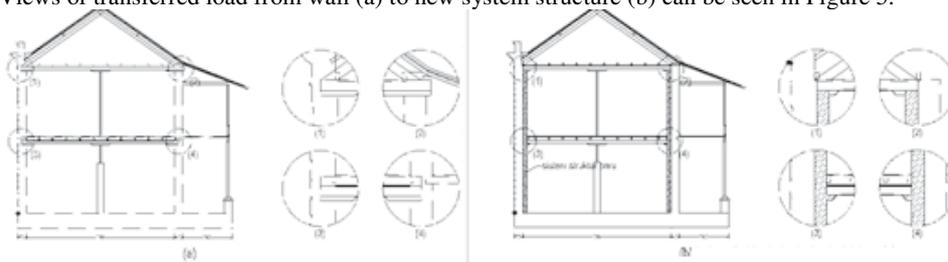


Figure 5: Transferring Load. a) Load from the truss and floor 2 beam is directly supported by the wall. b) Load from the truss and floor 2 beam is directly supported by the new structure in the building interior.

### 4.4. Handling Formulation using Precast System Structure

The strengthening alternative is determined base on strengthening identification. There are 3 (three) problems that become main issue in the strengthening identification:

- a. Effective loading distribution.
- b. Placement of structural elements that have strength and stiffness according to the load plan.
- c. Building strengthening in order to be used again refer to rules of rehabilitation of historical buildings.

Based on those main issue, we can determined the strengthening alternative by the placement of precast system structure which consist of form beams and columns in the building. There are 2 (two) alternative forms of precast system structure:

- a. Alternative 1

Alternative 1 is done by placing the form of columns at the joint of the main beams and replacement of wood main beam at the 2nd floor with precast beams. This beam is intended to eliminate the pipe's columns inside the 1st floor and the terrace column.



Figure 6: Alternative Structure Model 1.

- b. Alternative 2

Alternative 2 is conducted by placing the form of columns at joint of main beam while maintaining the wood structure of 2nd floor. The main wood beams and the pipe columns were retained. The exterior wood structure is placed to the column by the console.

**4.5. Strengthening Analysis**

Analysis result of model 1 and model 2 can be reviewed as follows:

a. Alternative 1

Based on the technical data plans, the dimension simulation input to confirm the SAP 2000 for further analysis to the planned system structure. Simulation result on structure model alternative 1 provides the optimum system structure composition data as shown in Table 3.

Deformation in model alternative 1 is due to load combination 3 can be seen in Figure 8. The larger horizontal deformation were on joint number 82 at coordinates H, 1, 891 at 0.2953 cm, while largest vertical deformation were on joint number 52 at coordinates C, 2, 457 at 0.2233 cm.



Figure 7: Alternative Structure Model 2.

Table 3. Technical Data Plan Element Model

No	Description	Dimension	Note
1	Column K-1	30 cm x 60 cm	Precast column
2	Beam B-1	25 cm x 40 cm	Main Beam
3	Beam B-1x	37.5 cm x 72.5 cm	Beam E-1/4
4	Beam B-1y	25 cm x 45 cm	Beam 2-A/E
5	Beam B-2	25 cm x 35 cm	Canopy Beam
6	Beam B-3	25 cm x 35 cm	Beam between column
7	Beam RB-1	25 cm x 40 cm	Rear Ringbalk
8	Beam RB-2	25 cm x 30 cm	Ringbalk between column
9	Height of first floor	457 cm	Distance between the floor surface and beam's surface
10	Height of second floor	424 cm	Distance between beam's surface and ringbalk



Figure 8: Deformation Model Structure Diagram Alternative 1 due to Load Combination 3.

The beam section check conducted to analyze the beam shows the favorable result, i.e.  $A_s \text{ max} > A_s \text{ analysis result}$ . The description of the beam section check analysis which evaluated some beams can be seen in Table 4.

Table 4: Beam Section Check Element Model Alternative 1.

No	Dimension (cm)	Beam	Mmax (Ton)	$A_s \text{ result}$ ( $\text{mm}^2$ )	$A_s \text{ max}$ ( $\text{mm}^2$ )	Rec
1	37.5x72.5	Beam E-1/4	23.72	1233	7745	OK
2	25 x 45	Beam 2-A/E	2.62	854	3060	OK
3	25 x 40	Beam 3-A/E	2.74	1368	2677	OK
4	25 x 40	Ringbalk 8-A/E	2.52	569	2677	OK

The performance serviceability limit ( $\Delta_s$ ) and ultimate performance limit ( $\Delta_m$ ) confirm the requirement of the maximum storey drift.  $\Delta_s$  may not exceed the value 30 mm based on calculations using Formula (1). Calculation was done with those formula, and we obtained the value of  $\Delta_s$  of 36,34 mm, maximum deviation value was set at 30 mm. The maximum  $\Delta_m$  determined by 0,02 multiplied by the height of the space between the reviewed storey. The review of  $\Delta_s$  and  $\Delta_m$  value between storey in x and y direction can be seen in Table 5, 6, 7 and 8. The review was conducted on the axis with the largest deformation.

Table 5: Review of  $\Delta_s$  x Direction

Level	$H_i$ (m)	$A_s$ (mm)	Drift $A_s$ between level (mm)	Req Drif $A_s$ (mm)	Note
2	4.24	2.95	2.68	30.00	OK
1	4.57	0.29	0.29	30.00	OK

Table 6: Review of  $\Delta s$  y Direction

Level	Hi (m)	As (mm)	Drift As between level (mm)	Req Drif As (mm)	Note
2	4.24	1.92	1.84	30.00	OK
1	4.57	0.09	0.09	30.00	OK

Table 7: Review of  $\Delta m$  x Direction

Level	Hi (m)	As (mm)	Drift As between level (mm)	Req Drif Am (mm)	Note
2	4.24	10.34	9.34	84.90	OK
1	4.57	1.00	1.00	91.40	OK

Table 8: Review of  $\Delta m$  y Direction

Level	Hi (m)	Am (mm)	Drift As between level (mm)	Req Drif Am (mm)	Note
2	4.24	6.47	6.43	84.90	OK
1	4.57	0.31	0.31	91.40	OK

$\Delta s$  and  $\Delta m$  performance of alternative model 1 according to the Table 5, 6, 7, 8 show that the model confirmed the requirement.

b. Alternative 2

Based on the technical data plans, dimension simulation input are required in SAP 2000 program for further system structure analysis. Simulation result on alternative 2 structure model provides the optimum system structure composition data as shown in Table 9.

The deformation in alternative 2 model is due to fact that the load combination 3 can be seen in Figure 9. Larger horizontal deformation were found on joint number 61 at coordinates F, 1, 891 at 1.1427 cm, while the largest vertical deformation happened on joint number 6 at the coordinate D, 8, 891 at 0.0184 cm.

Table 9: Technical Data Plan Element Model 2

No	Description	Dimension (cm)	Note
1	Column K-1	30 x 65	Precast column
2	Column K-2	35 x 65	Precast column
3	Beam B-1	25 x 44	Rear Beam
4	Beam B-2	25 x 62.5	Beam I-H/I, 4-H/I & 4-I/I
5	Beam B-3	25 x 40	Beam between column
6	Beam B-4	27.5 x 65	Beam I-A/B, I-A/C & I-I/I
7	Beam RB-1	25 x 40	Rear Ringbalk
8	Beam RB-2	25 x 30	Ringbalk between column
9	Height of first floor	457	Distance between the floor surface and beam's surface
10	Height of second floor	424	Distance between beam's surface and ringbalk

The beam section check was conducted to analyze the beam, and it confirms that  $A_s \max > A_s$  analysis result. The description of the beam section check analysis to review some beam can be found on Table 10.



Figure 9: Deformation Model Structure Diagram of Alternative 1 Due to Load Combination 3.

Table 10: Beam Section Check Element Model Alternative 2.

No	Dimen-sion (cm)	Beam Name	Mmax (Ton)	As result (mm <sup>2</sup> )	As max (mm <sup>2</sup> )	Rec
1	25 x 45	Beam J-1/4	-12.49	525.00	3060.00	OK
2	25 x 62.5	Beam I-A/B	1.40	86.60	4395.00	OK
3	25 x 40	Beam I-E/F	-1.06	27.70	2677.00	OK
4	25 x 45	Ringbalk J-1/4	-7.20	386.57	3060.00	OK
5	25 x 37.5	Ringbalk J-1/5	-0.61	14.7	2486.25	OK

In accordance with the requirements of  $\Delta s$  and  $\Delta m$  in the discussion of alternative model 1, review of  $\Delta s$  and  $\Delta m$  values between storey in x and y direction can be seen in Table 11-14.

Table 11: Review  $\Delta s$  x Direction

Level	Hi (m)	As (mm)	Drift As between level (mm)	Req Drif A (mm)	Note
2	4.24	1.89	-9.54	30.00	OK
1	4.57	11.43	11.43	30.00	OK

Table 12: Review  $\Delta s$  y Direction

Level	Hi (m)	As (mm)	Drift As between level (mm)	Req Drif As (mm)	Note
2	4.24	2.99	1.53	30.00	OK
1	4.57	1.46	1.46	30.00	OK

Table 13: Review  $\Delta m$  x Direction

Level	Hi (m)	As (mm)	Drift As between level (mm)	Req Drif Am (mm)	Note

2	4.24	6.62	-33.37	84.80	OK
1	4.57	40.00	40.00	91.40	OK

Table 14: Review  $\Delta m$  y Direction

Level	Hi (m)	As (mm)	Drift As between level (mm)	Req Drift Am(mm)	Note
2	4.24	1.39	0.01	84.80	OK
1	4.57	1.38	1.38	91.40	OK

$\Delta s$  and  $\Delta m$  performance of alternative model 2 according to the Table shown above shows that the model confirms the requirement. Model alternative 1 and model alternative 2 is in line with the structural requirement design. Both alternatives can be compared according to several variables to give consideration to the advantages and disadvantages of each alternative. Comparison summary of two model structures can be seen in Table 15.

Table 15: Comparison Structure Model Alternative 1 and Alternative 2

No	Description	Alternative 1	Alternative 1
1	Changing in space	Available	No
2	Changing in the building exterior	Available	No
3	Cost based on the volume of beton	Higher	Lower
4	Simplicity of structured system pattern	More complex	Simpler
5	Ease of execution	More complex	Easier

Based on Table 15, it can be explained that alternative 1 provided possibilities on interior space with the removal of pipe column on the 1st floor. Alternative 2 does not change the space which still retains structural wood and pipe column. Exterior view changing appears on the alternative 1 because the terrace column have been replaced by cantilever beam. Alternative 2 still gives the initial appearance because the terrace element remains as before. Based on the concrete volume required, alternative 1 is more than alternative 2. Concrete requirement is indirectly related to the construction cost. Alternative 2 provides simple system structure than system structure alternative 1 with the absence of the long span beam as cantilever. Construction of model structure alternative 1 is more complicated than alternative 2 because of the long span beam and cantilever, although technically it still can be done. Furthermore, there should be a laboratory experiment to get the best model of beam as the composer of precast system structure with compressive strength of 40 MPa.

#### 4.6. Test Beam Models

Loading test performed on 5 (five) beams give the deflection value at each loading level. Comparison of the deflection value at the same point of each beam can be seen in Figure 10, 11 and Figure 12. Point 1 and 3 are points with the distance of 100 cm from pedestal and the same point under the load point. Point 2 is the midpoint of beam (1/2 L). Deflection value shows the level of beam elasticity. The greater deviation value indicates better security level of the beam when there is an over load. In addition, the maximum load supported by each beam also shows the *maximum strength of the beam*.

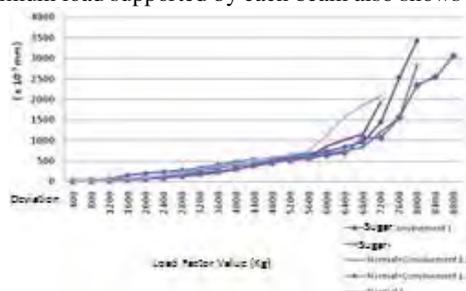


Figure 10. Comparison of Deflection at Point 1

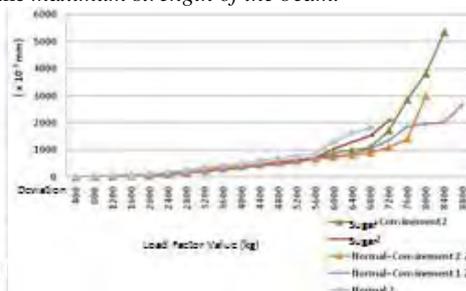


Figure 11. Comparison of Deflection at Point 2

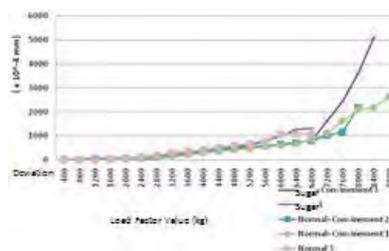


Figure 12. Comparison of Deflection at Point 3

From the figures it can be seen that the beam quality can be sorted as follows:

- Beam with the sugar based additive composition and confinement.
- Beam with the normal composition with confinement.
- Beam with the composition of sugar-based additive.
- Beam with normal composition.

## 5. CONCLUSION

Analysis of the experimental test in this research have lead to the following conclusion. Ex Mabrigif 6 block B building is included in dangerous category and require carefull act for users around the building. Advice given on the building damage classification assessment and follow up determination can determine the possibility to act as “repairing or strengthening (for further investigation)”. Rehabilitation effort by transferring load to new system structure is an alternative solution which might be chosen related to maintain the building’s historical value. Wearing out of material and deterioration of ex Mabrigif 6 block B building is caused by the condition in which structural service life requirements have not been covered. New system structure that sustain the load design is capable to support and maintain building authenticity. Two alternative of precast system structures proved that the structural capability sustain the load design. Alternative 2 has better fitness related to the rehabilitation effort compared to alternative 1. Beam model with sugar based additive composition and confinement on its bar have provided significant results. This can be conducted to increase the deflection level and the safety factor for precast construction beam.

Further research on improvement of wall construction, increasing the material wearing and strengthening foundation can be done to provide comprehensive discourse on the building rehabilitation. Beam test on samples with various composition is still limited to the deflection test. Further research on connection system and method of implementation of the use of precast structural system as an alternative method for building rehabilitation can be conducted. Building rehabilitation using precast system structure in theoretical way can be implemented to provide strengthening of old building. Further research is needed to compare the study result, and to ensure a realistic research outcome.

## REFERENCE

- [1] Akhmad, A. and Moin, K., 2009. *Strength Assesment of a Heritage Brick Masonry School Building Against Earthquake*, International Conference on Rehabilitation and Maintenance in Civil Engineering (ICRMCE), Solo.
- [2] Allen, R.T.L., 1993. *The Repair of Concrete Structures Second Edition*, Blackie Academic of Professional, Glasgow G64 2NZ, UK.
- [3] Anonim. 2008. Guideline from the Minister of Public Works, Number: 24/Prt/M/2008 Tanggal 30 December 2008 on the Guideline for Building Maintenance, Ministry of Public Works. Jakarta.
- [4] \_\_\_\_\_. 2006. *Standard Method of Detailing Structural Concrete, A Manual for Best Practice Third Edition*. The Institution of Structural Engineers. London, United Kingdom.
- [5] \_\_\_\_\_. 2002. Guideline for Resilience for Earthquake for Building’s Plan, Indonesian National Standard *SNI 03 – 1726 - 2002*. Indonesia National Standard. Jakarta.
- [6] \_\_\_\_\_. 1996a. Guideline for Reinforced Concrete, *SK.SNI – 1991*. Department of Public Work. Jakarta.
- [7] \_\_\_\_\_. 1996b. Technical Requirement for Building. Department of Built Environment and Area Infrastructure. Jakarta.
- [8] \_\_\_\_\_. 1987. Guideline for reinforced concrete and reinforced wall structure for house and building. Yayasan Badan Penerbit PU. Jakarta.
- [9] Ayyudin, 2010. *Analisis on Seismic Resistance Structure Using Direct Displacement-Based Design*, Makassar International Conference on Civil Engineering (MICCE2010), Makassar.
- [10] Budipriyanto, A. and Wahyudi, D.I., 2009. *Structural Damage Assessment of A Shear Building Under Earthquake Excitations*, International Conference on Rehabilitation and Maintenance in Civil Engineering (ICRMCE), Solo.
- [11] Boen T., 2001. *Earthquake Resistant Design of Non-Engineered Buildings In Indonesia*, EQTAP Workshop IV, Kamakura, Jepang.
- [12] CSI, 1998. *SAP2000® Integrated Finite Element Analysis and Design of Structures*, Computers and Structures, Inc. Berkeley, California, USA. Eljarm. A.M, 2009. *Rehabilitation and Rearrangment of The Old*
- [13] Farooq, S.H., Ilyas, M., and Ghaffarb, A., 2006. *Technique for Strengthening of Masonry Wall Panels Using Steel Strip*, International Asian Journal Of Civil Engineering (Building And Housing) Vol. 7, No. 6, 2 August 2010.
- [14] Iranata, D., Tavio, Wahyuni, E., Soegihardjo, H., Tajunnisa, Y., Tirtajaya, R., Trimurtiningrum, R., Mahmud, F., and Budianto, 2010. *Earthquake Resistant Design of Precast Concrete House*, Makassar International Conference on Civil Engineering (MICCE2010), Makasar.
- [15] Juwana, J.S., 2005. *Guideline for High Rise Building: for Architect and Building Practicionaire*, Erlangga, Jakarta.
- [16] Komputer, W., 2003. *Structure Analysis and Calculation with SAP2000*, Salemba Infotek, Jakarta.
- [17] Mandang, Y.I. and Pandit, I.K.N., 1997. *Guideline for Wood Identification in the field work*, PROSE
- [18] Pamungkas, A. dan Harianti, E., 2009. *Earthquake Ready Reinforced Concrete*, ITS Press. Surabaya.
- [19] Susilorini, R., dan Sambowo, K.A., 2010. *Local Utilization of Local Material for a Sustainable Environmentally Friendly Reinforced Concrete*. Report of Competence Grant of Directorate General of Higher Education, Universitas Katolik Soegijapranata. Semarang.
- [20] Tular, R.B., 1981. *Planning for an Earthquake Ready Building*. Building Problems Research Foundation. Bandung.

# **Analysis of Construction Management Accomplishment on Building Project of Manufacture Industry in *PT. Damai Indah Kaca Tipis - Indonesia***

**Nurlaelah<sup>1,a</sup>, Usman Sudjadi<sup>2,b</sup>**

<sup>1</sup>*Department of Civil Engineering, Diponegoro University,  
Jl. Hayam Wuruk 5-7, Semarang 50275 Indonesia.*

<sup>2</sup>*Center for Nuclear Fuel Technology, National Nuclear Energy Agency,  
Kawasan PUSPIPTEK, Serpong-Tangerang 15314 Indonesia.*

*[nurlaelah.73@yahoo.com](mailto:nurlaelah.73@yahoo.com), [usmannunung@yahoo.com](mailto:usmannunung@yahoo.com)*

## **ABSTRACT**

*The construction management accomplishment on building project of manufacture industry in PT. Damai Indah Kaca Tipis – Indonesia with Analytical Hierarchy Process (AHP) and expert choice software method was analyzed. The parameters of the construction management accomplishment were the quantity of the worker, bill of quantity, time progress report, and time schedule. The quantity of the workers consists of project manager, site manager, supervisor, surveyor, mechanic, etc. The bills of quantity consist of bar chart diagram. The time progress reports consist of daily report, weekly report and monthly report. The time schedules consist of S curve. The analysis shows that the time progress report was the most important of the construction management accomplishment in PT. Damai Indah Kaca Tipis building project.*

**Keywords:** *Analytical Hierarchy Process, expert choice, construction management accomplishment, manufacture industry, building project, PT.Damai Indah Kaca Tipis.*

## **1. INTRODUCTION**

The construction industry is the uniquely industry, because every project has a different characteristic from the other project. Starting from the first step is planning process, and the second step is designing process, and the third step is an auction process and the last step is the accomplishment of the project. According to many of construction projects, the development of construction management could not separated from the development of construction service industry. In other side, the development of construction service industry is very close with the development accomplishment will be encourage in this time. Generally, the construction service industry related to all of the physically development project for human being such as high rise building, property, bridge, and so on, including the installation of each project. According to the complexity of the development accomplishment of each project, it should be followed to the good of the development of construction management, which is less cost, good quality and less time to do every project. To realize the development accomplishment

of every project that less cost, good quality and less time, we can calculate with using the parameters of the construction management accomplishment, they are the quantity of the worker that consist of project manager, site manager, supervisor, surveyor, mechanic, etc. The bills of quantity consist of bar chart diagram. The time progress reports consist of daily report, weekly report and monthly report. The time schedules consist of S curve. In Indonesia, the parameters of the construction management accomplishment have to concern for every parties of a construction contract, the owner and contractor, because, sometimes the project has time overrun and cost overrun, especially for the project that have less time (less than one year). In addition, the main goal of the parties involved in a project's construction is to have a succesful project. This is defined as a project that has been constructed in accordance with the plans and specifications, within the time and cost originally anticipated. To determine the relative importance among the parameters of the construction management accomplishment, an analytical hierarchy process (AHP) and expert choice software method is used to analysis the construction management accomplishment on building project of manufacture industry in *PT. Damai Indah Kaca Tipis*. *PT. Damai Indah Kaca Tipis* is a company that produce the sheet of glass for automotive industry such as motorcycles, cars, bus and trucks and they produce the product to sufficient for local and international demand. Besides that, *PT. Damai Indah Kaca Tipis* is a developer for manufacture industry building in Mekar Jaya Industry area in Jl. Raya Mauk Km. 7, Tangerang, Banten in 4 Hectare area, that has built a building of Indonesia 130 t/d Horizontal Drawing Glass Production Line Works. The accomplishment development of this project devided in to Combined Building Work Area, Batch House, Substation and Infra Structure for about five month (since March 1st 2010 to August 1st 2010) with cost US\$ 3.400.000,-. *PT. Damai Indah Kaca Tipis* is an owner and developer of Indonesia 130 t/d Horizontal Drawing Glass Production Line Works project and as a main contractor is *PT. Dasatria Utama* and *PT. Perkasa Adiguna Sembada* as a Sub Contractor, the two contractor lead the accomplishment of the development of this project. Whereas *PT. China Triump* as a planner and controlling consultant. There are four important point that have to concern to accomplish the development of this project, i.e: The Quantity of The Worker, The Bill of Quantity, The Time Progress Report and The Time Schedule. Based on Introduction, so we try to formulate about the poblems of this paper is how was the construction management accomplishment on building project of manufacture industry in *PT. Damai Indah Kaca Tipis* with the parameters of the construction management accomplishment (the quantity of the worker, bill of quantity, time progress report, and time schedule) using Analytical Hierarchy Process (AHP) and expert choice software methode? And the objective of this paper is to analyze about the construction management accomplishment on building project of manufacture industry in *PT. Damai Indah Kaca Tipis* with the parameters of the construction management accomplishment (the quantity of the worker, bill of quantity, time progress report, and time schedule) using Analytical Hierarchy Process (AHP) and expert choice software methode [1-8].

## 2. METHOD OF RESEARCH

The AHP is applied via three main problems solving approaches: decomposition, comparative judgements, and synthesis of priorities (Saaty 1980). Decomposition structures a complex problem into its basis elements, working from the goal objective down through various levels, from the more general to the particular and definite elements. It provides an overall view view of the complex relationship within the situation. Comparative judgements are used to determine priorities among elements of every level. This is achieved by asking the decision makers or experts to evaluate level elements pairwise with respects to elements in the next higher levels. Saaty suggested using a nine-point scale for making numerical judgments in the AHP pairwise comparisons. Using the scale, the decision makers or the experts exercise judgment about the prioritie such the factors

and the subfactors can be compared among them selves in relations of the elements of the next higher level. This leads to the construction of matrices from which relative weights of the elements with respect to each element of the level above can be determined. As for the synthesis of priorities, the constructed matrices are used for computing weighted priorities for elements of a given level over the other elements of the same level with respect to each element of the level just above. In this way, the priorities of the factors can be determined. Priorities can be calculated by a software package called *Expert Choice* (1986). And a nine point scale (1: equal importance; 3: moderate importance of one over another; 5: strong importance; 7: very strong importance; 9: extreme importance; 2,4,6 and 8: intermediate values between the two adjacent judgements) which is widely used in surveys for obtaining data for evaluation of weightings among the attributes of a complex issue through the use of AHP (e.g, in the study of Lai and Yik (2011). In short, Analytical Hierarchy Process is a technique of many criteria decision making to involve the consideration of two factors, which is objective and subjective factor to choose the best alternative. The approximation is used to get ratio – scale of cardinal rank from the alternatives that made a fool of many attributes decision making. Besides that, we have to observe about decomposition, comparative judgment, synthesis of priority and logical consistency to use the Analytical Hierarchy Process as a tool of decision making problems [4-8].

## 2.1 Measurement and Data Collection

The data collection was based on interview with five worker who have to responsible about the accomplishment of this project. They are Project Manager, Site Manager, Supervisor, Surveyor and Chief Worker. Each of this worker was asked to evaluate and assign relative scales in a pairwise fashion with respect to the subfactors of one level of hierarchy given the criteria at the next higher level of hierarchy. As a result, a set of pairwise comparison judgement matrices corresponding to the construction management accomplishment of *PT. Damai Indah Kaca Tipis* were used in all levels of the hierarchy as shown in Fig 1 below:

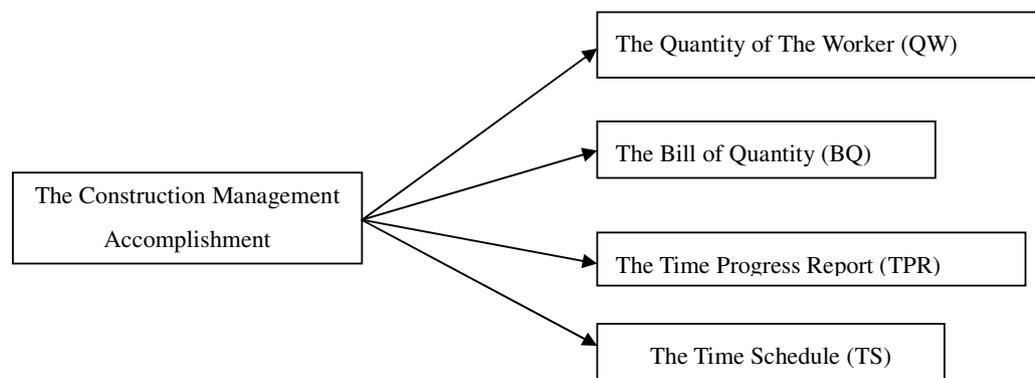


Fig 1. The Parameters of Construction Management Accomplishment in *PT. Damai Indah Kaca Tipis*

In this paper, I try to calculate about the construction management accomplishment on building project of manufacture industry in *PT. Damai Indah Kaca Tipis* with the parameters of the construction management accomplishment (the quantity of the worker, bill of quantity, time progress report, and time schedule). The first step I make comparison matrice of criteria level, the second step I calculate the criteria level in pairwise matrice to choose the alternatives and the third step I calculate about the inconsistency ratio for the criteria, if the result is smaller than 10 %, it means that the calculating of this analytical

hierarchy process is correct. Besides that, I use expert choice software to equip the analyze of the construction management accomplishment.

## 2.2 The parameters of the construction management accomplishment

### 2.2.1 The Quantity of the Worker (QW)

The quantity of the worker in this project consist of 15 qualification of the worker. They came from *PT. Dasaria Utama* as a main contractor and *PT. Perkasa Adiguna Sembada* as a main contractor, we can look at the table 1 below:

Table 1: The Quantity of The Worker

No	Qualification	Amount
1	Project Manager	1
2	Site Manager	1
3	Drafter/Technical Adm	2
4	Supervisor	4
5	Surveyor	2
6	Safetyman	1
7	Purchasing/Keeper Storage	1
8	Mechanic	2
9	Driver/Equipment Op.	4
10	Foreman	4
11	Chief Worker	4
12	Mason	23
13	Steel Bar Worker	34
14	Carpenter	58
15	Digger	68

(Source: PT. Dasaria Utama, 2010)

In this paper, I choose Project Manager, Site Manager, Supervisor, Surveyor and Chief Worker who very responsible to controll this project, to give their answer about the construction management accomplishment.

### 2.2.2 The Bill of Quantity (BQ)

The Bill of Quantity is used to make a schedule of the work accomplishment of this project using Bar Chart Diagram. It is important to do because we can make sure for how long the accomplishment of the project can finish with the existing resources

in there, such as quantity of the worker, material and machine. So, we can control about the progress of each activity every time and minimize the latest time or the failure of the project that could be done.

### 2.2.3 The Time Progress Report (TPR)

The time progress report in this project i.e. daily report, weekly report and monthly report. These all report should be joined to The Bill of quantity to get the comparison of the reality work and the planning work. Besides that, we can control about the activity in critical path without neglect the other activity.

### 2.2.4 The Time Schedule (TS)

The time schedule (for this project I use S Curve) is used to know for how long we need to finish the activity from the preparation work to acceptance work to *PT. Damai Indah Kaca Tipis* as an owner and developer .

## 3. RESULTS AND DISCUSSION

### 3.1 Calculating the analytical hierarchy process using manual methode

In order to study whether the construction management accomplishment in *PT. Damai Indah Kaca Tipis*, the explanation from the project manager, site manager, supervisor, surveyor and chief worker are very usefull as the input judgments at all levels, as shown in Table 2. According to Saaty, if the overall consistency of the input judgements was within the acceptance ratio of 0,10, this implies that the pairwise comparison judgments supplied by the project manager, site manager, supervisor, surveyor and chief worker were not bias and thus acceptable.

Table 2: Pairwise comparison for construction management accomplishment

	QW	BQ	TPR	TS
QW	1	½	1/5	1/3
BQ	2	1	1/3	½
TPR	5	3	1	2
TS	3	2	½	1
Amount	11	6,5	2	3,8

Table 2 explains about pairwise comparison for construction management accomplishment in *PT. Damai Indah Kaca Tipis*. The table made by comparative judgement based on the explanation from the worker in this project, such as project manager,

site manager, supervisor, surveyor and chief worker who lead the activity in there. After that, I try to calculate the input judgements at all levels using manual method, as shown in Table 3.

*Table 3: The input column divided to the amount*

	QW	BQ	TPR	TS	The Amount
QW	0,09	0,077	0,1	0,078	0,345
BQ	0,18	0,154	0,15	0,13	0,614
TPR	0,45	0,46	0,5	0,526	1,936
TS	0,27	0,307	0,25	0,263	1,09

Table 3 explains about the continuation of pairwise comparison. The numbers in the table 3 are from the input data divided to the amount data, such as column 1 is  $1 : 11 = 0,09$ , column 2 is  $0,5 : 6,5 = 0,077$ , and so that column 3 and column 4. If the table is completed, so every line should be sum, so that we can get the value of every alternative, such as line 1 is sum of  $0,09 + 0,077 + 0,1 + 0,078 = 0,345$ , line 2 is sum of  $0,18 + 0,154 + 0,15 + 0,13 = 0,614$ , and so that line 3 and line 4.

*Table 4: Value of the criteria of the construction management accomplishment*

QW	$0,345/4 = 0,086$
BQ	$0,614/4 = 0,153$
TPR	$1,936/4 = 0,484$
TS	$1,09 /4 = 0,272$

Table 4 explains about the value of the criteria, and we can use them to pick up the rank of the construction management accomplishment. The value of the criteria is time to the matrix pairwise comparison that made by comparative judgement (see table 2). The calculation of importance level of main criteria in comparison matrix are :

$$\begin{pmatrix} 1 & 1/2 & 1/5 & 1/3 \\ 2 & 1 & 1/3 & 1/2 \\ 5 & 3 & 1 & 2 \\ 3 & 2 & 1/2 & 1 \end{pmatrix} \times \begin{pmatrix} 0,086 \\ 0,153 \\ 0,484 \\ 0,272 \end{pmatrix} = \begin{pmatrix} 0,3409 \\ 0,6062 \\ 1,917 \\ 1,078 \end{pmatrix}$$

The result of the multiplication of the matrix shows :

$$\begin{pmatrix} 0,3409 \end{pmatrix} \rightarrow \text{The fourth rank}$$

- 0,6062 → The third rank
- 1,917 → The first rank
- 1,078 → The second rank

To get a correct calculation from pairwise comparison above, we should check them in the calculation of Inconsistency Ratio that have shown below:

$$D = \begin{pmatrix} \underline{0,3049} & \underline{0,6062} & \underline{1,917} & \underline{1,078} \\ 0,086 & 0,153 & 0,484 & 0,272 \end{pmatrix}$$

$$D = \begin{pmatrix} 3,963 & 3,962 & 3,961 & 3,963 \end{pmatrix}$$

$$\Lambda_{\max} = \frac{3,963 + 3,962 + 3,961 + 3,963}{4} = \frac{15,849}{4} = 3,96225$$

The value of Inconsistency Ratio (CR) is :

$$CR = \frac{3,96225 - 4}{2 \times 0,9} = -0,02 < 10\% \dots \text{OK}$$

The results shows that the rank of the alternatives of the construction management accomplishment are:

1. The Time Progress Report (TPR)
2. The Time Schedule (TS)
3. The Bill of Quantity (BQ)
4. The Quantity of The Worker (QW)

The first rank is the time progress report, it means that the most important thing to be consider from the contractor. It could be understand because the time to build the manufacture industry building that known Indonesia t/d Horizontal Drawing Glass Production Line Works just 5 month (from March 1st to August 1st).

### 3.2 Calculating the analytical hierarchy process using expert choice programme

In accordance with Saaty [8], the pairwise comparison for construction management accomplishment, was processed of the determination of normalized weights, and “Expert Choice” was used to transfer the pairwise comparison judgments matrices into the largest eigenvalue and then the normalized local weights was determined. Based on these normalized priority weights, the relative importance of success factors can be asseced according to the construction management accomplishment in *PT. Damai Indah kaca Tipis*.

***the construction management accomplishment***

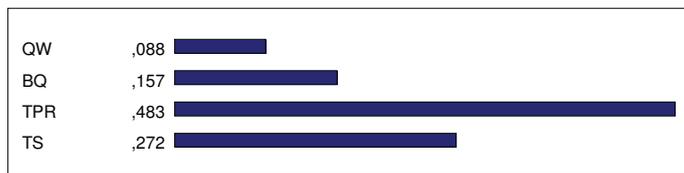
Node: 0

Compare the relative IMPORTANCE with respect to: GOAL

	BQ	TPR	TS
QW	(2,0)	(5,0)	(3,0)
BQ		(3,0)	(2,0)
TPR			2,0

Row element is \_\_\_ times more than column element unless enclosed in ()

Abbreviation	Definition
Goal	the construction management accomplishment
QW	THE QUANTITY OF THE WORKER
BQ	THE BILL OF QUANTITY
TPR	THE TIME PROGRESS REPORT
TS	THE TIME SCHEDULE



Inconsistency Ratio =0,01

***For Student Use Only***

**4. CONCLUSION**

The construction management accomplishment in PT. Damai Indah Kaca Tipis was decided in four factors. They are The Quantity of The Worker, The Bill of Quantity, The Time Progress Report and The Time Schedule. The findings from AHP and the result of the case studies have provided that The Time Progress Report is the most important thing they should be attention for this project. It should be noted that the priority weights among critical factors presented in this paper are based on the project manager, site manager, supervisor, surveyor and chief worker opinions who are very responsible leading the project.

## REFERENCES

- [1] Holloway, C.A., *Decision Making Under Uncertainty, Model and Choice*, Prentice-Hall, New Jersey, 1979.
- [2] Taha, H.A., *Operation Research, an Introduction*, New York, Macmillian, 1982.
- [3] Haedar, T., *Principles of networking planning*, PT. Gramedia, Jakarta, 1997.
- [4] Nurlaelah and Usman Sudjadi, "Analysis of Property Contractor of The Work Record Base Quality of The Work Result Using Quantity & Complains Type of Customer as Parameter in the Citra Garden Residence", *Proceeding of The 1<sup>st</sup> International Joint Conference on Advanced Engineering*, 18-19 October 2012, ICT Center Diponegoro University, Semarang-Indonesia, pages 238-246, ISBN: 978-602-097-299-2, 2012.
- [5] Siti Latifah, *Basic Principles of Analytical Hierarchy Process*, USU University, 2005
- [6] K.S.Chin and T.W.Choi, "Construction in Hong Kong: Success Factors for ISO 9000 Implementation", *Journal of Construction Management and Engineering*, ASCE, 2003.
- [7] Joseph H.K. Lai and Francis W.H.Yik, "An analytical method to evaluate facility management services for residential building", *Journal of Building and Maintenance*, Elsevier, 2011
- [8] Saaty, T., *The Analytical Hierarchy Process*, Mc Graw - Hill, 1980.

## Plenary 1

# Architecture for People: Educating, Empowering, and Sustaining

**Dr. Yandi A. Yatmo**

*Faculty of Engineering Universitas Indonesia  
yandi@arsitektur.net*

Intervention to human living environment becomes meaningful when it is strongly grounded on the real everyday contexts and when it could offer certain benefits for the people. This presentation illustrates an idea of how the process of architectural intervention can play a significant role in enabling and empowering society. Architecture is not merely present as a physical material of building, but it embodies the process of engaging the people, promoting collective actions and celebrating localities. Research into the everydayness of the society and local knowledge forms an integral part of design method development. The making of architecture is a process of engaging the whole community. Such engagement becomes an opportunity for the community to learn what they have: existing local resources, culture and technology. The design incorporates the use of local construction methods and local materials, and celebrates local craftsmanship through the use of various craft elements and methods that are familiar to the local people. In this way, architecture becomes the process of building the community awareness of their own aspiration and strength, which is much more meaningful than just the process of building the physical materiality. It also becomes a process of generating a special form of aesthetics that represents localities and everydayness. The architecture is eventually created as a physical manifestation of the whole process of educating and empowering the people, and consequently it would be able to sustain its existence within the society.

**This paper is not available from the author(s)**

# Building not Growing Case of study : *nDalem Pangeranan* Kasunanan Palace at kampong Baluwarti Surakarta

*Dyah.S.Pradnya.P<sup>a</sup>*

<sup>a</sup> *Architecture Department, Faculty of Engineering, Sebelas Maret University  
 E-mail : dyah\_pradnya@yahoo.com*

## ABSTRACT

The phenomenon of commercial building, governance and social increasingly crowded urban spatial structure. Efforts over the function becomes significant with the construction of new buildings and changes ownership. Factors of accelerating the flow of traffic density, use of open space (RTH) and environmental degradation were widespread. Commercial efforts also affect the physical stability and function of *nDalem Pangeranan*. However, consideration of the existence of noble values and ownership have prompted Kasunanan Palace, to issue *Pikukuh/Palilah*. The legislation imposes a ban on building and changing conditions *nDalem Pangeranan*. Although the role of its has stimulated turning internal conflict regarding building improvements and cost limitations, but has bound existence *nDalem Pangeranan* in the original function. Then, the researcher is interested in exploring the influence of *Pikukuh* onto the physical existence *nDalem Pangeranan*, which can be used as a reference base construction efforts to control the growth of the city. This research was done using Naturalistic Qualitative method for 6 months. Sampling was used as the unit of exploration of 15 *nDalem Pangeranan* at Kampong Baluwarti. For Observation, the researcher explored every data and took information from some sources. Collecting data using Purposive Sampling technique, Snowball Sampling technique and Cross Sectional System. The result of this research showed that, generally conclusion are the buildings and environments of *nDalem Pangeranan* being stable, an nobility soul become the main force of attraction, change of functions *nDalem Pangeranan* allowed in conditional

### Keywords

*Over the function, density, renovation, stability, degradation of the normative, traditional law*

## 1. INTRODUCTION

*nDalem Pangeranan* is one of the assets of Kasunanan Palace that got the enforcement of *Pikukuh/Palilah*. The facility serves as an endorsement of the status of the building as well as to avoid the process of buying and selling of buildings of cultural heritage (BCB). Although the renovation efforts have also been undertaken in some *nDalem Pangeranan*, but the authenticity of the building forms are retained. Beside that, it also serves to seek the stability of shape and function of the building from the development efforts of the building. The effort is an example of the positive efforts that can maintain the stability of the quantity and quality of the spaces of the city. Also as a precedent to issue Act ( UU ), PP or Perda for procurement and construction complex of government buildings, social or commercial. Regarding the location of *nDalem Pangeranan*, described in the following figure:

## 2. CITATION AND REFERENCES

### 2.1. Authenticity research

In the process of collecting data, researchers have been looking for a number of studies analyzing regarding ever kind of rules in building. In several the research such are :

GRA.Koes Isbandiyah, Theses, *Kebijakan Karaton Surakarta Hadiningrat Dalam Pengelolaan Tanah Dan Bangunan Setelah Keputusan Presiden Nomor 23 Tahun 1988 Tentang Status Dan Pengelolaan Keraton Kasunanan Surakarta Di Kelurahan Baluwarti Kota Surakarta*, UNDIP, 2008. The research [1] explain about the Kasunanan Palace apply information about regarding status of land and building. Information was divided into three types namely *Palilah Griya Pasiten Anggaduh*, *Palilah Griya Pasiten Magersari*, and *Palilah Griya Pasiten Tenganan*. For *Palilah Griya Pasiten Anggaduh* and *Magersari* are rent testament while *Palilah Griya Pasiten Tenganan* is borrow-wear testament.

Lego Karjoko, Theses, *Budaya Hukum Keraton Surakarta Dalam Pengaturan Tanah Baluwarti Sebagai Kawasan Cagar Budaya*, 2005. The research [2] explain about in spite of differences of opinion regarding the status of the land of Kasunanan Palace, more people are expecting the economy to power the Palace ground in the life of society

Perda no.14/ 2011 on the amendment on Perda no. 6 / 2008 about organization and management regional taskforce the city. Regulations [3] explain about Data regional and cultural heritage the preparation of a database regional and cultural heritage labelisasi region and the preservation of cultural heritage and cultural area and heritage

Moch. Tauchid, *Masalah Agraria, Sebagai masalah Penghidupan dan Kemakmuran Rakyat Indonesia*, 2009. The study [4] explains about *Hak Tanah bagi Rakyat Indonesia ( in Kingdom era )* / Chapter 5

N. Introduction to LPKJ. The memorandum [5] explains *Penguatan Dasar Tata Kelola untuk Penguatan Ekonomi Kerakyatan dan Manifestasi Karakter Budaya Jawa/Lokal dalam Lingkungan Fisik*”

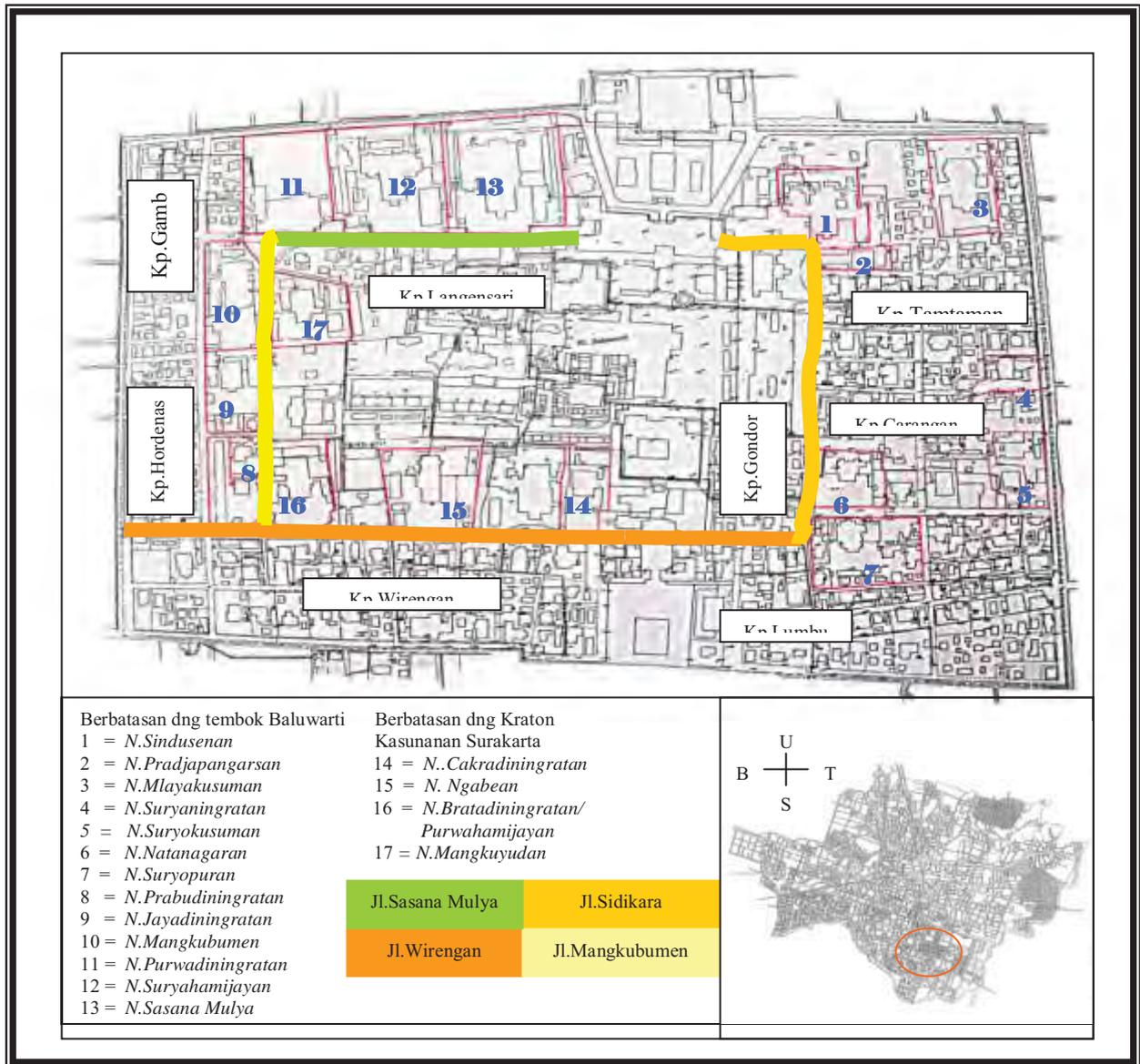


Figure 1: The nDalem Pangeranan at kampung Baluwarti  
 Source : Data research group, 2010

### 3. THEORIES

#### 3.1.Space

The human need for expression in the area of visual space as well as abstract. Visual space is limited by walls, partitions, furniture, while the abstract is limited by space activities, time, gender. Such a statement from Tuan (1977), [6] that is:

*Space zone changes as well as the abstract is not limited by walls, the partitions as well as limiting forms. For example: a space in the world, understood as play areas. While the site, located at a position that is more limited and fixed. For example: a place in the world of the geology of the area defined as the source of petroleum coal*

#### 3.2.House

The house is a product architecture for personal and communal activity, and reflect the personality of the owner. Same of Heidegger opinion in the Schultz (1971), [7] that:

*Dwelling is the basic principle of existence*

With regard to the process of human life, Gaston Bachelard in Schultz (1971), [8] further explained that:

*The house as “ one of the great integrative forces in man’s life*

In addition, in 1971, Bachelard Schultz ( 1971) similarly, [9] added that:

- *The image of the house, therefore, depends on the existence of differentiated places which interact among themselves and with the environment in varying ways.*
- *The character is determined by concrete ‘things’ such as the fire place, the table and the bed*

Related to the image home, Schultz (1971) , [10] explains that:

*The essence of the house as architecture, therefore, is interior space. In the city, we are still outside, although we have left the open landscape. In the house we are alone with ourselves, we have withdrawn*

### 3.3.Symbol

The symbol is a descriptive image that describes visual and non visual description about the object. Example: painting, sculpture, calligraphy, composition, time. Such explanations Argest and Gandelsonas (1996) in Nesbitt (1996), [11] that:

*A theory of symbols, describe and explain the link between society and the environment awakened from cultural differences and models produced*

On the other hand, Jenks explains (1969) in Nesbitt (1996), [12] that

*This is perhaps the most fundamental idea of semiology and meaning in architecture, the idea that any form in the environment or sign in language is motivated, of capable of being motivated*

While regarding the existence of the building as a symbol, the Handler (1970) in Nesbitt, [13] said:

- *A building is the embodiment of logic when a point on the outer side of the material and visualization form a universal principle valid, when it gives the vision of regulation in addition to the owner field, the range of a few things that have purpose and push to present back into a general concept that provides explanations and interpretations in the wider scheme*
- *The definition of the logic that is represented by the symbol does not signify the abstraction of religion, education, legal or community*
- *The logic expressed by the symbol cannot be seen because it is abstract and universal*
- *Human effort and social behavior depending on alignment with the logic of behavior*

Conceived as a symbol of an applicative forms of understanding. As explanation of Rapoport (1986), [14] that:

*The region attributes modified human action. There are divided in 3 levels , namely :*

1. *Fix feature : building*
2. *Semi fix feature :furniture*
3. *Non fix feature :behavior*

Applicative symbols as mistycal meaning, described by Eliade (1957), [15] that:

*Cosmic symbolism is found in the very structure of the habitation*

On the other hand, Morris (1938) in Nesbitt (1996) , [16] explain the symbols in the semiotic, namely:

- *Pragmatik “ deals with the origins, uses ( by those who actually make them ) and the effects of signs ( on those who interpret them ) within the ( total range of ) behaviour in which they occur*
- *Semantic “ deals with the signification of signs in all modes of signifying “ that is with the ways in which they actually “ carry “ meanings*
- *Syntactic “ deals with the combination of signs ( such as the way in wich words are put together to form sentences ) without regard to their specific significations ( meanings ) or their relation, to the behavior in which they occur “ thus ignoring the effects those meanings have on those who interpret them*

Then Eco (1968) in Nesbitt (1996), [17] providing 2 definition, namely:

- *Denotation : The meaning which a form has for all who use it*
- *Connotation : The special shades of meaning ( based on emotional or other factors ) that a form has for its individual user*

While Pierce (1974) in Nesbitt (1996), [18] explained the application symbol in sign is divided into 3 classifications, namely:

- *An icon is a sign which refers to the object that it denotes by virtue of certain characters of its own and which it possesses just the same, whether any such object actually exist or not*
- *A symbol is ‘a sign which refers to the object that it denotes by virtue of law, usually any associations of general ideas, which operates to cause that symbol to be interpreted as referring to that object’*
- *An index is a sign, or representation ‘which refers to its object not so much because of any similarity of, or analogy with it, nor because it is associated with general character which that object happens to posses, but because it is in*

*dynamical ( including spatial ) connection, both with the individual object on the one hand and with the senses or memory of the person for whom it acts as a sign*

Thus it can be understood that the sign is visible in the message that an object while a symbol is a message that is not visible in an object.

### 3.4. Typology

Engineering architecture can be a native form and development that will produce variation type. Budi A sukada ( in Eko Budiarjo ( 1991 ), [19] explained that that:

To drill beginning of the establishment of an architectural, objects to be learned through third thing, namely:

- Determine forms basic ( formal structures ) that is in every object an architectural
- Determine basic properties owned by was object an architectural, based on the fundamental forms of
- Studies the developmental process form the base until the form current

The types are explained through the display form of each work. Moneo in Rossi (1978), [20] explains that:

- *The concept of a typological series is generated by relationship among the elements that define the whole*
- *Typology views it as a frozen mechanism that denies change and emphasizes an almost automatic repetition*
- *The type is carefully avoided in favor of a generic and actual description of the current world*

Then Quatremere de Quincy in Rossi (1982) , [21] supports the explanation through types as follows:

- *Archetype is the original pattern from which copies are made*
- *Prototype is the first or primary ty of anything*
- *Stereotype is shift to something permanent and reproducible*

### 3.5. The frame of theory

As for some of the theories that support the process of research are :

- Space as the boundaries that load meaning
- House have basic function as facilities
- Symbol manifest in visualization engineering room
- Type of building is characteristic of association that is both stabl and non stable

## 4. RESEARCH METODHOLOGY

This research was done using Naturalistic Qualitative method for 6 months. Sampling was used as the unit of exploration of 15 *nDalem Pangeranan* at Kampong Baluwarti. For observation at those object , the researcher explored every data and took information from some sources. Then , researcher exploration of some themes related the problem. Some themes analized at discussion and conclusion process. Furthermore collecting data of research process using Purposive Sampling technique, Snowball Sampling technique and Cross Sectional System.

## 5. DISCUSSION

### 5. 1. The Consistency Visual Characteristics of Prototype Building

*nDalem Pangeranan* building is always in the form of buildings that remain. The efforts made to control changes to the form and the main function of the building. Although the owner of has the economy ability to build of building , but the efforts of change as well as the development of the building remain banned. In addition, Kasunanan Palace also enacted similar regulations for homes that are complex of *magersari* at *nDalem Pangeranan*. Whereas in order to improve the quality of living space, the Kasunanan Palace only allow for the renovation. Thus, the shape of the historic building remains consistent with historical value. These conditions are described in the following figure:

#### Conclusion:

The stability of the visual form of *nDalem Pangeranan* is an attempt being made to retain the original character of building. These efforts are intended to make the historical value can always be traced to inherited and hereditary. A complex environment the *nDalem Pangeranan* is also a great complement that describes the past situation. The rules that bind the existence of visual form the building has restricted the development of the situation. So even though less effective following the development of situation in modern era, but the regulation had managed to pack the traditional impression that lasts. The condition can control the acceleration of the process of development and the expansion of land degradation which affects the quality of the environment. It is described in figure 3.

Based on the image above, then the efforts made in the area of heritage buildings (BCB), referable on the development process of various government, social or commercial buildings . The development process is more appreciated and is oriented on the renovation effort and avoids the expansion of land. The balance of prosentase in the project page utilization, becoming a reference for calculating the tax of building (PBB). In addition, also in order to save on construction materials, renovation costs, traffic flow and congestion because the process of the project. It is very important for the sustainability of growth does

not mean expanding the field of maintenance and effort the project but instead a function on the natural energy into the main orientation



Figure 2: nDalem Pangeranan at kampong Baluwarti  
 Source : Personal documents and document Research Group, 2010

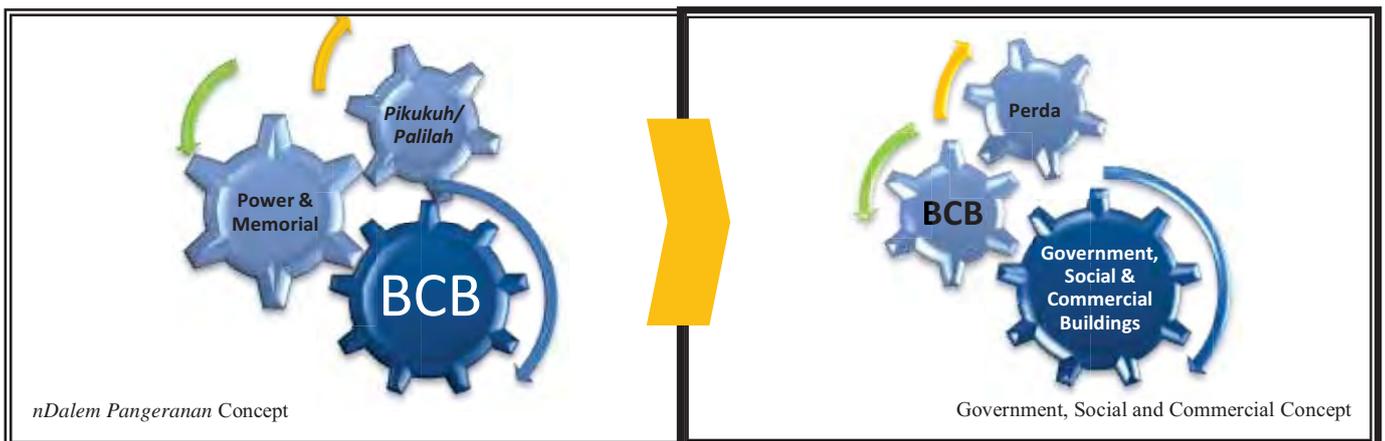


Figure 3: Contribution to the process of the construction of government, social and commercial buildings  
 Source : Personal analysis, 2013

### 5.2. The Consistency Location of *Genius Loci*

The presence of the *Genius Loci* was the location of the primary capital at the nDalem Pangeranan, because it has the ability to animate the atmosphere and situation to sacred. The *Genius Loci* are present in two forms, namely:

- Tangible : the owner (The Prince), *Krobongan*, and *Pelataran*

- Intangible: the presence of an aura of nobility that icon of location functioned as the main attraction of the *nDalem Pangeranan* and positioned as a sacred place-the mystical. Thus, among the descendants of the nobles and guests, it's easy to understand the situation of the past and be respectful of the cultural heritage. In addition, *Genius Loci* icon is also constantly being in the space that remains despite the quality of the spaces have been damaged. It is described in the following figure:



Figure 4. Interior of *nDalem Pangeranan*  
 Source : Personal documents and document Research Group, 2010

**Conclusion:**

The existence of the *Genius Loci* at the *nDalem Pangeranan* it is always preserved by the descendants of the owner and the Kasunanan Palace. Because of these efforts mean to the inner relationship with the deceased ancestors. Because inner peace become a vitality which controlled and controlling way of life. Thus, the strength and power of the memorial into something beautiful and sacred to the descendants of the nobles. Although not located on the same life period with its ancestors, but stories and ornaments in *nDalem Pangeranan* has psychic and inner binding. It is described in figure 5.

Inner bonding that occurs at the area of heritage buildings (BCB) can be used as a means of socialization to build understanding in building the space station. Efforts are being made in the area of heritage buildings (BCB), referable on the development process of various government buildings, social or commercial. The building is oriented on the preservation efforts and not change. So that the land of the magnet can be used for new buildings. Since many projects which utilize of historic buildings (e.g.: *nDalem Pangeranan*), but does not parse the *Genius Loci* of the original building from scratch. So that the efforts of the façade of the building modification efforts on the interior into a solution that often closes a location icon *Genius Loci* of the original.

### 5.3. Control-over the Building Function

*nDalem Pangeranan* not always functioned as home living (personal activity), but also enabled for communal activities. Those activities among other things for the school, where practicing of dancing, sociality, Conference Hall. Nevertheless, the complex of *nDalem Pangeranan* only functioned as a loan facility, so the activity functions are controlled by the permissions associated with it. So that there is stability of the function and a support that do not interfere with each other. Likewise *magersari* houses around the *nDalem Pangeranan*. Monitoring is also conducted through communal various related parties, e.g.: Sasana Wilapa, Stub, Wards and other social facilities. Thus, it served as the residence of each event in the *nDalem Pangeranan* can be controlled and known by the Kasunanan Palace. In order for any activities that take place in synergy with cultural activity regions. It is described in figure 6.

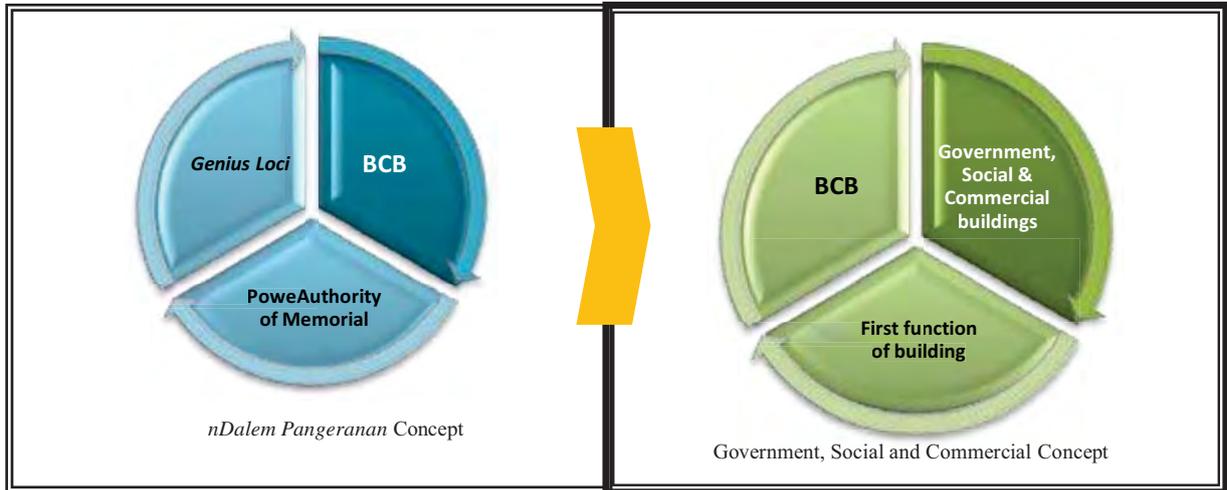


Figure 5. Contribution to the process of the construction of government, social and commercial buildings  
 Source : Personal analysis, 2013



Figure 6. Over the function of *nDalem Pangeranan*  
 Source : Personal documents and document Research Group, 2010

### Conclusion

Function changes of *nDalem Pangeranan* is oriented to meet the family economy owner. Existence facilities a great house and tend to empty has stimulation of various activities. But because it was under the supervision of family and Kasunanan Palace, then function changes be in scope culture of Java. Enactment the rule aimed the atmosphere and function *ndalem pangeranan* unchanged. So cultural identity everlastingly can be presented in a perennial manner and thorough. It was explained in a drawing the following :

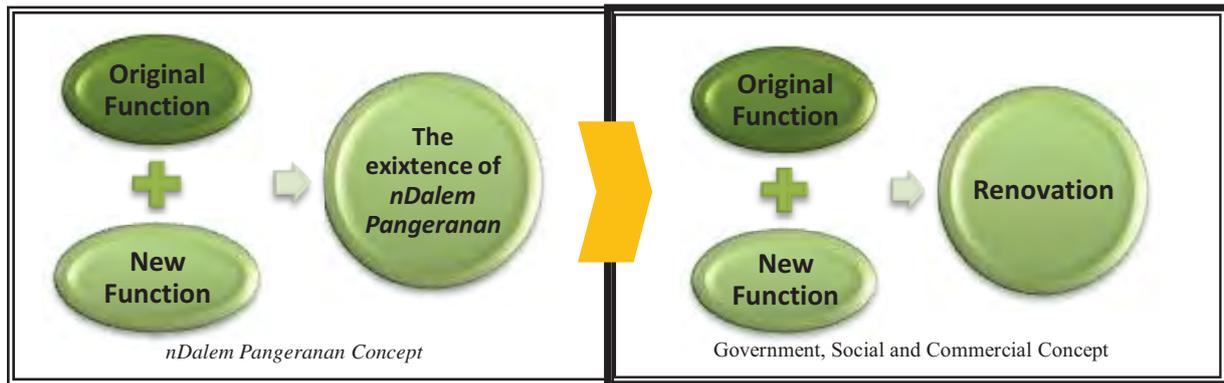


Figure 7. Contribution to the process of the construction of government, social and commercial buildings

Source : Personal analysis, 2013

Efforts are being made in the area of heritage buildings (BCB), referable on the development process of various government, social or commercial buildings. The building is oriented in an effort of renovation and not the expansion of land. The balance of prosentase in the project page utilization, be a reference counting of the tax. In addition, also in order to save on construction materials, renovation costs, traffic flow and congestion because the process of the project. It is very important For the sustainability of growth does not mean expanding the field of maintenance and effort the project but instead a function on the natural energy into the main orientation

## 6.GENERAL CONCLUSION

- Building forms and environment of the *nDalem Pangeranan* stabilized
- Aura of nobility is still the main attraction
- Transition function of the *nDalem Pangeranan* permitted by conditional

## 7.SUGGESTION

- Building construction not always have to open new land but may be conducted through renovation and refunction
- Building after habitation / after wear
- Research results can be included basic to draw up act development government buildings, social and commercial
- Limit the use of over the function and open land, so rth and reserve water stable
- Reduce traffic congestion as a result the development process new building
- Rules about area heritage buildings ( BCB ) done not only on the memorial but also to government buildings, social and commercial
- Renovation precedence more than construction process new building

## REFERENCES

- [1] Amos Rapoport, *House Form and Culture*, University of Wisconsin, Milwaukee, 1995
- [2] Burhan Bungin, *Analisis Data Penelitian Kualitatif*, PT.Raja Grafindo Persada, Jakarta, 2003
- [3] Budihardjo, Eko. *Jati Diri Arsitektur Indonesia*, Alumni, Bandung, Kotak Pos 1282, 1991
- [4] GRA.Koes Isbandiyah, Tesis, *Kebijakan Keraton Surakarta Hadiningrat Dalam Pengelolaan Tanah Dan Bangunan Setelah Keputusan Presiden Nomor 23 Tahun 1988 Tentang Status Dan Pengelolaan Keraton Kasunanan Surakarta Di Kelurahan Baluwarti Kota Surakarta*, UNDIP, 2008
- [5] Kate Nesbitt, *Theorizing A New Agenda For Architecture*, Princenton Architectural Press, New York, 1996
- [6] Lexy J Moleong, *Metodologi Penelitian Kualitatif*, PT.Remaja Rosdakarya, Bandung, 1989
- [7] Lego Karjoko, Tesis, *Budaya Hukum Keraton Surakarta Dalam Pengaturan Tanah Baluwarti Sebagai Kawasan Cagar Budaya*, 2005
- [8] Mircea Eliade, *The Sacred & The Profane : The Nature of Religion*, Harcourt Brace Javanovich Publisher, USA, 1959
- [9] Moch.Tauchid, *Masalah Agraria, Sebagai Masalah Penghidupan dan Kemakmuran Rakyat Indonesia*, 2009
- [10] Nota Pengantar LPKJ 2011
- [11] Perda no 14 tahun 2011, *Perubahan atas Perda Nomor 6 tahun 2008 tentang Organisasi dan Tata Kerja Perangkat Daerah Kota*
- [12] Roosi, dkk. 1982.
- [13] *Typologi*, MIT Press, Cambridge MA, 1982

## The Application of Sustainable Development System at Dr. Kariadi-Hospital in Semarang

Eddy Hermanto<sup>a</sup>, Sukawi<sup>b</sup>

<sup>a</sup>Department of Architecture Faculty of Engineering Diponegoro University, Tembalang Semarang 50275  
 Telp: 024 76480837 Fax: 024 76480836 E-mail: eddyhermanto@gmail.com

<sup>b</sup>Department of Architecture Faculty of Engineering Diponegoro University, Tembalang Semarang 50275  
 Telp: 024 76480837 Fax: 024 76480836 E-mail: zukawi@gmail.com

### ABSTRACT

This paper reports the implementation of synergies between the design-construction partnering with health services to achieve sustainable development as system in Semarang at General Hospital-Dr. Kariadi. The main problem is how to achieve sustainable development for health care activities and development activities that are common in the same area. Where the combination of both of these activities have been considered in the design phase by the owner and designer. Development activities and the activities of health services running at the same time has achieved success, such as there is no accident for both project activities and for health service activities, without disputes and litigation.

### Keywords

*Sustainability, system, technology, partnering*

### 1. INTRODUCTION

Land development and conservation have increased significantly in many cities in Indonesia over the last three decades because of the increasing population and economic development. The concept of sustainability was raised because of growing awareness of the global links between mounting environmental problems, socio-economic issues to do with poverty and inequality, and concerns about a healthy future for humanity (Hopwood et al. 2005). On land plot there are 2 distinct areas, namely areas that allowed for the construction and conservation area. Buildings that contact life-cycle performance, durability, energy efficiency, occupant well-being and productivity are known as sustainable development. There is broad recognition that these buildings demand increased levels of optimization among architectural, structural, envelope, mechanical, and electrical systems. To quantify the benefits of delivery for sustainable of high performance buildings, that included project team characteristics, design integration, construction applications, owner commitment, contractual arrangements, procurement methods, and project delivery methods. Development by using the partnership as one method to achieve sustainable development project success through sustainable design.

Sustainability covers three interdependent and mutually reinforcing pillars, which are environmental responsibility, economic return (wealth creation), and social development (UN 2005; Ding 2008). Chan et al. (2004) describes seven main categories of critical success factors of a construction project. Those factors are support from top management, adequate resources, mutual trust, long term commitment, effective communication, efficient coordination, productive conflict resolution. All of those factors can be addressed in the delivery of the project.

Shortly speaking, physical development ahead remain oriented to the concept of organic architecture is flexible enough to be applied for and has been proven for a long time (8). The construction of the building from the side view system known as the order of the input-process-output-outcome-impact-benefit. In the system approach the boundary of the system is framed which is also meant the legal aspects in the matters of development (2, 7). Sustainable development is closely related to green: system, concept and strategy if there is a simultaneous development with very small negative impact (Low Impact Development/LID) while obtaining greater benefits known as sustainable development based on the sustainable design (4-6).

Physical development through the design of the hospital based on the master plan, so the site plan that has been in the master plan does not change the basic framework. Once the decision is made to build, start thinking of the principles of project management, design management and construction management consists of: knowledge and skills of construction, architectural, mechanical-electrical, and environmental design (7, 9). It connotes the critical success factors for the construction project, namely: Time, Quality, Cost, Meet the expectations of the owner, and small construction issues. From the Quality through performance specification of building products in the end as the terms known that the performance of buildings demonstrate the performance and leverage in the role of physical health function operated in the long term (3-6). It is therefore very important and critical for any land development in an area, particularly in the project objectives and goals of health care activities at the same time.

The objectives of the study are to determine design of the developed area; and to develop a model of system to achieve building performance.

## 2. METHODOLOGY

This paper presents case study conducted through under-construction interviews with key project team members. This case study points out important achieving project success for sustainable, mid performance buildings. The research team interviewed project participants of field office project located in Semarang. The building is 38,000 square meters and belongs to a public owner. Owner, designer and contractor (in this case a design bid build) of the project were interviewed separately. The sustainability performance of the projects was evaluated under Leadership in Energy and Environmental Design (LEED) rating system. LEED is a point based system developed by Green Building Council Indonesia (GBCI) focusing on the: sustainable site development, water savings, energy efficiency, materials selection, indoor environmental quality, and innovation in design. The interviews addressed several architectural, structural, mechanical, and electrical systems and open ended questions regarding the building design process and its relation to the performances outcomes in term of cost, time, quality (owner satisfaction) and performance achievement of the buildings.

## STUDY AREA

The study would be carried out in the developed area of GarudaII Building, Medical Rehabilitation Building, Education and Training Building, and Inpatient Building Grade 3-General Hospital Dr.Kariadi located on Dr.Soetomo, Semarang(Fig. 1).

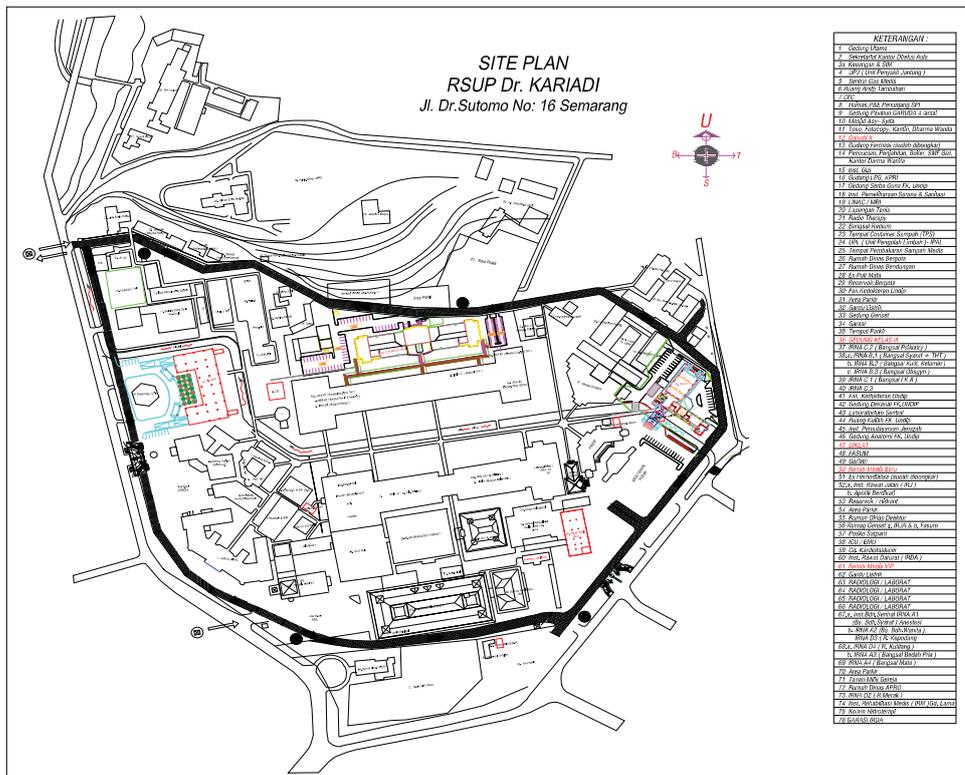


Fig. 1: Location of Study Area

This study is an observational study in the field of general hospital Dr. Kariadi during the construction of four buildings and health care at the same time. Dr. Kariadi hospital area is about 210,000 m<sup>2</sup> and the building floor area is about 190,000 M<sup>2</sup>. This condition gives a signal that has not occurred since the construction optimization building regulations stipulate Floor Area Ratio is 5 to downtown Semarang. So there is still a potential for a large area to be built in the future. Dr. Kariadi gates as access requires rethinking with regard to speed of access, safety and convenience by taking into account: the density of traffic circulation around the land, increasing the number of visitors, access to the ambulance, queuing theory.

Buildings were built in 2011-2012 consisted of Garuda II building (8 floors, 12,000 M<sup>2</sup>) with a capacity of 400 beds, Education and Training Building (3 floors, 4000 M<sup>2</sup>), Rehabilitation Medic Building (7 floors, 5600 M<sup>2</sup>), Installation Inpatient Class III Building (7 floors, 14,000 M<sup>2</sup>) with capacity of 400 beds. Thus, in 2012 RSUP Dr. Kariadi has more than 1200 beds

totally. In the present, parking capacity that uses the principle of on-street and off-street parking is full even less because every day there are 1800 cars and 2340 motorcycles taking place of parking-lot. These are demanding that the building will be constructed and parking area is already set in two places connected by the outer ring road in the general hospital area. There is flexibility for the construction industry technology options, technology tools and technology in both medical device types and in the amounts, namely: conventional, rational and industry. Implementation of building can be done by methods: cast in situ, cast in place and precast or prefab depending on circumstances. These are supported by the existence of space between buildings and the outer ring road of Dr. Kariadi hospital.

### 3. RESULTS AND DISCUSSION

The objectives identified by the different project teams show that construction projects are now considering both soft management issues and sustainable development as central to the successful delivery of construction projects. During the process of project implementation arrangements made by the contractor, as follows: physical limits of each activity, traffic project activities and activities of health services, physical security net. The result was no accident, building performance is achieved. This project has managed to cut costs up to 6%, time-saving 5% of the project, and construction claims 3%.

The concept of sustainable intended initial attention has been considered for pedestrian safety for visitors and staff, speed of ambulance services for 24 hours, the speed of other services, and physical development that has little impact for health care. Most of the rainfall water is discharged out from the land through the river. The existence of a small river not intervened so that the function of the drainage water is still running smoothly without sedimentation. The river discharge is extremely higher during rainy season, even been higher than the river capacity. The application of bio-retention is useful in order to cope with the flood and for groundwater reserves.

The orientation of new buildings facing the north and the south, thereby reducing the effect of the sun's heat directly against the glass. Planning of open space considered as an area for evacuation, green or garden, natural air flow, natural lighting, rainwater inflow into the ground, and playground or sports. In this case, the impact of land development to the runoff change would be managed by means of bio-retention system. With the LEED green building certification process buildings can achieve a certification, silver certification, gold certification or platinum certification (GBCI 2010). Main characteristic of general hospital Dr. Kariadi orientation is expressed in the design on the sides of the LID through considerations of: Planning (Master plan, Feasibility Study); System (open/closed; hard/soft; approach); Green Concepts and Grand Strategy. Sustainable design considering implementation methods either series or parallel. The substance of the design conducted design review and value engineering prior to the construction site. The view point above description is included aspects of Whole Life Costing (WLC), which has been measured so that management role can be expected.

Based on owners, users and experts of Dr. Kariadi hospital held frequent communication about the development of an appropriate scope of future requirements combined with the policy of the Ministry of Health and international rules Joint Commission International (JCI) to produce a design that supports a minimum standard of health care and Standard Operating Procedures (SOP). Discussion was also made in relation to the future problem solving and decision making and forecasting. The role of the function of these activities will lead to the need for facilities that are closely linked: Development management; Technology of construction industry; Technology of utilities and Technology of health equipment.

Within the scope of the hospital operation, on the one hand Dr. Kariadi process Eco Management Audit System (EMAS) in the system of Waste Water Treatment Plant (WWTP). Processing installation internally to maintain systems that have been built while externally conducted by the Environment Agency of Middle Java Province (BLH-Prop) with weekly-monthly evaluation reports and field investigations per semester. On the other hand, based on the policy of the Ministry of Health in accordance with the era of globalization in the Millennium Development Goals (MDGs), Dr. Kariadi follow the rules that apply in the JCI in terms of standard of health care through completion of facilities and infrastructure that meet the technical requirements and applicable law. In this case means that the use of partnering for construction projects of complex building that are in stages: planning, design, procurement, construction. At the stage of human bionomics also used partnering on operations and maintenance.

### 4. CONCLUSION

The study, however, indicate that design-construction partnering can achieve substantial sustainable development through sustainable design. Based on the above description, it can be concluded about the basics are as follows:

- a) Sustainable design has a central role toward sustainable development in the system of construction projects.
- b) Design-construction partnering consists of: owner, consultant, contractor, and supported by top management.

### ACKNOWLEDGMENT

The Authors would like to thank to the Department of Architecture, Engineering Faculty, Diponegoro University; and the General Hospital-Dr. Kariadi, Semarang.

## REFERENCES

- [1] Alexandar Subic, 2008, **Sustainable Design**, *International Journal of Sustainable Design*, Book 1 Volume 1.
- [2] Benyamin Handler, 1970, **System Approach to Architecture**, Elsevier Publ.
- [3] C Black, A Akintoya, Fitzgerald, 2000, **an analysis of success factors and benefits of partnering in construction**, *International Journal of Project Management* Volume 18, Issue 6, 1 December 2000, Pages 423–434.
- [4] Chan, A.P.C. Chan, D.W.M. Chiang, Y.H. Tang, B.S. Chan, E.H.W. and Ho, K.S.K., 2004. Exploring critical success factors for partnering in construction projects. *Journal of Construction Engineering and Management*, 130(2), 188-198.
- [5] Dainty, Austin, Koutsikouri, 2008, **Critical Success Factors in Collaborative Multi-Diciplinary Design Projects**, *Journal of Engineering, Design and Technology*, Vol. 6 Iss: 3, pp.198 – 226.
- [6] LB Robichauld et al, 2011, **Greening Project Management Practices for Sustainable Construction**, *J of Constr Eng & Mangt (ASCE)* 27(1):48-57.
- [7] Peng Wu et al, 2010, **Project Management and Green Buildings: Lesson from the Rating Systems**. *J of Constr Eng & Mangt (ASCE)*, 136(2):64-70.
- [8] Wong, Lam, Chan, 2006, **Contributions of designers to improving buildability and constructability**, *Design Studies Journal*, Vol.27, Issue 4, 2006, pp: 457-479.
- [9] Snyder, Catanese: **Introduction to Architecture**, McGraw Hill, 1978.
- [10] Testa, Carlo and Thomas Schmidt, 1969, **System Building**, Praeger Publisher, New York.

## **Towards a Grand Scenario: Innovations in Green Architecture**

**Diane Valerie Wildsmith**

*Department of Architecture, Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail: idc2003@cbn.net.id*

### **ABSTRACT**

This design research analyzes the merits of innovations in green architecture as an ecological response to meet the QIR 2013 conference objectives of 'Towards a Grand Scenario: Policy for Sustainable Growth.' Jakarta, along with Bangkok, Delhi, and Mumbai, finds itself in the unenviable category of multiple risks in five urban typologies that is related to future proofing cities against high energy use and carbon footprints, flooding, and risks to regional ecosystems and resource supply networks. High rise green architecture reduces the impact of urban sprawl, excessively high carbon footprints, and transportation costs, yet this typology increases high energy use with glass facades, high tech materials and construction costs. Greening Asian megacities is an urgently required challenge, which needs to be tackled not only with technological solutions, but also with high quality, culturally relevant design scenarios.

### **Keywords**

*Future Proofing Cities, Green Architecture*

**This paper is published in International Journal of Technology (IJTech)**

# Green Open Space Approach to the Building Mass Arrangement in Yogyakarta: Case Study of the Revitalization of the Tugu Rail Station

Suparwoko<sup>a</sup>

Faculty of Engineering and Planning, Islamic University of Indonesia  
E-mail: wokos2002@yahoo.com

## ABSTRACT

This paper is to analyze the green open space approach to the building mass arrangement in urban block areas. The case study is “The Project Preparation Consultant for Revitalization of Yogyakarta Rail Station and Pedestrianization of Malioboro” proposed by application of ADB Loan No. 2264-INO (SF): Infrastructure Reform Sector Development Program. Due to the building mass, the building code of the railway station area state that (1) the building coverage ratio (BCR) is 85% and the Floor Area Ratio (FAR) varies (from 3 up to 4,8) based on the Yogyakarta Municipality Building Ordinance. The Green Open Space (GOS = RTH or Ruang Terbuka Hijau) Regulation in Indonesia states that the minimum green open space in urban area is 30%. With an 85% BCR, the railway station project tends to maximize the lot for building construction. Therefore, it is difficult to wish the building ownerships providing 30% GOS from their lots. Due to such a problem concerning on the GOS regulation, how to encourage building ownerships to provide at least 30% of their lots to be GOS during their site development in central urban lot areas for the future constructions for any public services such a railway station. This paper tries to model and encourage (public and private) urban developers to provide more green open space on their lots to be replaced by more space on top of its floor area ratio based on the current building code. The method is using the case study of the Tugu rail station development of in Yogyakarta as a model of analysis. To provide more open (green) space, the model is to reduce the current BCR so that the new BCR has a more open green space. This different of a green open space will be rewarded as an incentive for the additional floor area on the top of the maximum floor area. The researcher believes that the incentive floor area to reduce the current BCR will increase green open space on urban lot areas. In this respect, the character of the building mass is determined by the BCR and representing how the green approach of its open space. This model will support the urban GOS regulation in Yogyakarta and Indonesia generally to have minimum 30% of GOS in the near future urban areas.

## Keywords

*Green Open Space, BCR, FAR, Tugu Rail Station.*

## 1. INTRODUCTION

The high rate of population growth is mainly because urbanization is one of the problems of cities in Indonesia. The big number of urban population is creating a high pressure on the utilization of urban space, especially the reduction of open spaces in urban areas, both green open space (GOS) and non Green Open Space [1]. In this case, GOS consists of public and private green space. Ideally, the city has a GOS least 30% of the total area of the city, referring to the Earth Summit in Rio de Janeiro, Brazil (1992), and reaffirmed at the summit Johannesburg, South Africa in 2002 [1, 2]. Regulation of the Minister of Home Affairs Decree No. 1 of 2007 on Spatial Planning can be obtained the information that the minimal of green open space in urban areas is 30%, which consists of 20% public and 10% of private GOS [3]. Based on data from the Environment Agency of Yogyakarta in 2010, the public GOS was amounted to 17.17% (557,90 hectares) of the city area of Yogyakarta. That number is still less than 20% as stipulated by the Public Work Regulation Number: 05/PRT/M/2008. Lack of the development of public GOS in urban areas caused by: 1) the limited cultivable land for green space development, 2) the rise of a variety of development projects that violates environmental rules. So the government needs to increase the number of Yogyakarta urban public green spaces. In order to increase the GOS of Yogyakarta, the Municipality Government issued regulations including the Yogyakarta Mayor Regulation No. 5 of 2007 regarding on green open spaces and the Mayor of Yogyakarta Regulation No. 6 of 2010 regarding the Provision of Private Green Open Spaces. This shows a good willingness of the city of Yogyakarta due to the provision of urban green spaces in its urban area. In order to reach the ideal size of GOS as mandated in the Spatial Planning Act, the city of Yogyakarta facilitated by the Provincial Government of the Yogyakarta Special Region (YSR or DIY) and the Directorate General of Spatial Planning - Ministry of Public Works, planned a public provision of green space in the form of increased green spaces through community initiatives that embodies the design competition for the detailed engineering design to be implemented [1]. However, there is no significant impact from the competition to the GOS growth in the Yogyakarta urban area so far. This means that the Yogyakarta government has some difficulties to increase more public GOS due to the limited budget and the number of grey land limitation. In this respect, the government should encourage any public and private development in Yogyakarta to provide more GOS by providing building volume incentive of any urban building construction. Therefore, it is crucial to create a model regarding a Green Open Space

Approach to the Building Mass Arrangement in Yogyakarta urban area. This approach will use case study of the revitalization of the Tugu Rail Station in the city of Yogyakarta.

Supporting to the Spatial Planning Act, this paper is proposing to analyze a green open space approach to the building mass arrangement by using the case study of the revitalization of the Tugu rail station in Yogyakarta. The objective this paper is to encourage public and private building development to provide more green spaces by promoting the government in providing some floor area incentive more than the existing Floor Area Ratio based on the Yogyakarta Municipality Building Code.

The method to provide some building volume incentive more than the basis Floor Area Ratio is by 1) increasing open space from the basis BCR and 2) Increases/decreases bonus floor area ratio based on the greenery ratio. To provide some incentive building volume, the site development has to provide green open spaces in their site development more than the BCR basis as seen on Figure 1. To increase/decrease the bonus building volume in the site development is to increase their greenery ratio as seen on Figure 2 including: 1) increasing bonus floor area ratio for any developments of greenery ratio more than 45% and 2) decreasing bonus floor area ratio for developments of greenery ratio below 35% [4].

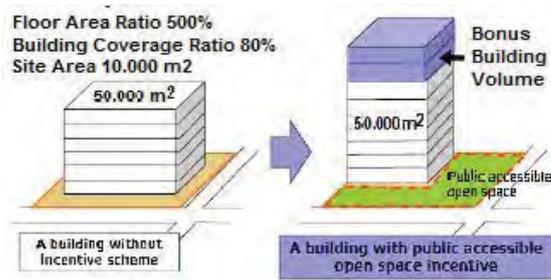


Figure 1. Three Dimension Analysis and Approach to encourage private green open space incentive in urban area [4]

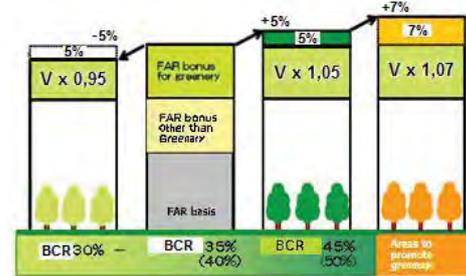


Figure 2. Increases/decreases bonus floor area ratio; [4]

## 2. GREEN OPEN SPACE APPROACH

The concept of greening of the city, or *green urbanism*, shows an important design approach to the sustainable urban development form. The urban sustainability is included on the green open space which has an ability to contribute positively to some key agendas in urban areas [5]. Urban greening approach tries to find the integration between the urban itself and natural environment as a dynamic urban of city dwellers through a diversity of open landscapes [6, 7].

The GOS is an open space area outside the building, which serves for various activities. Regulation of the Minister of Public Works No. 05/PRT/M/2008 concerning on the Guidelines for the Provision and Use of green open space (GOS) in urban areas states that the GOS in offices, shops, and places of business generally in the form of sidewalk and parking lane. Provision of green space in this area are as follows: 1) To the extent Building Coverage Ratio (BCR) 70% -90% will need to add a potted plant, 2) Offices, shops and places of business with BCR over 70%, have at least 2 (two) small tree or medium were planted on land or in pots above 60 cm in diameter, 3) tree planting requirements in offices, shops and business premises with BCR below 70%, such as the requirement applies to yards with GOS, and planted in areas outside the BCR has been determined. Spacious yard complies with BCR in urban areas, as set out in the Regional Regulation on spatial planning in each city. To facilitate classification yard in the specified category yard large, medium and small. Large courtyard is spacious yard with a larger 500 m2. Due to the case study Tugu Rail Station has lots more than 500m2 of commercial activities (shopping, office and hospitality), the appropriate rules of GOS model used for this concept is on the Big House category [8].

*Building Coverage Ratio (BCR)* and *Floor Area Ratio (FAR)* are the most commonly used to indicate for quantifying the building density at lot scale. The BCR is defined as the ratio of the building coverage area (i.e. the area of building footprint) to the size of land lot. Since the footprint represents the planimetric shape of a building, the BCR measures the building density in two-dimension (2D) space. The FAR is defined as the ratio of gross building floor area to the size of lot. The value of FAR is determined not only by the planimetric shape of the building, but also by the vertical distribution of the floors in different height and it represents the three-dimensional (3D) building density. *Open space ratio (OSR)*: is the percentage of open space to the area of the land or lot. An open-to-sky space without a roof is considered an open space. The location, size, distribution and surface nature of open spaces could change the local environment by altering the air flow, humidity and heat balance with the urban canopy layer [9]. *Green coverage ratio (GCR)*: is the percentage of the total area of all green spaces (including above green and below green coverage) to the area of the land or lot. Trees and smaller plants such as shrubs, vines, grasses, and ground cover, help cool the urban environment. Thus, *GCR* is an important parameter in describing urban surface cover, which is affects urban climate such as radiation and surface temperature through shading and evapotranspiration. Generally the sun's

energy reaches the area of trees, with the remainder being absorbed by leaves and used for photosynthesis, and some being reflected back into the atmosphere [10].

The Big House category in the Regulation of the Minister of Public Works No PU 05/PRT/M/2008 provides green space provision of the following schemes: 1) a category that includes big house is a house with a land area of over 500 m<sup>2</sup>, 2) green open space is the minimum required land area (m<sup>2</sup>) less extensive base building ( m<sup>2</sup>) in accordance with local regulations, and 3) the number of shade trees to be provided a minimum of 3 (three) combined with shade trees and shrubs as well as shrubs and ground cover or grass. Furthermore, the green space on offices, shops, and businesses, in addition to the utility, can be used also as an open parking area, carport, and a place to organize various outdoor activities such as ceremonies, fairs, sports, and others [8]. The provision of Public Open Space in Private Development (POSPD) seeks primarily to achieve better quality design, optimisation of land use, better site planning, and/or synchronising the availability of open space and the community needs arising from developments. With proper design and management, POSPD could contribute towards the provision of quality leisure and recreational space and improve urban living environment [11]. A lot of recently developed commercial and residential areas comprise higher FAR and lower Building Coverage Ratio (BCR), compared with old ones [12]. Timely and complete information about urban building density and morphology has need of the measurement of land use intensity and efficiency, design and adjustment of zoning regulations and land use policy, monitoring and enforcement of urban management policies [13, 14].

Urban designers should control some crucial variables shaping the building form and massing in the contexts of urban design including building line, setback, land use, floor area ratio (FAR), and building coverage ratio (BCR) [15]. The green building character to lower impact on local site ecology is to 1) increased green space (small building footprint, minimal surface parking), 2) provide green roofs and has highly efficient building envelopes [16]. The compact city is designed to make more efficient use of existing land resources and infrastructure, as well as reducing automobile usage as public transportation becomes more viable at higher urban densities [17]. The legislative and regulatory framework for stimulating "green" projects has been gradually taking place in Europe, particularly in France. For new residential construction, a decree relative to the Energy Policy Orientation Program authorizes the building coverage ratio up to 20% provided in all other local planning rules respectively [16].

To respond the green open space approach on the site and building scale, there are four concepts including 1) Specific block, 2) Intensive Land Use District, 3) District Planning with Redevelopment Promotion, and 4) Comprehensive Design [4]. Due to the preparation of initial design of the Tugu Rail Station, particularly on the building mass arrangement, the comprehensive design concept will be omitted on to this discussion. The analysis model of the green development approach concerning on the building form and massing of the Tugu Rail Station will use the three dimension analysis to see the schematic approach. Building Coverage Ratio (BCR) and Floor Area Ratio (FAR) are the most commonly used indicates for quantifying the building density at land parcel scale. The BCR is defined as the ratio of the building coverage area (i.e. the area of building footprint) to the size of land lot in Eq. (1), where S is the building coverage area, and S<sub>L</sub> is the area of land lot. Once the association between building footprints and land lots is determined, the BCR for each land lot can be computed using Eq. (1). Since the footprint represents the planimetric shape of a building, the BCR measures the building density in two-dimension (2D) space. The FAR is defined as the ratio of gross building floor area to the size of land lot (Eq. (2)) [12, 14]

$$BCR = \frac{S}{S_L} \dots\dots\dots Eq.(1)$$

$$FAR = \frac{\sum_{i=1}^t A_i}{S_L} \dots\dots\dots Eq.(2)$$

Where A<sub>i</sub> is the area of the first floor, and t is the total number of floors. The value of FAR is determined not only by the planimetric shape of the building, but also by the vertical distribution of the floors in different height and it represents the three-dimensional (3D) building density .

A study of a proposed project implementation is part of a development scenario. An example that the study on “*Downtown Edmonton Commercial, Office and Residential Forecasts 2009 – 2044*” examined the development growth of residential units, retail and service commercial, and office building in the Downtown. The study had two alternative approaches concerning on a „Baseline“ and „Alternate“ scenario. The „Baseline“ scenario assumed a „status quo“ or „business as usual“ scenario and the „Alternate“ scenario assumed that the vision outlined in the Plan for the Downtown would be implemented [18]. It can be seen that the „Alternate“ scenario is part of planning and development process. It can be seen that spatial and infrastructure development is always behind the economic growth resulting physical construction that is driven by social and economic activities without referring the urban spatial plan. This will be naturally growing that existing economic activities do not fit with the current urban development plan.

### 3. TUGU RAIL STATION PROJECT IN YOGYAKARTA

The Yogyakarta Special Province (Daerah Istimewa Yogyakarta, or DIY) is located in south-central Java surrounded by the province of Central Java with the Indian Ocean to the south (See Figure 3). Yogyakarta in 2009, the population and area of DIY is 3,281,000 people and 3,185.80 km<sup>2</sup> respectively with density of 1,030 people per km<sup>2</sup> and annual population growth rate is about 0.9 % per year. The Gross Regional Product (at nominal prices) is Rp. 3.5 trillion in 2000 and Rp. 4.7 trillion in 2007. Rail passengers rose from 1.7 million in 2000 to 1.9 million in 2007. Vehicular traffic has been increasing annually in the area where the proposed project is located at the Tugu rail station of the Malioboro Business District. Due to the large number of passengers and tourists visiting to this area, traffic congestion on the Malioboro road and surrounding road networks has become more acute from year to year. Moreover, since the street is rather chaotic and congested with street vendors, it is necessary to achieve the smooth traffics and to accelerate the redevelopment to the Malioboro area. On the other hand, due to the budgetary constraints, the effective solution has not been carried out in the infrastructure development scheme [19].



Figure 3. Yogyakarta in the Central Java as a Part of Indonesia



Figure 4. The Tugu Rail Station in the Malioboro Area of the Yogyakarta Municipality

Under this circumstance, the study intitle “Public-Private Partnership for Urban Infrastructure Project, Pilot Project of Yogyakarta City” with two (2) stages were conducted in 2005 and 2008 respectively. By those studies, the several examinations were implemented to solve the above issues, which are 1) selection of potential project packages, analysis of technical and 2) financial feasibility, identification of legal issues, especially in land status, analysis of social and environmental impacts by implementing the proposed project, implementation of public consultation meetings among relevant government agencies. The study of the proposed project implementation “the Project Preparation Consultant for Revitalization of Yogyakarta Rail Station and Pedestrianization of Malioboro” is proposed by application of ADB Loan No. 2264-INO (SF): Infrastructure Reform Sector Development Program. The case Study is located in Malioboro urban area in the Yogyakarta Municipality which is the capital city of DIY [19] as shown in Figure 3, Figure 4, and Figure 5.

#### 4. ANALYSIS OF THE GREEN OPEN SPACE APPROACH

The Tugu Rail Station Project is located in the Gedongtengen Sub District of Yogyakarta Municipality. The land use and the building code of the site location of the proposed project can be seen on the Figure 5 and Table 1. The site location consists of four different zones including Zone 1, Zone 2, Zone 4, and Zone 7. The description of the zones and area are clearly stated on Table 1 concerning on uses, building height, BCR, and FAR of the Tugu Rail Station area. The proposed project covers 21 sites including 15 sites accommodating commercial, office, and residential uses, and six lots accommodating parks and building conservation of the Tugu Rail Station (see Figure 5, Figure 6, and Table 1).

On the current study, the project is using the existing building code (BCR 80% with the current respecting FAR) resulting maximum floor area 624.337 m<sup>2</sup> divided on to 4 up to 6 floors (see Table 2). The following outcomes (see also Table 2) are based on the same approach:

- 1) With BCR 70%, the maximum floor area is 670.250 m<sup>2</sup> divided on to 5 up to 7 floors.
- 2) With BCR 60%, the maximum floor area is 691.999 m<sup>2</sup> divided on to 6 up to 9 floors.
- 3) With BCR 50%, the maximum floor area is 710.526 m<sup>2</sup> divided on to 6 up to 10 floors.

It can be seen that the more GOS installed the larger bonus floor area can be received (see Table 2 concerning comparative green open space to the building mass arrangement). These schemes suggest that the municipality government of Yogyakarta should encourage vertical building development in its central business district (CBD) of Malioboro without providing the budget to purchase any land to provide more greenery in urban areas. The government with the GOS incentive could privately and publicly increase GOS in urban areas, especially in the Malioboro CBD without any additional government budget. Otherwise, the City Government would spend more money to increase GOS in central urban areas of Yogyakarta.



Figure 5. Land Use and Building Code of the Study Area

Tabel 1. Yogyakarta Municipality Building Code concerning on the Tugu Rail Station Area

Zo ne	Description	Land Area	BH	BCR	FAR
1	Buffer zone of natural and cultural, Trade and Services F.2.1 Medium-high Intensity of Land Use (Segmen)	40-100	18	90	2,7
		101-200	20	90	3,2
		201-400	20	80	3,0
		401-1000	20	80	3,0
		>1000	26	80	3,9
2	Buffer zone of natural and cultural, Trade and Services F.2.1 Medium-high Intensity of Land Use (Block)	40-100	16	90	1,8
		101-200	18	90	2,7
		201-400	18	80	2,4
		401-1000	18	80	2,4
		>1000	20	80	3,0
4	Fully Development Zone (Economy Social, and Culture). Trade and Services F.2.1 High Intensity of Land Use (Segment)	40-100	18	90	2,7
		101-200	20	90	3,2
		201-400	24	80	3,5
		401-1000	26	80	3,9
		>1000	32	80	4,8
7	Buffer Zone for Nature and Culture (Tugu Rail Station) Medium-high Intensity of Land Use	40-100	16	90	1,8
		101-200	16	90	1,8
		201-400	18	80	2,4
		401-1000	20	80	3,0
		>1000	20	80	3,0

Legend:	
BH	: Building Height
BCR	: Building Coverage Ratio
FAR	: Floor Area Ratio

Legend:	
4 - 17 - 14	: Building Demarcation and Setback
17	: Road or Path Way
4	: Building Setback from the Road or Pathway

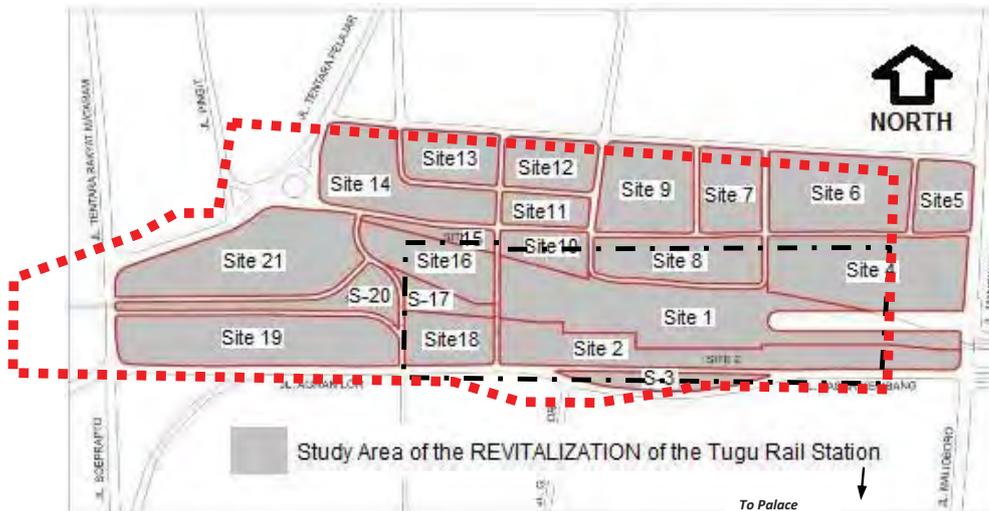


Figure 6. Site 1 up to site 20 located in the Tugu Rail Station

The 2D and 3D building mass arrangement scenario provides four different BCR base lines comparing BCR 80%, BCR 70%, BCR 60%, and BCR 50% (See Table 2, Figure 7 and Figure 8). The 2D and 3D model scenario benefit people to view spatially comparative pictures (as seen on Figure 7 and Figure 8). Figure 7 and Figure 8 showing the 2D and 3D landscapes comparatively concerning on the building mass arrangement based on BCR basis with other alternate BCR incentive affecting

different sizes of FAR bonuses (see yellow colors on Figure 7 and Figure 8). The more BCR decreased the bigger incentive FAR bonus.

Table 2. Green Open Space to the Building Mass Arrangement with BCR 70% and BCR 80%

No.	GREEN OPEN SPACE APPROACH	BCR=80%										BCR=70%										BCR=60%										BCR=50%									
		Effective Site Area (m <sup>2</sup> )	BCR (%)	FAR	FAR Basis as on the Building Code (m <sup>2</sup> )	First Floor Area - BCR (m <sup>2</sup> )	Number of Floors	First Floor Area - BCR 70% Area (m <sup>2</sup> )	Bonus Area - Open and Green Space (15%) (m <sup>2</sup> )	Decreased Bonus FAR (V x 0,95) (m <sup>2</sup> )	FAR Basis (m <sup>2</sup> )	New Total Number of Floors	First Floor Area - BCR 60% Area (m <sup>2</sup> )	Bonus Area - Open and Green Space (40%) (m <sup>2</sup> )	Increased Bonus FAR (V x 1,05) (m <sup>2</sup> )	FAR Basis with the Increased Bonus FAR (m <sup>2</sup> )	New Total Number of Floors	First Floor Area - BCR 60% Area (m <sup>2</sup> )	Bonus Area - Open and Green Space (50%) (m <sup>2</sup> )	Increased Bonus FAR (V x 1,07) (m <sup>2</sup> )	FAR Basis with the Increased Bonus FAR (m <sup>2</sup> )	New Total Number of Floors	First Floor Area - BCR 50% Area (m <sup>2</sup> )	Bonus Area - Open and Green Space (50%) (m <sup>2</sup> )	Increased Bonus FAR (V x 1,07) (m <sup>2</sup> )	FAR Basis with the Increased Bonus FAR (m <sup>2</sup> )	New Total Number of Floors														
1	Train Station Conservation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-													
2	Retail Shop House (Ruko) Building	16.291	80	3,9	63.535	13.032	5	11.404	4.807	4.643	63.535	6	9.775	6.516	6.842	63.535	7	8.148	6.146	6.716	63.535	8	6.723	5.000	5.320	63.535	9														
3	City Park and Commercial Facility	3.723	80	3,0	11.175	2.980	4	2.608	1.118	1.062	11.175	5	2.235	1.290	1.365	11.175	5	1.881	1.563	1.593	11.175	6	1.514	1.508	1.411	19.578	6														
4	Hotel & Its Facility	18.660	80	3,9	72.794	14.332	5	13.060	5.600	5.320	72.794	6	11.199	7.466	7.839	72.794	7	9.333	9.333	9.995	72.794	8	7.611	5.000	5.320	72.794	9														
5	Retail Shop House (Ruko) Building	5.020	80	3,9	19.378	4.016	5	3.514	1.508	1.411	19.378	6	3.012	2.068	2.108	19.378	7	2.510	2.510	2.688	19.378	8	2.008	1.508	1.593	19.378	9														
6	Rental Office & Its Facilities	14.711	80	3	44.333	11.769	4	10.298	4.413	4.193	44.333	5	8.827	5.888	6.179	44.333	5	7.356	7.356	7.870	44.333	6	5.885	4.413	4.693	44.333	7														
7	Rental Office & Its Facilities	7.011	80	3,0	21.033	5.909	4	4.908	2.103	1.998	21.033	5	4.207	2.804	2.943	21.033	5	3.506	3.506	3.751	21.033	6	2.805	2.103	2.242	21.033	7														
8	Apartment & Its Facilities	5.364	80	3,0	29.032	7.971	4	6.970	2.969	2.840	29.032	5	5.978	3.966	4.183	29.032	5	4.982	4.982	5.331	29.032	6	3.990	2.969	3.108	29.032	7														
9	Apartment & Its Facilities	11.251	80	3,0	33.753	9.061	4	7.636	3.395	3.207	33.753	5	6.751	4.500	4.725	33.753	5	5.426	5.426	6.019	33.753	6	4.434	3.395	3.534	33.753	7														
10	City Park as additional KLB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-														
11	Stack House & Its Facilities 3-3 Floor	3.693	80	3,0	11.079	2.954	4	2.503	1.108	1.053	11.079	5	2.216	1.477	1.551	11.079	5	1.847	1.847	1.976	11.079	6	1.478	1.108	1.153	11.079	7														
12	Stack House & Its Facilities 3-3 Floor	6.267	80	3,0	18.801	5.014	4	4.587	1.880	1.796	18.801	5	3.700	2.507	2.612	18.801	5	3.134	3.134	3.353	18.801	6	2.562	1.880	1.955	18.801	7														
13	Dwelling low intensity of 2-3 Floor	6.299	80	4,8	30.235	5.039	6	4.409	1.896	1.795	30.235	8	3.779	2.520	2.646	30.235	8	3.150	3.150	3.370	30.235	10	2.571	1.896	1.966	30.235	12														
14	Dwelling low intensity of 2-3 Floor	13.234	80	4,8	61.529	10.587	6	9.264	3.920	3.772	61.529	8	7.940	5.294	5.558	61.529	8	6.637	6.637	7.090	61.529	10	5.418	3.920	4.090	61.529	12														
15	City Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-														
16	Train Warehousing Conservation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-														
17	City Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-															
18	Retail Shop House (Ruko) Building	8.189	80	3,0	18.417	4.911	4	4.297	1.842	1.750	18.417	5	3.683	2.426	2.578	18.417	5	3.070	3.070	3.284	18.417	6	2.468	1.842	1.912	18.417	7														
19	Mall Building & Its Facilities	18.709	80	4,8	89.803	14.967	6	13.096	5.613	5.332	89.803	8	11.225	7.434	7.858	89.803	8	9.355	9.355	10.009	89.803	10	7.466	5.613	5.837	89.803	12														
20	City Park	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-															
21	Hotel & Its Facility	20.122	80	4,8	96.586	16.896	6	14.083	6.037	5.733	96.586	8	12.073	8.049	8.451	96.586	8	10.061	10.061	10.765	96.586	10	8.052	6.037	6.257	96.586	12														
		161.101			624.337	128.881		112.771	48.330	45.914	624.337		96.683	64.440	67.662	624.337		80.551	80.551	86.189	624.337		64.440	48.330	50.914	624.337															
					<b>624.337</b>						<b>670.250</b>					<b>691.999</b>											<b>710.526</b>														

Source: Analysis

The alternate BCR on Figure 7 and Figure 8 is showing the four scenarios concerning on the following schemes [4] (based on Figure 2 Formula):

- 1) the BCR 80% with no FAR bonus (the total site area is 161.101 m<sup>2</sup>)
- 2) the BCR 70% with a decreased bonus = 0,95 x 30% of the site area = 45.914 m<sup>2</sup>
- 3) the BCR 60% with an increased bonus = 1,05 x 40% of the site area = 67.662 m<sup>2</sup>
- 4) the BCR 50% with an increased bonus = 1,07 x 50% of the site area = 86.189 m<sup>2</sup>

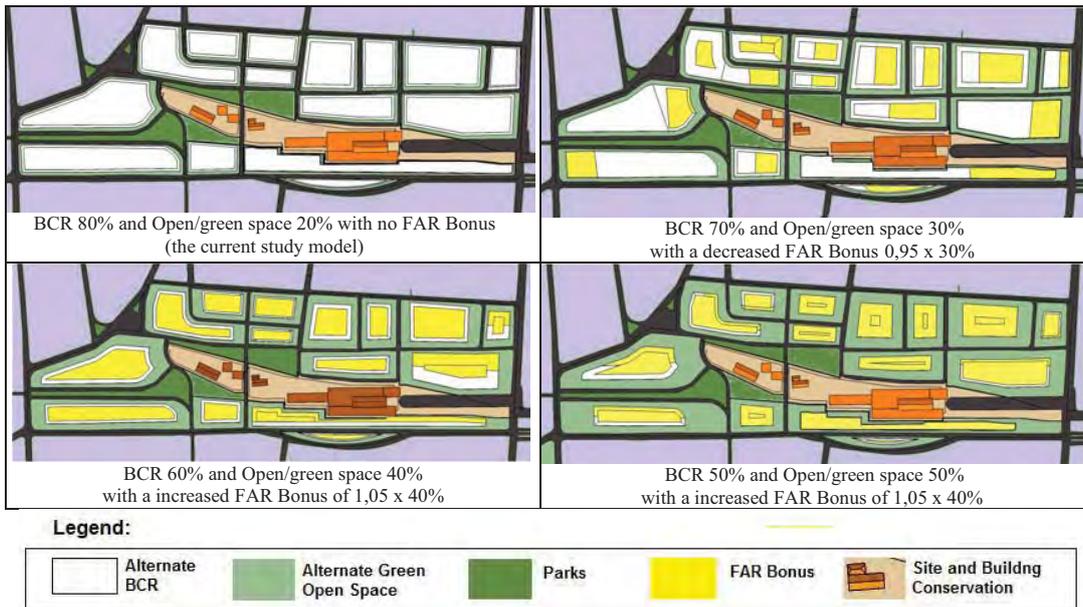


Figure 7. 2D of Green Open Space comparison concerning on FAR Basis and FAR Scenario Models

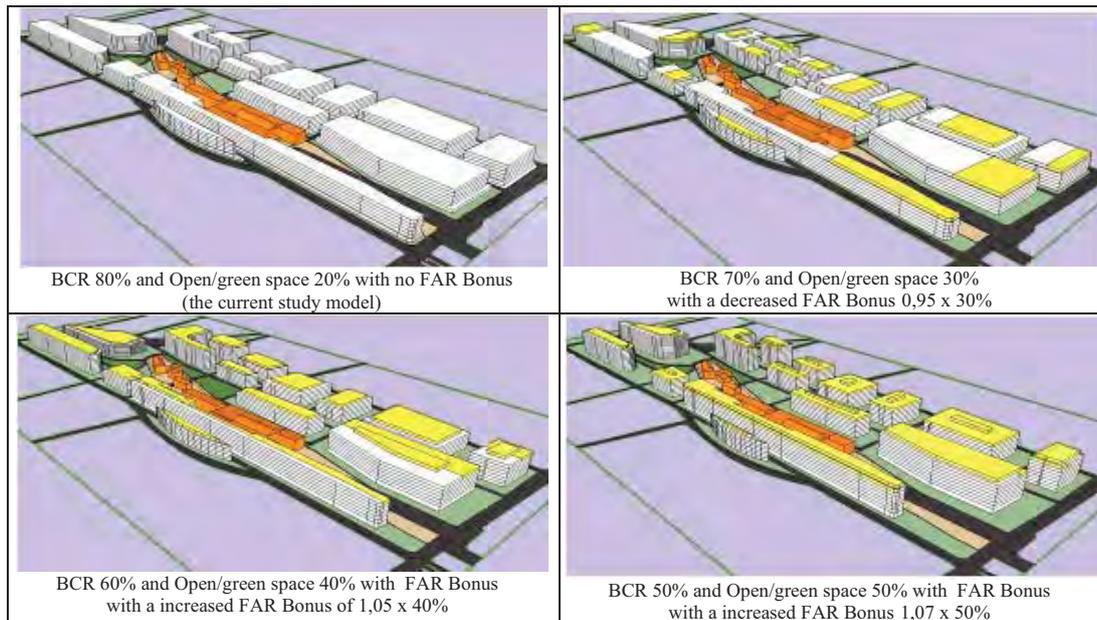


Figure 8. 3D of Green Open Space comparison concerning on FAR Basis and FAR Scenario Models

In this respect, the city government is to be sure to starting to improve its existing building code to provide some incentive floor area based on the alternate BCR as shown on Figure 7 and Figure 8. This green spatial approach also pulls and creates more opportunities for business activities and property development in central urban area concerning on commercial business growth (such as shopping, offices, hotels, apartments, etc.). Therefore, the design approach with using BCR 70% up to 50% as on Figure 7 and Figure 8 is confirmed with the concept of greening the city or green urbanism declared by Swanwick *et. al.* [5].

Therefore the Yogyakarta government should develop some key agendas in increasing GOS as part of the urban sustainability of Yogyakarta municipality. Greening more open space in the Tugu rail station is also in line with the integration between Tugu rail station area (as part of urban central area) and natural environment as a dynamic of the proposed Tugu rail station commercial and residential business activities. This also confirms with *Elkin et al* and *Jabereen's* theories concerning on diversity of open landscapes [6, 7].

This concept will also encourage more people living in central urban area because more regular people will stay in vertical housing due to easy for them to find jobs and public facilities such as retail, shopping, recreation, and vertical housing that economically fits with lower middle income. This opportunity should be captured by the city government to develop more scenario in planning the city area for the next 25 up to 50 years. This description also confirms with the master plan of the city of Edmonton [18] suggesting that the GOS approach with building mass arrangement to show its concept of sustainable vibrant well design accessible.

## 5. CONCLUSIONS

The green open space approach to the building mass arrangement in Yogyakarta urban area is a good scheme to be implemented due to the ability for the city government to increase more green open space in Yogyakarta urban area without any crucial budget to purchase land for urban greenery. The Tugu rail station project has been chosen because the project is in urban central area of Malioboro area and using the current building code that does not guarantee to provide more green open space in any construction project development in urban area. The case study of the revitalization of the Tugu rail station will be more greenary to support in sustaining Yogyakarta urban development for the future by using the floor area incentive. The FAR incentive will use two formulas including 1) increasing open space from the basis BCR and 2) Increases/decreases bonus floor area ratio based on the greenery ratio.

If this kind of approach could be implemented in urban area such as Yogyakarta. The preparation that should be conducted by the Yogyakarta government is including:

- 1) Vertical urban development zones outside airstrips and historical conservation areas.
- 2) Urban development area as a priority to increase social and economic investment gradually.
- 3) Based on the development area priority, the land consolidation to provide accessible motorized urban environment in Yogyakarta is important to be introduced.

- 4) Increasing the collaboration networks with urban business community to encourage the Public-Private Partnership for Urban Infrastructure Project to prioritize urban development areas.

This approach will promote more commercial and residential development scenarios respecting to more private investment and entrepreneur activities in Yogyakarta urban areas. If vertical urban development gradually increases due to more interesting FAR bonus schemes, it is believed that **public accessible green open space** in Yogyakarta central urban area will grow more areas without any special government budget for greenery program. Therefore, the green open space approach will support the future fresh and vibrant urban area and also promote the urban GOS regulation in Indonesia to have minimum of 30% GOS in Urban areas.

## REFERENCES

- [1] Kutanegara PM. Kebijakan Kependudukan Dan Daya Dukung Lingkungan Kota Yogyakarta In: *Diseminasi Hasil Penelitian dan Pengembangan Kependudukan - BKKBN di Hotel Horison Bekasi, 16-18 Desember 2011*. Bekasi PSKK Universitas Gadjah Mada, Policy Brief 2011.
- [2] Hasni. Ruang Terbuka Hijau Dalam Rangka Penataan Ruang. *Jurnal Hukum* 2009,4:39-65.
- [3] Minister of Home Affairs. Regulation of the Minister of Home Affairs Decree No. 1 of 2007 concerning on Spatial Arrangement of Green Open Space in Urban Area (Peraturan Menteri Dalam Negeri Nomor 1 Tahun 2007 Tentang Penataan Ruang Terbuka Hijau Kawasan Perkotaan) In. Edited by Affairs DoH. Jakarta: Department of Home Affairs; 2007.
- [4] Tokyo Metropolitan Government. Urban Development in Tokyo. In. Edited by Government RCSTM. Tokyo: Regional Coordination Section: Tokyo Metropolitan Government; 2011.
- [5] Swanwick C, Dunnett N, Woolley H. Nature, role and value of green space in towns and cities: An overview *Built Environment* 2003,29:94-106.
- [6] Elkin T, McLaren D, Hillman M. *Reviving the city: Towards sustainable urban development*. . London: Friends of the Earth; 1991.
- [7] Jabareen YR. Sustainable Urban Forms: Their Typologies, Models, and Concepts, . *Journal of Planning Education and Research* 2006,26:38-52.
- [8] Minister of Public Works. Regulation of the Minister of Public Works No 05/PRT/M/2008 concerning on Green Open Space Provisions and Utilization in Urban Area In: *05/PRT/M/2008* Edited by Works DoP. Jakarta: Department of Public Works 2008.
- [9] Adolphe L. A simplified model of urban morphology: application to an analysis of the environmental performance of cities. *Environment and Planning: Planning and Design* 2001,28:183-200.
- [10] Huang J, Akbari H, Taha. H. The Wind-Shielding and Shading Effects of Trees on Residential Heating and Cooling Requirements. In: *ASHRAE Winter Meeting, American Society of Heating, Refrigerating and Air-Conditioning Engineer*. Atlanta, Georgia; 1990.
- [11] Lam C. Public Open Space in Private Developments Design and Management Guidelines,: access on December 3, 2013 from In. Edited by Bureau D. Hongkong; \_\_\_\_\_.
- [12] Pan XZ, Zhao QG, Chen J, Liang Y, Sun B. Analyzing the variation of building density using high spatial resolution satellite images: the example of Shanghai City. *Sensors* 2008,8:2541-2550.
- [13] Kubota T, Miura, M., Tominaga, Y., Mochida, A... Wind tunnel tests on the relationship between building density and pedestrian-level wind velocity velocity: development of guidelines for realizing acceptable wind environment in residential neighborhoods. . *Build Environment* 2008,43 1699-1708.
- [14] Yu B, Liu H, Wu J, Hu Y, Zhang L. Automated derivation of urban building density information using airborne LiDAR data and object-based method. *Landscape and Urban Planning* 2010,98: 210-219.
- [15] Poerbo HW. Building Height Regulation in Indonesian Major Cities, September 20, 2012 In. Bandung: Department of Architecture, Institut Teknologi Bandung; 2007.
- [16] Association HQE - GT International. SUSTAINABLE BUILDING IN FRANCE: A PROGRESS REPORT, Prepared for , 2008, p.12-14. In: *the SB08 Conference Melbourne, Australia* Melbourne, Australia 2008.
- [17] Arbury J. From Urban Sprawl to Compact City – An analysis of urban growth management in Auckland. In. Auckland; 2005.
- [18] City of Edmonton, Consultants 2010. Capital City Down Town Plan: Sustainable vibrant well design accessible. In. Edmonton: City of Edmonton 2010.
- [19]. Ministry of National Development Planning (BAPPENAS). Project Preparation Consultant for Revitalization of Yogyakarta Rail Station and Pedestrianization of Malioboro (Loan ADB No. 2264-INO (SF)) Infrastructure Reform Sector Development Program. In. Jakarta: Yachiyo Engineering Co., LTD 2012.

# Partnership between Private Sector and Low-income Community in Self-Help Housing as a Model for Urban Settlement

Antony Sihombing<sup>1</sup>, Azrar Hadi<sup>1</sup>, Rini Suryantini<sup>1</sup>

<sup>1</sup> *Departement of Architecture, Faculty of Engineering, University of Indonesia, Depok, Indonesia*  
*a.sihombing@eng.ui.ac.id,*  
*azrar\_ind@yahoo.com,*  
*rinisuryantini@gmail.com*

## ABSTRACT

As one of the sectors that play a role in good-governance, the private sector or the business sector is the most self-sufficient than the other two sectors, namely the government and civil society. The society gives a mandate to the government, while the government holds responsibility to the public. This gives chance for the government to play a role in facilitating cooperation and partnership between business and society. Regarding the demands for housing, particularly for self-help housing, the relation of the three sectors can be developed into a model of partnership, in which the private sector has possibility to play a bigger part. This can result in the acceleration of housing provision, particularly for the low-incomes. Through public forums / associations, they can start the partnerships with the private sector, not solely rely on the government. The forms of cooperation that already exist for this partnership are trainings, funding, provisions of building materials, etc.. This can be developed furthermore in the pattern / model and the concept of a partnership that can address the needs of the community suitably and sustainably. The aim of this article is to explain the model of the partnership for self-help housing and settlement provision in which the private sector can play bigger role, especially for the poor in urban areas. Therefore the big picture: city without slums can be achieved. The method used in this study is a literature review, secondary data analysis and review case studies of other self-help housing in neighborhoods in the city of Jakarta and Depok. Will be discussed is the private sectors that provides funding partnerships (such as CSR) and the urban poor in furtherance of the self-help housing. From the identification of the role each sector, a model of partnership can be developed. This also relates to the approach or method for the self help housing project.

## Keyword

*Partnership, private sector, low income, self-help housing*

## 1. INTRODUCTION

The welfare issue can be characterized by an increasing quality of life of worth and dignity, among others, through the fulfillment of housing and livable neighborhoods. Housing and settlements is one of the basic human needs, which has a strategic role as the center of family education, nurture, and improving the quality of future generations, as well as the embodiment of national identity. For the people of Indonesia, a house is a reflection of one's existence, either as individually or as a unity along with the natural environment.

One of the housing and settlements problem exists in Indonesia is due the incompatibility of the housing supply and demand. Siswono (1991) addressed these as issue related to population, finance, technology, building materials and related industries, public participation, rule of law, and business. On the other hand, the rapid population growth is not comparable to the provision of housing has led to serious problems. The unstoppable flows of migrants to urban areas due to the uneven development between urban and rural areas causes of population problems since a long time. The migrant flow is closely linked to economic activity and infrastructure development, which is still concentrated in urban areas. As an impact, the emergence of slums in urban areas become unavoidable and cannot be controlled, urbanism processes (urbanization), both physically and because of the mobilization of the population outside urban areas has led to the housing crisis (Drakakis-Smith, 1980).

Around 85% of housing in Indonesia is built and developed by the community without government assistance through the housing, private/residential developers or non-governmental organization or foundation. Aside real estate housing and housing that provided by the government, self-help housing is also one of the possibilities in meeting the need of housing in Indonesia. As a matter of fact, a large number of housing needs in Indonesia are met through this self- help housing patterns and it becomes a major asset in Indonesia. Through this pattern, the society can build and maintain the house on their initiative and effort alone, without going through a formal development procedure, either as individual or in groups/in mutual cooperation. This type of housing is often identified with the informal housing, because the construction is generally performed by low-income group, independently.<sup>1</sup> An important characteristic of the self-help housing by the low-income groups is the emphasizing the process (construction) itself rather than housing as a product. One of the factors is because the process is

---

<sup>1</sup> A. Sihombing, R. Suryantini, D. Mangiring, Sustainable Maintenance and Management in Self-Help Housing Revitalization, QIR 2011

controlled by the owner/user, which means, the initiative, the decision and the execution are made by the owner. It really depends also on the availability of the capital, not only financially, but also socially and the know-how or knowledge in constructing a house. Most of the time, the low income cannot fully maintain their house and settlement and this leads to the degradation of the house and their environment, eventually generates slums.

That kind of environmental degradation can be prevented. It seems that in most of the case in urban areas, the low income people are responsible for the quality of their housing and settlement. As the Law No. 4/1992 on Housing and Settlement Article 29 mandates that "every citizen has the same rights and opportunities to participate in the housing and settlement development", the housing and settlement is actually a responsibility of all sectors in Indonesia. Both the government and non-government, namely the civil society and private sector as well, are responsible for the provision of housing and settlement.

To understand the responsibility of the sectors involved in housing and development in Indonesia, each sector will be identified. As government institution there is the Ministry of Housing, which has the task to assist in formulating policy and coordination in the field of public housing, as decided by the President of Indonesia, PP No. 9/2005 on the Establishment of the Ministry of Housing (MENPERA/Menteri Perumahan Rakyat). Although through participatory project conducted by government or NGOs, it is not yet adequate to solve the problem. A more suitable approach or model which can accelerate the programs is required. The private sector is one sector that most self sufficient in financial, access and technology, which can be the additional force for the acceleration in solving the housing and settlement problems, mentioned above.

## **2. METHODS**

To find a suitable model of partnership in self-help housing and settlement in Indonesia, it is important to identify each sector involved, their role and possible contribution in self-help housing and patterns of relationship present in Indonesia. Based on the finding from the research using the quantitative and qualitative methods, four self-help housing communities will be involved as case study: Kampung Lio and Kampung Tambak in Depok, Kampung Wadas and Kampung Manggarai in South Jakarta. Issues related to self-help housing for the low income in urban areas, such as the availability, the maintenance and the habit of the community itself are being examine thoroughly based on observation, interviews and focus discussion group. The local government and some private sectors related to building material and technology were also discussed. Thus, pattern of partnership between each sector and their contribution in self-help housing in urban areas can be generated.

## **3. RESULT AND DISCUSSION**

Resources as financial aid, technology, building materials and related industries, public participation, conducive political will and regulation, are the issues often encountered in provision and maintenance of the self-help housing of the low income. The problems found in the maintenance and management of self-help housing, among others, is that the income level is very low, so that it is very difficult to access funds (formally), building materials, technology, and other housing resources. The difficulties in accessing the resources and its information are the obstacle for them. Their dependency on grants from the government or donator is relative high, although there are some projects that actually intended to achieve sustainability in providing and maintaining self-help housing. These were shown in the four research areas. Most of the programs conducted in the previous time by the government are consists of only physical aspects and make the sustainability of the programs questioned, because most of them are project oriented (depends on the fund from government – top down concept) and not all the problems can be solved physically. Lesson learned from those projects is that the low income housing communities need to be empowered to reach equality with other stakeholders in this housing sector, since the community empowerment method can be the key in the maintenance and development of self-help housing in order to sustain.

But it is not enough, because housing problems is necessarily only a problem for the government, but also a shared responsibility. Identified actors in housing in accordance to the function and role in housing and settlement are the government and the private sector, besides the people themselves. The role of the NGO and other institution should be developed and reckoned in the program. Most of those programs need assistance, for e.g. through competent facilitators, not only technically but also socially, psychologically and politically. Another point of view is that many of the resources are being exercised fluently by the private sector and this can be utilized as a potential attribute for the model of partnership and corporation in self-help housing.

Partnership is an agreement between both parties to achieve a mutually beneficial goal. The agreement relationship resembles a legal partnership and usually involving close cooperation between parties having specified and joint rights and responsibilities. Three principles of partnership that should be held are equity, transparency and mutual. A partnership network of interrelated schemes works together, supports each other and combines different functions, roles and responsibilities to achieve the same goals: the success of a program. Partnership in accordance with the characteristics or elements within it should be mutually supportive and mutually beneficial and based on the principle of openness and equality.

The basic scheme of the partnership is expected to build and strengthen and increase commitment among actors, in this case for example both the Central government and local government should act as a regulator and facilitator, no longer as executor in the channeling of funds and resources to improving the welfare of society. Private sector which usually acts a source of funds and other resources is expected also to be involved in selecting and determining the form of aid and where and in what manner the source of funds and resources will be channeled. The communities themselves are expected to also be able to systematically distribute both information and resources available to them for improving the welfare of the people, at least in the environment of their own.

The model of the partnerships can be very interesting, because current the approach adopted is usually the top-down approach, compared to bottom-up concept, which tries to generate action for a sustainable society, especially through the provision of information considered less. The partnership for a sustainable society will require significant attention to the transformative environment for models that are sensitive to the actions of government and the constitution of the dynamic power relations. Consideration of the political, bureaucratic, financial and all those involved in meeting the needs of low-income people need to be considered to enhance the attractiveness of the programs, which required a conducive situation for all actors.

The partnership may also have an important role in developing the operational framework of sustainable development, but unfortunately, their positive contribution can not always be guaranteed. Partnership requires to be placed on each roles and responsibilities, and greater extent of transparency in terms of the desired outcome. If the goal of the partnership is to achieve sustainable development by empowering people, then at least it would seem appropriate to involve them in the process of problem identification and definition of the program.

In the implementation process, the partnership doesn't always in the form of ideal, because the implementation is conducted based on the interests of each actors. If the partnership formed between the private sectors and the government and the community as well, they can form the third scenario, productive one. In this case, identification of actors / stakeholders, their roles and potential in the partnership needs to be done.

Several institutions have important roles in housing and settlements in Indonesia, namely central government, the provincial / district / city, businesses, donors, non-governmental organizations (NGOs), R & D institutions, Universities and Public Institutions (traditional institutions, religious institutions, and the other communities). These institutions need to cooperate and coordinate in their activities, in which one may be related another. Therefore their cooperation need to be institutionalized.

In Act No. 4 of 1992 on Housing and Settlement, every citizen has the right to occupy and or have a decent home in a healthy, safe, harmonious and orderly. It also mentions that the Government shall develop the enterprise in the field of housing and settlements in the form of regulation, guidance, assistance, convenience, development, planning, implementation, monitoring and control. The community can participate in the development of housing and settlements, by utilizing local techniques and technologies, building materials industry, construction, engineering and design of appropriate technology and environmentally friendly. According to the Act, there are three approaches in

Under the legislation, the Government should and are expected to create a conducive environment for the provision of housing and housing for the community and other agencies including the business community, associations, R & D institutions, NGOs, donor agencies, and other community agencies. Governments have a duty to facilitate the delivery of housing and settlements. There are three schemes developed to overcome slums and environmental degradation, namely restoration, revitalization, or resettlement. By using these schemes, the model of partnership can be adjusted.

Both central and local government has the authority to set policy and regulation, supervision, coaching, coordinating and providing subsidies to the public. The central government should coordinate and involve the local government to carry out the implementation of housing and settlements. Local government will directly provide services to the community in the area. Government Inter District / Municipality borders must cooperate and coordinate in the implementation of housing and settlements to be integrated and mutually beneficial. The local government together with the community should pursue the implementation measures of housing and settlements and or rejuvenation and improvement of the environment or to improve the welfare of its inhabitants.

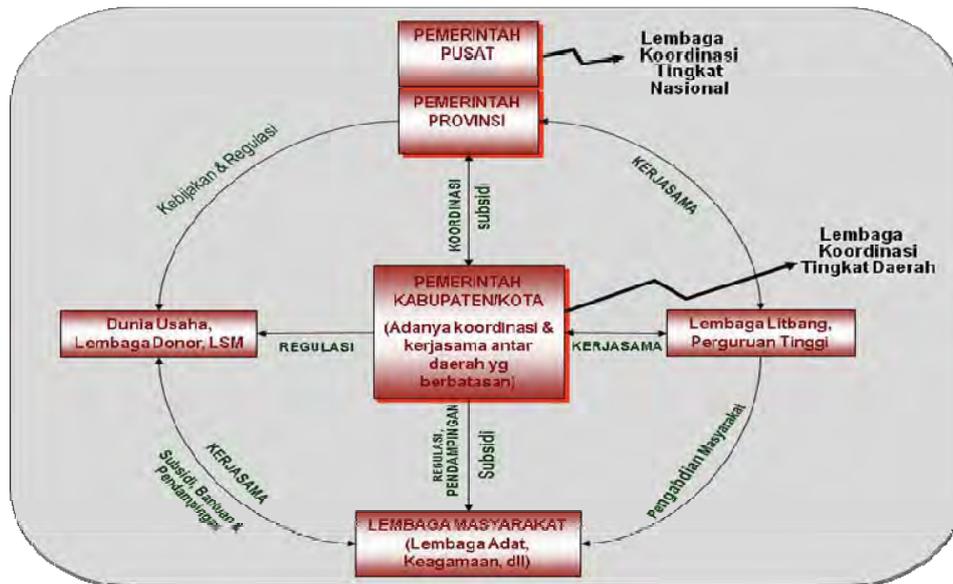


Fig 1: The Concept of Partnership in Urban Housing and Settlement  
 (A.Sihombing, et.al, 2012)

The private sector can act as a partner for the government to manage the resources, to assist the government in the business world in running the economy and leads the development, to generate income to the government, among others in the form of taxes. Private sectors, donors and NGOs can work directly with the community but should still notify the local government and obey the laws and regulations in force in the area. Forms of participation that can be done by these institutions include subsidies, support (financial and other resources) as well as assistance. In addition, these institutions can also cooperate with the government in terms of sharing of housing and settlement programs. The government both central and local governments are to facilitate the activities of these institutions through policy and regulation. Policy and regulation is certainly partial to the welfare of society.

In the last two decades, NGOs increasingly accepted as a key actors in the new partnership that allows local governments and officials' dialogue and collaboration with community organizations / civil society organizations on the issue of poverty alleviation, housing and basic services. Nevertheless, it is important for NGOs to withhold customs dominate or speak the name of community partners and is not always easy to do.

Research institutions and universities can contribute in by conducting research in form of a housing policy formulation settlement as mentioned in the previous chapter, while the government provides facilitation and regulation to support the implementation of the research. Universities can also provide service to the community as one of its functions in the form of mentoring and more. Research institutions and universities can work with government and the government should not limit with regulations in the research objective carried out by research institutions and universities. Research institutions and universities are given more freedom to innovate is responsible in carrying out its activities, for the welfare of the community.

Both the central government and local governments must coordinate with each other in the administration of housing and settlement as described in the previous. It is intended that policies, programs and activities will not overlap , but complementing each other in a synergy. Government can share program in the administration of housing and settlements. This shared program is intended as an example in the management of housing and settlement in a location where the Ministry of Housing undertake housing development or housing assistance stimulant, Ministry of Public Works provides the infrastructure development program, and the Coordinating Ministry for People's Welfare to carry out the National Program for Community Empowerment (PNPM) Mandiri.

Cooperation between central government, local governments and the central government to local governments that have been carried out starting with an agreement or Memorandum of Understanding (MoU). Cooperation agreement in the field of housing and settlements has been done by the government, in particular the cooperation agreement / MoU between Indonesia governors at the Ministry of Housing.

The community acts as a subject and as well as an object of development should be involved in the administration of housing and settlements. This is because the people who know best what their needs and wants. The intervention can be done by groups

such as traditional institutions, religious institutions and other community based organizations. Cooperation between stakeholders or stakeholder that originally accompanied the public should apply independently. The needs of the community in perpetuating social service institutions may not easy to be achieved. These needs include the need for the Budget, Facilities Support, Facilitator / Employment Assistance, Procedures Manual.

Cooperation with other institutions to do in the administration of Housing and Settlements can be done through a cooperative agreement in the form of a Memorandum of Understanding (MoU). This was already done by some of the providers of housing and settlements. From the discussion, it can be identified the role of government, society and the business community in the implementation of housing and settlements and can be described as follows:

- Government, has a leading actor, which drives, facilitates and regulates housing matter in Indonesia. This role requires the government to implement policies consistently and consequently through the realization of good governance.
- The private sector community has a role as a provider of services and driving the achievement of objectives. Idealism and good work ethic owned businesses must be maintained with the view that the profit is not everything to be achieved.
- Community as consumers, supervisors and controllers. The community has a part to play a role as well in the administration of housing and settlements with no prejudice, but also in attention to every process.
- NGO's, academics as contributor, supervisors and controllers. They serve and intervene the community through their disciplines.

Furthermore, the division of roles in the partnership relating to the slums model patterns that can be proposed are as follows:

- In the case of restoration, the partnership is expected to occur more between the Government and Society,
- In case of revitalization, a partnership may be preferred is between Entrepreneurs and Society,
- As for the case of resettlement, the partnership is expected to take place between the Government and Employers.

#### 4. CONCLUSION

From the identification of the sectors involved in the housing and settlements and the proposed partnership model, it requires further review and response. Based on the survey conducted, so far the activities and roles for each sectors was incidental and not coordinated in an integrated program or a road-map that is well planned. Scattered locations and in the form of small-scale activities resulted in positive impact on improving the quality of housing that is not always experienced by the community in particular and other stakeholders in general. This affects the sectors involved in the partnership which have less satisfaction with the results. It will have an impact on the long term, a lack of interest to participate in partnership programs and other cooperation.

Therefore it is very important to develop an appropriate road-map or model of partnership to overcome slums, taking into account environmentally, socially, economically and culturaly suitable of local communities, private sectors as well as the readiness of the Government's program (Region) in achieving sustainability partnership and cooperation. In addition, this model should be tested to see conformity and obstacles that may arise so that it can be used as a lesson-learned for the improvement of a model of partnership and cooperation and or adjustment road-map.

#### REFERENCES

##### Books

- [1] Skinner, R.J., Rodell, M.J., (1983), *People Poverty and Shelter, Problems of Self-Help Housing in The Third World*.
- [2] Sudaryono, S., (1995), *Masalah Permukiman Kota : Permukiman Kumuh, Perumnas, dan Real Estate*, Forum Geografi, Jurnal Fakultas Geografi Universitas Muhammadiyah Surakarta, Surakarta.
- [3] Drakakis-Smith, D. 1980: *Urbanisation, housing and the development process*
- [4] John F.C. Turner, *Housing by People Towards Autonomy in Building Environments* ,

##### Regulations

- [5] Act No. 4 of 1992, *Kementerian Perumahan Rakyat Republik Indonesia*

# Contestation of Public Space: Areas Surrounding the Public Transport Terminal Kampung Melayu, Jakarta

Triatno Yudo Harjoko<sup>a</sup>, Joko Adianto<sup>b</sup>

<sup>a</sup>Urban Settlement and Housing Study, Department of Architecture, Faculty of Engineering, Universitas Indonesia  
Email: gotty@eng.ui.ac.id

<sup>b</sup>Urban Settlement and Housing Study, Department of Architecture, Faculty of Engineering, Universitas Indonesia  
Email: joko.adianto@gmail.com

## ABSTRACT

Various modes of urban public transport in Indonesia have caused environmental concern as a result of the competition among them in a limited urban public space, i.e., roads. They give rise to usurpation of public space, blockage of the traffic and squeezing tightly into space. This study seeks to uncover such a behavior that is aggravated by the trip makers, and associated activities such as street vending. Findings have shown that habitus of actors and their virtual networks of illegal, informal activities sustain their existence.

### Keywords

*Dual-society, habitus, contestation of public space, meta-space*

## 1. INTRODUCTION

The practice of transport planning in Indonesia has been characterized by a Euro-centric empirical model. Such an approach overlooks what really is in reality. It denies the actual modes of the public transport in Indonesia that indicates the reality of the socio-economic practices and conditions of the society as a whole in urban formation and development. While the urban population continues to increase at an unprecedented rate and the gap between the rich and poor is widening, the resolution of transport problems has never been conclusive. The critical state of urban transport in Jakarta as a whole has become alarming. Some scholars have envisaged that in the coming year up to 2014, Jakarta will risk a total congestion.

However, parallel to the issues of congestion in a macro level, there are critical micro issues regarding the movement problems that are worth requiring a serious attention and study. It is a corresponding problem related to transport movement. It is a socio-cultural issue rather than technical. Within the road design and the carrying capacity of it, in practice, there has been a 'pressing problem' of public transport behavior and associated informal economic activities along the way. Such urban informality practices have never been seriously investigated. This research focuses on this particular issue – traffic behavior and its associated issues.

The research seeks to unravel the deep structure of so called 'illegal activities' associated with urban transport with a particular reference to the Urban Transport Terminal at Kampung Melayu, Jakarta. Such a structure is conceived in terms of its spatial formation, production and reproduction. The research objectives are to uncover *habitus* and tactics of different actors engaged in the usurpation process of public space – *meta space* (space as perceived and conceived by them like two chess players facing a chess board); and, to establish a contextual transport analysis in Indonesia which is not empirical but explanatory.

## 2. RESEARCH INQUIRIES

Understanding urban transportation issues and systems simply from its mechanism or parametric approach of design in the built environment may overlook the deep structure on how a city works – especially the lived space. This is crucially the case in the country like Indonesia where it is constituted by the dual society, i.e., modern-capitalist/traditional-bazaar, embodied in the duality of formal/informal sectors. Their respective structuration processes evolve and compete over scarce urban space. This includes urban transport problems. Urban transport in Indonesia has long been operated by two modes of services – modern/capitalistic which is very limited in service, and traditional/'bazaar'.<sup>1</sup> They are mutually exclusive in their existence.

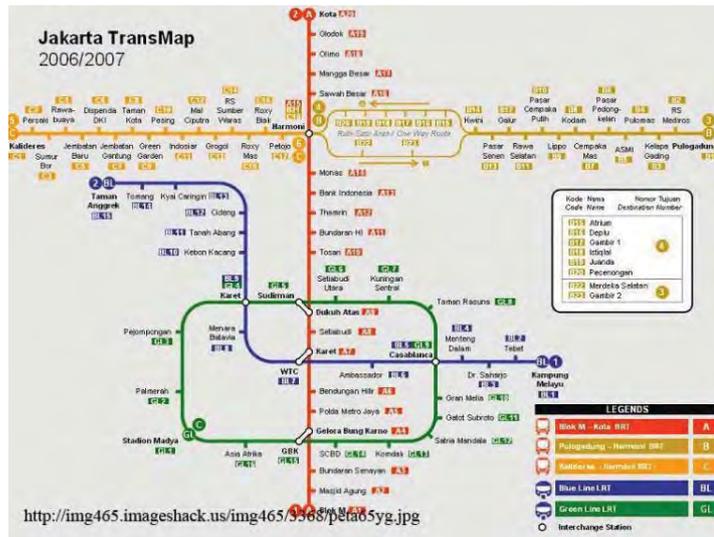


Figure 1  
 Ideal Scheme for the Mass Transit in DKI Jakarta 2006/2007.  
 Public transport system as conceived by transport planners.  
 (<http://img465.imageshack.us/img465/3368/peta65yg.jpg>)

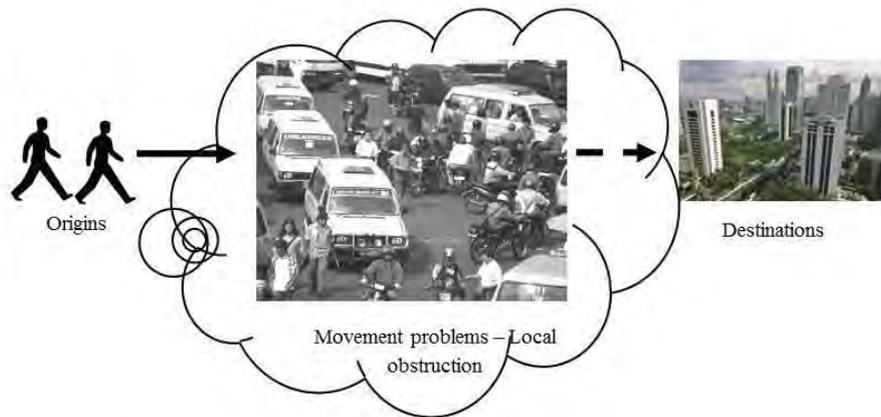


Figure 2. The Problem  
 The 'real world' of people movement in Jakarta – Space contestation amongst public transport operators and other associated activities in public space

Based on such an understanding, the research inquiries why there are enduring problems of black-spots and constrictions generated in the traffic movement in Jakarta, which are not simply caused by the technicalities? What and who are they that generate them?

To answer the research questions and objectives, three main concepts and theories are posited to understand the nature of urban society, its constitution; and its impacts on urban living space, especially to understand the hidden dimension of human behavior, interactions and particularly contestation over the scarcity of urban space.

*Dual-Society*

The theory of dual-society helps us to understand the constitution of the urban society – as a continuum between modern/capitalist and traditional/bazaar economy – its production as well as its reproduction. In terms of the constitution of society, such as two extremities of society produce and reproduce respectively. This production-reproduction has adverse effects on urban space, while the capitalist society manages to negotiate and appropriate space/land, the other in its powerlessness manages to contest and usurp urban space as much as possible.

Herman Boeke<sup>2</sup> in his PhD dissertation in 1910 proposed an influential thesis concerning the apparent dualism of urban culture

in Indonesia. His argument was based on the fact that in Indonesia there were two social and economic systems. The Westernized element in the economy is seen to be materialist, rational, and individualist, and was presented as the epitome of exploitative and unyielding capitalism. The Eastern element, by contrast, was seen to be pre-capitalist, characterized by a prevalence of and preference for self-employment, was unresponsive to variations in prices, and was not profit-orientated. This dualism persists until recently.

Anthony Giddens<sup>3</sup> in his social theory of *structuration*, argues that a society is produced and reproduced through the creation and reproduction of social systems. Systems, according to him, refer to reproduced relations between actors or collectivities, organised as regular social practices. The social systems in which structure is recursively implicated comprise the situated activities of human agents, reproduced across time and space. In social systems the role of human agents or agencies are then crucial. Hence, various forms of human knowledge, worldviews, expertise including planning and design, emerge and are maintained. In this sense, localities of action can be investigated upon how these are politically allocated and dominated by particular groups in the society. They can be observed as both spatially confined and extended.

#### *Social Closure*

Parkin<sup>4</sup> introduces the idea of social closure. In terms of their spatiality, situated activities may signify closures. In this sense, similarly situated practices will also be investigated as a process of social closure. There can be identified three modes of social closures: exclusivity, usurpation, and dual closure (not discussed here). The distinguishing feature of exclusionary closure is the attempt by one group to secure for itself a privileged position at the expense of some other group through a process of subordination. Usurpation is that type of social closure mounted by a group in response to its outsider status, and the collective experiences of exclusion.<sup>5</sup> Dual closure refers to a usurping action against a higher opponent group, for example against the state, combined with exclusionary activities against presumably a lower or a less-organised group, for example, against ethnic minorities or gender related groups. These closures are not static and will depend on the structuration process over time and space.

#### *Habitus*

This theory helps to answer questions concerning behaviour of individual or a group of individuals as a system of disposition. In a society like Indonesia, where cultural extremities are so wide and multifaceted, different conditions for the possibility of social practices may be manifest. Bourdieu terms this condition *habitus*. He argues that *habitus* refers to a “durably installed generative principle of regulated improvisations”, or to a complex net of structured predispositions into which we are socialized at an early age.<sup>6</sup> *Habitus* is constituted in practice and “always oriented to practical functions.”<sup>7</sup> In this concept, social relations among actors is being structured by, and in turn, is contributing to the structuring of, the social relations of power among different positions (of class, gender, etc.). The practices happen in a space called *afield* in which actors play out their engagements with each other.

### **3. Methodology**

The research concerns urban space contestation and seeks to understand the deep structure of extensive existence of ‘informal’ activities in the public space within the domain of transport in the vicinity of bus terminal of Kampung Melayu, in Jakarta. The main objective of the research is to disclose a ‘virtual map’ or *meta-space* of activities generated by various actors associated with public transport services. The conspicuous and chaotic existence of such activities has caused serious congestion. It will focus on the usurpation process of public space by the intensifying numbers of the production and reproduction of ‘informal’ or illegal undertakings almost round the clock. In this mode, spatial structure may manifest by and in multi-layered processes.

It is a grounded research from which theses or theories are based or grounded on data. Respondents such as pedestrians are selected at random. An in-depth interview method is purposively chosen, namely those of transport operators as well as vending traders to ‘capture’ their respective *meta-space*. They are actors that may conceive of different images of a space and supposedly have critical opinions on the consumption or usage of the critical space around the bus terminal.

### **3. RESULTS**

#### **3.1. Understanding *Transport rakyat* People’s Transportation**

The term people’s transportation (*transport rakyat*) is more apt than a generic public transport considering that the population of Jakarta is classified under the low-middle income as still being the majority. They serve this majority of the urban population. This phenomenon results from the very fact of socio-economic duality. *Transport rakyat* emerges as part of the constitution of urban society – modern/capitalist and traditional/bazaar. *Transport rakyat* meet especially the demands for mobility of the urban poor in urban area. It entrenches within the society.

Despite its legal, formal existence, this type of service is, however, comparable to everything under the category of

the 'informal sector'. These services include *Metromini*, a medium size bus; *Mikrolet*, a van type public transport, *Angkot*, mini bus; *Bajaj*, tricycle transporters, and mobile and the omni-presence of *ojeks* or motor-cycle transporters. These modes of transport sustain the life of the urban poor. The dominant *habitus* of these modes of transport are peculiar, distinctive to each community or society. They operate on an 'individual' basis, resulting in competition between one and another. This gives an image of *semrawut* or chaotic activity.

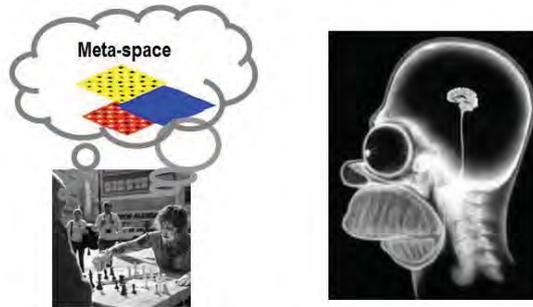


Figure 3  
 Uncovering *meta-space* and "X-Ray" technique

(Sources:

- 1) after [http://d11alstwiwz2br.cloudfront.net/images\\_users/articles/12938\\_s.2.jpg](http://d11alstwiwz2br.cloudfront.net/images_users/articles/12938_s.2.jpg)
- 2) [http://sleeveage.com/wp-content/uploads/2007/08/homer\\_simpson\\_xray.jpg](http://sleeveage.com/wp-content/uploads/2007/08/homer_simpson_xray.jpg),

Both downloaded on 28 October 2012.



Figure 4.  
 Study Area: Bus Terminal Kampung Melayu, Jakarta  
 Seven Locations of Observation

### 3.2. *Transport rakyat* and the Phenomenon of *Supir Tembak* (Substitute driver)

Ideally, the public transport system will primarily serve the public during a rush hour or at the peak periods, particularly in the morning and afternoon; and, outside these periods they normally go back to their depot or garage. However, this is not the case for *transport rakyat*. Once they are all 'out' on the road and serve the public, they will stay on the road until late at night. Such transport vehicles may either be owned by the driver himself (most are male) or driven on behalf of the owner. In fact, both drivers are driven by the target of *setoran* or the amount of money or earnings per day. It varies from 100,000 to 150,000 rupiahs per day.<sup>8</sup> While the pricing policy stipulated by the government states the maximum distance and subsequent charge of about 3,500 rupiahs per person, the reality may be different. It is a very low price if we consider the sustainability of the services, but it is *transport rakyat*. As a consequence, the road everywhere is crowded by *transport rakyat* of different sizes – *Metrominis*, *Mikrolets*, *Angkots*, *Bajajs* and *Ojeks*. Their numbers have already exceeded the demand and as a result they compete with one and another.



Figure 5  
 Metromini

(Sources: Left: [http://www.sewatitikiklan.com/images/metro\\_advertising.jpg](http://www.sewatitikiklan.com/images/metro_advertising.jpg);  
 Right: <http://stat.kompasiana.com/files/2010/05/metromini1.jpg>, downloaded 31 October 2012)



Figure 6.  
 Mikrolet and Angkot

(Sources: Left: <http://warungkuning.files.wordpress.com/2010/06/mikrolet1.jpg>, Right: :  
<http://cerita7rizkaa.blogdetik.com/files/2011/06/angkot1.jpg>, downloaded 31 October 2012)

To operate the *transport rakyat* that is almost round the clock, the drivers of Metromini, Mikrolet and Angkot must ensure some place to park to take a rest. This is made possible by the help of *preman* (thugs or 'freemen' agents) who have control over certain territory in the public space. This *preman* usually is accompanied by local unemployed persons. The latter are those who are present and visible in the area – organizing the activities in the crowded public space. While the drivers take a rest, there are *supir tembak* or substitute drivers of their kin or friends who replace them, they also desperately need jobs of whatever type they can access. In the low peak periods when the *transport rakyat* 'take a break' and rests or *ngetemon* the road space 'available' that is secured by the *preman*.

### 3.3. Ojek the free rider

*Ojek* operators are *free riders* – those who enjoy the benefits of an activity without paying. They are present in the urban market place due to a simple principle – supply/demand. They are very agile move between traffic jams. There are two kinds of 'free riders' who take advantage of such economic opportunities ie, ojek and street vendors. Ojeks and street vendors usurp the public space side-by-side. In many cases, ojeks park their motorcycles at right angles to concrete curbs, which add to the narrowing of the road space. They are usually much more organized and share cohesion among themselves. This type of independent service is very problematic to be attached and connected into the 'formal' system of public transport. The operators are omni-present like mushrooms everywhere in Jakarta in locations ranging from localized residential areas to the hectic urban environment.

### 3.4. *Habitus* of Trip makers

Trip makers are the triggers and generators of this entirely muddled transport problem. The erratic behaviour of trip makers such as stopping the public transport vehicles both to get in and to get off in any place they like. Pedestrians take the short-cut to move from place to another, including taking the risk to cross the busy roads. The situation is aggravated by the occupation of the side-walk by any kind of vendors. The only space left for pedestrians is the road tarmac.

*Habitus* of trip makers includes crossing the streets, getting on or off the public transport vehicles in whatever places, as well as eating and drinking in the street. In so doing, they predispose responses, thus their actions suit particular purposes that are mutually exclusive amongst each other and in competition to one another. Crowding formed through 'consensual' acts among actors of different interests become inevitable over a limited available space.



Figure 7.  
 Left, Bajaj and right, Ojek  
 Ojek move swiftly and versatile

(Sources: Left: <http://www.langitberita.com/wp-content/uploads/2012/06/bajaj1.jpg>,  
 Right: [http://1.bp.blogspot.com/-wIC14y2\\_VnI/T2RjL0DR6rI/AAAAAAAAABk8/b03oL4TP\\_XQ/s1600/ojek+02.jpg](http://1.bp.blogspot.com/-wIC14y2_VnI/T2RjL0DR6rI/AAAAAAAAABk8/b03oL4TP_XQ/s1600/ojek+02.jpg),  
 downloaded 31 October 2012)



Figure 8.  
 Mikrolet 'ngetem'



Figure 9.  
 A man collect money for Mikrolet that 'ngetem'

### 3.5. Practice of Usurpation

The practice of usurpation of various actors and activities in the public space public spaces is possible by the support of the *preman*. The process uncovers such clandestine operations and organization between *preman* and the oknum or individual authorities such as a police and those form the Traffic and Highway bodies. In return of their warranty and surety or protection, the *preman* bribe them. In the actual operation, the *preman* then employs those local thugs who desperately need the jobs. The practice of usurpation and of closures within the public space is exercised to protect against an invasion of strangers to join these usurping practices.



Figure 10.  
 Ojeks wait and intercept passengers



Figure 11.  
 Erratic and dangerous movement of trip makers as pedestrians  
 Crossing the street and getting in and off the public transport

Itinerant traders



Figure 12.  
 Pedestrians buy foods from ambulant trader

Figure 12.  
 Pedestrians buy foods from ambulant trader



Figure 13.  
 Traffic and Highway Authority 'in action'



Figure 14.  
 Arena of 'Trans-action':  
 Preman is distributing 'shares' to those engaged in the 'business'

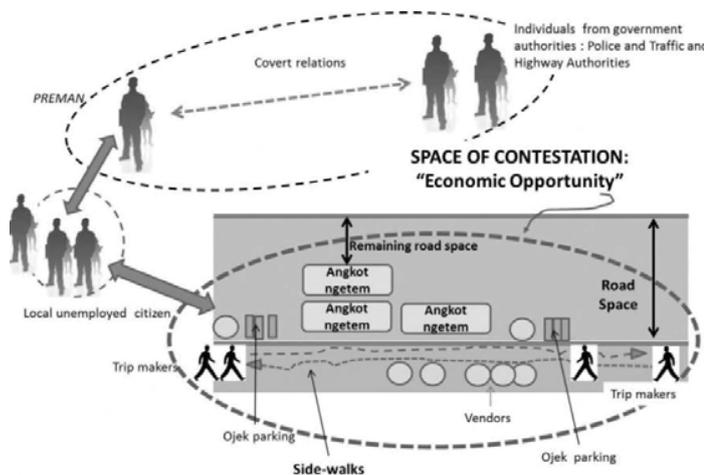


Figure 15.

Web, Connectivity and the Space of Contestation:

Meta-space and deep structures of various different actors

Habitus and symbolic interaction can be traced as a web of connectivity among actors interested in the 'businesses' of usurping public space.

#### 4. CONCLUDING REMARKS

Dual society, its production and reproduction, has a spatial implication. While the modern/capitalist is capable of negotiating the scarcity urban space, the traditional/bazaar is not. This is no exception in the sphere of public transport services. In Indonesia public transport can be distinguished into such a binary undertaking. I will use the term 'traditional society/bazaar economy' *orbazaarism* – to refer to social attitudes where social institution and way of life are one. This usually manifests in huge numbers, individual and unrelated economic form of petty commerce. Consequently, understanding public transport in Indonesia requires deep comprehension of the society as a whole – an archipelagic nation and its dualism. Traditional society and its bazaar economy straightforwardly will address those of the poor community – rural or urban. In other words, *bazaarism* in the public transport sector means also the engagement of traditional society in transportation. The services of *transport rakyat* are provided by and used by the majority of the urban poor as the trip makers. The latter further complicates the bazaarism in the urban transport services.

The presence of an enormous number of trip makers in the vicinity of the Bus Terminal in Kampung Melayu further invites the *bazaar* economy in the areas where people are gathering with various locals. Usurpation of limited public space is then intensified by various modes of *transport rakyat*, vendors and itinerant traders. This contestation over limited public space is mediated by the *preman*; and the *preman* organize the area through clandestine deals with corrupt individual policeman and those from the authorities of the Local Traffic and Highway Bodies. The *habitus* of those engaged in the 'businesses' and their *metaspace* are inter-connected. This creates as a virtual web of bazaar economic undertakings.

Space around the Bus Terminal convoluted and turned into some kind of 'barricade' in the public space, i.e., in the roads. The severe problems of congestion in Jakarta are then complicated further by such practices

The political issue of the public transport in Indonesia results from the socio-economic conditions of a country, especially related to those of the low income or urban poor. The choice for improvement between the current public transport system adopted either i) to continue and let individual operators involved in the public transport system; and to strictly enforce the traffic laws and regulations. However, problems remain that the government lacks of capacity to detect clandestine operations of bazaar economy in the grassroot level, that, in fact, also involves corrupt government officials; or ii) a more unpopular, authoritative measure, to *take over* current 'informality' of public transport system (i.e. individual operators of the public transport) into the formal system under the local government as well as private management.

#### REFERENCES

- [1] Geertz argues that 'bazaar' economy is an economy which is based on " ...the independent activities of a set of highly competitive commodity traders who relate to one another mainly by means of an incredible volume of ad hoc acts of exchange", Clifford Geertz, *Peddlers and Princes. Social Change and Economic Modernization in Two Indonesian Towns*, 1963, p. 28.
- [2] The Boeke's idea of dualism was originated back to his Ph.D dissertation in 1910s. It was first specifically introduced into English by Furnivall in 1939 and the translation of Boeke's works in 1953. See *Interdependent Development*, Methuen & Co Ltd, 1975, p. 54-55; and especially Boeke, J.H., *Economics and Economic Policy of Dual Societies – As exemplified by Indonesia*, New York: International Secretariat, Institute of Pacific Relations, 1953, also Furnivall, J. S., *Netherlands India. A Study of Plural Economy*, Cambridge: The University Press; New York: Macmillan Company, 1944.
- [3] Giddens, A., *The constitution of society*, Berkeley and Los Angeles: University of California Press, 1984., chapter 1 passim.
- [4] Frank Parkin on his critique of a rigid notion of class in Marxism, argues that, regardless of any notion of class, social practices or action manifests in what he calls social closure. Social closure, as Weber suggests, means a process by which social collectivities seek to maximise rewards by restricting access to resources and opportunities to a limited circle of eligibles. This entails the singling out of certain social or physical attributes as the justificatory basis of exclusion. He distinguishes three types of social closure: exclusion, usurpation, and dual closure. Parkin, F., *Marxism and Class Theory: A Bourgeois Critique*, Tavistock Publication, 1979, p. 44, and especially chapters 4,5, and 6.
- [5] Parkin, F., *op. cit.*, p. 74.
- [6] Bourdieu, P., *Outline of a Theory of Practice*, Cambridge University Press, 1977, p. 78
- [7] Bourdieu, P., *The Logic of Practice*, Stanford University Press: Stanford, 1980, p. 52.
- [8] One US dollar equals about 9,625 rupiahs.

## Urban Invasion and Contestation of Space: Houses to Shop-houses to Street Vendors along Madura Island's Primary Collective Road

Dita Trisnawan<sup>a</sup>, Nevine R. Kusuma<sup>b</sup>

<sup>ab</sup>Department of Architecture, Faculty of Engineering, Universitas Indonesia  
 Email: dita.trisnawan@ui.ac.id, ditadesign@gmail.com, nevine\_rk@yahoo.co.id

### ABSTRACT

The invasion of street vendors in many countries has become such a problematic issue. In fact, within the urban spatial management cases, street vendors are mostly agreed as the objects of which disrupting the order of the urban environment, for its invasive existence. The arguments in this paper analyze the position of traditional commercial vendors along the primary collective roads of Madura Island, formed and growth organically from only as strip of houses into shop-houses and later extended as 'formal' street vendors. As the product of 'ribbon developments' in nature, into a complete commercial street then, this phenomenon offers a fascinating approach and discourses to the practice of urban design and planning in dealing with certain traditional and local elements, against the capacity requirements of a planned road infrastructure.

### Keywords

*Urban invasion, contestation of space, street vendors, Madura Island, urban design.*

### PRIMARY COLLECTIVE ROADS OF MADURA ISLAND (SOUTHERN MID SECTIONS)

Ribbon developments have shaped the street frontages (the building forms) along the Madura Islands' collective primary roads. Public Markets (*Pusat Jasa Prioritas/Pasar*) along the Southern Mid Section of the road, have been analyzed and studied based on recent transportation analysis of BPWS Project 2012<sup>1</sup>. The analysis concludes that two public markets will be redesign as they impact the road's designated functions, its accessibility, the road's width, etc. These two are: Pasar Tanjung Dharma–Pasar Bandaran of Sampang–Pamekasan municipality and Pasar Keppo of Pamekasan municipality.

Several causes of the traffic congestions along the roads of the Centers (Public Markets), especially the traditional markets, can be clearly identified, primarily the traffic disturbances in the form of emerging commercial and service activities, which intervene the existence of the southern mid section roads.

External Factors directly impact the market's intensity, they are: 1). The closer the markets to the city/municipality centers, the crowd-ness potentiality and traffic congestion numbers will be higher, related to its higher raises on accessibility and transportation's potential, 2). The closer the markets to the immediate main arterial road (regional level road), the higher traffic congestion numbers will be. Internal factors are coming from inside the Public Markets themselves, impacting the activities. Within the cases of the Public Markets along the regional roads of Madura, these factors consist of these several indicators: frequency of actions/movements, volume: size/scale, and its commodity types. Based on these two factors, the differentiations are then derived into problems, which are spatially analyzed as they exist in reality on location. Road traffic interferences exist in the forms of non-transportation activities along the study areas, following the urban spatial contestations which arose, and the local policies which can be taken toward the growing problems.



Figure 1: Public Markets PasarTanjung Dharma-PasarBandaran( marked 1 and 2)

Source: Google Earth-modified by author.

## RATIONAL ANALYSIS AND REASONING APPROACH

This research uses rational analysis to understand the complexity of problems within the study area. By breaking the parts of activities within the area, practical methods applied to define strategic physical discovery. The characteristic of rationality any action, belief, or desire, that makes choices optimal under a set of constraints<sup>2</sup>.

Normative concept of reasoning in the sense of rationality derives conclusions in a consistent way. It relates to the conformity between beliefs of one(s) and the other(s), and the beliefs to take action(s) based on those beliefs. A rational is not just reasoned, but also has best possible answer (optimal) in achieving goal(s) or solving problem(s). Determining optimality for rational behavior involves formulation of problems and the definition of key assumptions.

Rationality factors engage how much information is available to complete the knowledge of the related topic. These formulation and background assumptions then became models within which rationality applied. The problems must be framed and formulated by specifying the background model assumptions to achieve a meaningful rationality.

Reasoning is connected with ways of thinking, cognition, and intellect. It is related to what thinking comes from one idea to other related idea. Thus, rational beings understand themselves to think about the reason(s). Reasoning juggles between cause and effect, truth and falsehood, and what is good or bad. Reason is the capacity for consciously making sense of things, for establishing and verifying facts, and changing or justifying practices, institutions, and beliefs based on new or existing information<sup>3</sup>. The concept of reason is sometimes referred to as rationality and sometimes as discursive reason, in contrary of intuitive reason.

The arguments in this paper analyze the position of local fishery goods street traders/vendors along the primary collective roads of Madura Island. Rationally formed and growth organically from only as strip of houses into shop-houses. As reasons (why-ness) took place, these functions later appear extended as 'formal' street vendors along the main road's Right of Way(s). The discourse offers a fascinating approach and discourses to the practice of urban design and planning in dealing with certain traditional and local elements. The research then further discussed the contestation of space between those elements against the spatial capacity of a planned road infrastructure.

## STUDY AREA'S REDESIGNING VARIABLES (REVITALIZATION)

Revitalization becomes significant, whenever most of the key elements of vitality of places have diminished. It is when considerable disturbances and intrusions to the ideal motions condition have become substantial for changes. In the case of Jalan Raya Bandaran, as the Primary Collective Road, the purpose of the site planning process is to revitalize its very existence. During the process, there are several assumptive variables to be considered to use, they are:

- a) **Triggering Activity Factor;** relative distance to city (municipality) center and arterial road, affecting the intensity of the markets' activity, because it relates to accessibility, which then generates denser triggering commercial, service, and logistic activities along the road.
- b) **Site Support and Future Development;** Traffic jamming potentials will get higher as the result of the denser triggering activities within the district. Thus, supporting capacity variables to anticipate the growth become quite important. This also directs the possibilities for area development and other aspects to optimize the study area potential.
- c) **Scale and Size of The Right of Way;** can be used as variable defining the success to manage the problems, especially related to the ability to flow vehicle movements, which are just passing-through the study area, as designated lane of "free or very minimum disturbance lane".
- d) **Market's Activity Frequency;** can be used as variable defining the planning results applied in the forms of policies of Operational Management, can be flexible, depending on and matching with the schedule of 'Hari Pasar' (The Markets' Day), events, momentums and time intervals of activities in every season or the markets' day periods.
- e) **Trading Commodity;** the types of commodities for trading, can be used as variable, which affect the mode of transportation use, since its spatial intervention relates to scale and size, ultimately influence the intrusion (disturbance) of traffic along the study area.

#### SPATIAL ANALYSIS OF PASAR TANJUNG DHARMA-PASAR BANDARAN (KAB. SAMPANG-KAB. PAMEKASAN)

Tanjung Dharma Market and Bandaran Market are categorized as Fisherman's Market, located in between Camplong Market and Tlanakan Market. These markets are positioned on the side of the National Road (Southern Mid Sections) with Primary Collective Road status.

Since the distance between Tanjung Dharma market and Bandaran market around 6.75 kms, and the distance to the main road is less than 50 meters, these markets have strong level of service and accessibility. Spatial condition is within high density level, especially along the southern mid section of this Primary Collective Road, close to Tanjung Dharma market and Bandaran market. (image 1, marked 1 and 2).



Figure 2: Corridors of Street Vendors along PasarTanjung Dharma-Bandaran district

Around Tanjung Dharma market and Bandaran market, there are housing settlement areas and coastal areas, since they are located along the southern coastal of Madura Island. This area has a small traditional fisherman's port, adjacent to Tanjung Dharma market and the coastal zone of the Southern Mid Section of this Primary Collective Road of Jalan Raya Bandaran.

Considering the area condition along this Southern Mid Section, the settlement growth is organically triggered by two factors: 1. The existence of Collector Road, and 2. Estuary and Coastal Access. This model can be seen based on the present growth tendency, which happening along the coastal southwest side, around a couple of hundred meters from Tanjung Dharma market.

Reclamation activities slowly carried out by the fishermen. Since logically their boat can be moored directly, at the backside (water-side) of the fishermen's house. Tanjung Dharma-PasarBandaran markets have uniqueness as fishermen markets, which are bordering and relatively attached to the coastal, along the Primary Collective Road. Its outsides are facing directly to the coastal edges. Based on the field survey, some recent reclaimed lots, on the south side are within the one kilometer radius from the study area location.



Figure 3: .Road/street conditions along the Primary Collective Road (Southern Mid Sections). Houses becoming storages and shophouses, then Street Vendors occupying public (Road) space (Source: Field Survey, September 2012)

Within the next growing phases, this coastal area widens, creating road boundaries, which appear to be narrowed, since they frame the settlement's on the left and the right side of the street/road corridors. The coastal strip area had become land area, with some permanently built housing settlements on top.

Private space established through the pattern of uses. Thus, it is possible for the formation of shifted designation of public into quasi to private. The importance of the pattern of uses, slowly but surely create a sense of belonging. This action provokes territorial behavior of the urban settlers. While private space has fixed boundaries, it is also stationery.

Tanjung Dharma – PasarBandaran markets daily activities happen all day mornings and afternoons, within the interval 6AM – 10AM and 3PM-6PM. Commodities are dominated by fishing products, freshly captured fishes, directly sold in retail, or in wholesale. These can be analyzed based on the field facts, where woods/bamboos' made 'displays' for retail (street vendors), icebox and containers for storage, and ex-liquid jugs, which have been modified for storage purposes. These 'portable' cold storages are used to maintain the freshness of the fisheries products. Beside the street vendors, local groceries (*tokokelontong*) which sell daily needs, primary foods and extras are also open. Within the operational hours, the local traffic is congested from two directions along this Primary Collective Road.

The existences of their (street vendors) equipments which dominate the public area, was causing traffic during the day.



Figure 4: Street Vendors along the main road between PasarTanjung Dharma and PasarBandaran. PasarTanjung Dharma kompleks, under construction (September 2012).

Factors that caused the traffic congestion are:

1. **Spatial/Space Expansion.** The expansion phenomena enforced by the needs to show, the needs to have a 'display space' for the selling products. This behavior had caused the (street vendor) traders, filling the space up to the edge of the main road. The main road's shoulder (bahujalan) is filled with their presences, the movements of traders (buyers and sellers). The most important element of this behavior is the 'requirement' of 'being seen', the need to build the interactions, to define interests and preliminary communication between the upcoming buyers and the sellers. It is all began from the visual contacts among them.  
 The spatial expansion occurred by encouragement of spatial needs in displaying the goods. Thus, this activity engendered claiming over pedestrian space by the seller. In other words, in relation to the nature of performance, the pedestrian area becomes a stage for 'their performance', and their display as 'the setting' has an active part in the performance<sup>4</sup> (Madanipour A, 2003). Moreover, Cohen-Cruz (1998) stated in his book, *Radical street performance*, the more obviously seen, the more people will be attracted to what we show, thus 'we need to be seen'<sup>5</sup>.
2. **The Goods 'Displays' Positions,** the invasion to the pedestrian designated spaces along the main road. The position of their goods display (fish storage and boxes) invaded the pedestrian space. In terms of private and public space in the city, the physical objects, such as boxes and fish storage, seen to be used in establishing their personal space in public area. Likewise, it demarcates a territorial claim over space<sup>6</sup> (Madanipour A, 2003).
3. **Spatial Intervention.** The use of partial body of the main road for (undesignated) pedestrian movement. This spatial intervention shifted several functions enforced by the contemporary/overlapping usages of public space into quasi-public/quasi-private spaces. Hence, it caused a portion of the main road that belongs to vehicles also used by pedestrians in this case the buyers along the road. Public spaces are places outside the boundaries of individual or small group control, mediating between private spaces and used for a variety of often overlapping functional and symbolic purposes. In fact, the nature of public spaces has to be open or available to people and being used or shared by all members of community<sup>7</sup> (Madanipour A, 2003). Otherwise, in this case there was an inequality shared of space.
4. **The Market core Location** (Image 4. righthand-side) is still under construction allocated for the designated Tanjung Dharma Market.

As Primary Collective Class Road, Jalan Raya Bandaran (the Southern Mid Sections) serves as a corridor of public space, one main economic infrastructure for its surroundings. There were reason(s) for it to change overtime. Its shifted usages perpetuate the abnormal condition of its designated service. This condition bares the rationality and reason(s) of a complex substance.

Why this matter could happen? Due to the nature of public space, that is a place of simultaneously, which means a site for display and performance, a test of reality, an exploration of differences and identity and arena of recognition. As a site of display and performance, the urban actors were among individuals who need the very existences, the spatial occupants for different objectives. The reality exist is driven by the power of shifting functions, related to communal (groups) power within the environment, beyond the capacity of the enforcements of laws. The differences and identity are explored to be recognized, where each and every place usually has their own character. Within the case of Pasar Tanjung Dharma – Bandaran, the existences of the fishery traders' equipments that dominated the public (corridor) area, including activities beyond their existences, were causing these predictable traffic congestions during the day.

## VARIABLE AND PLANNING STRATEGIES

Based on the site rational analysis and reasoning approach, the site planning strategy of Tanjung Dharma-Pasar Bandaran Markets needs to consider some of these keypoints:

1. **Road Spaces are free** from or have less intervention form commercial and traffic activities from both directions.
2. Trading **Goods display positions shall not disturb the Right of Way** space of pedestrian corridor along the road.
3. There shall be **designated drop-zone areas**, which are free from any flowing traffic. **Traffic lanes are planned well** separating the normal lane, passing lane, transitional lanes, where curb cuts for property/building entrances, drop-off zones, temporary parkings are technically calculated.

4. Market main area shall have parking and drop zones, which are **NOT within the Right of Way of the Primary Collective Road**.
5. **Road Width** shall be bigger in size, widened from 5 meters to 7 meters, allowing enough space for passing-trough for 4 wheeled vehicles.
6. When it is possible for widening the road, **re-touring traffic flows** are still recommended to minimize the crossings, passing the traffic portion **to some alternative roads**, away from the public market area.
7. **Alternative Roads are proposed with pre-requirements:** a). using the government property land or low priced acquisitioned land. b). able to spread the urban/spatial density, by developing other parts of the vicinity.

## REFERENCES

---

- [1] *Laporan Akhir Proyek 2012, Penataan Pusat Jasa Prioritas Sepanjang Jalan Lintas Tengah Selatan Madura*, BPWS Suramadu, Jawa Timur
- [2] 1999, **Rationality**, *The Cambridge Dictionary of Philosophy*, p.772, Boston Massachusetts
- [3] Kompridis, Nikolas, 2010, *International Journal of Philosophical Studies* 8, **So We Need Something Else for Reason to Mean**, Routledge, 3, p.271-295
- [4] Madanipour A, 2003, **Public and Private Spaces of the City**, Routledge, p. 205, London and New York
- [5] Cohen-Cruz, J 1998, **Radical street performance**, Routledge, USA and Canada.
- [6] Madanipour A, 2003, **Public and Private Spaces of the City**, Routledge, p. 202, London and New York
- [7] Madanipour A, 2003, **Public and Private Spaces of the City**, Routledge, p. 202, London and New York

# The Triadic Column and Pivot Hinge: To Realize the 'Beautiful House' to 'Wong Cilik' As the Architecture Innovation to Low Cost Housing

Yuke Ardhiati<sup>a</sup>

<sup>a</sup>Faculty of Fine Art and Design, Trisakti University of Jakarta  
E-mail : yuke\_ardhiati@yahoo.com

## ABSTRACT

The national problem in settlements in Indonesia is found reduction costs to provide housing for “the lower class” people. On the other hand, the professional architect role their social responsibilities to find the national problems. Through social media, they can socialize their ideas to the lower class in suitable architectural design of their condition. After investigation the problem settlement, formulated a concept house for “Wong Cilik” as “the lower class” people to improve their dignity as the based philosophy. Refers to Grounded Theory, formulated a beautiful house for “Wong Cilik” among others: a) the minimal dimensions, b) the design innovations aimed at reducing costs, c) the efficiency of design, and d) enhance the facade as well as the art expression, and vertical garden. The cost reduction changes to the original design of practical column rectangle into a triangle, and reduce the door frame element, and replace it with a swivel-pivot hinge. Create the ‘open space’ design with the service zone at the side of the house to maximize the function. To raise the ‘Wong Cilik’ dignity, create in vertical of façade as the surface of the aesthetical work and vertical garden.

## Keywords

*Low cost housing; the triadic column practice; the pivot hinge; vertical façade*

## 1. INTRODUCTION

The term of “Wong Cilik’ is Javanese language is a concept used in my paper to discuss the need of lower class people for architectural design that meets their condition. ‘Wong Cilik’ is the low-income peoples is a part of the national problem in Indonesia. The low cost housing is the important discourse related to provide their settlement to the low-income people. Between in the 1970s and 1990s, noted the participation of the people in housing and human settlement became the central issue by the government and the non-government organizations. They found the solution by develop of housing and human settlements from “top-down” to the “bottom-up” approach. The stake holders, among other: the universities, academia, the professional, and developer were involved to finding the various solution related to the preparing low-income urban housing and settlements.

Unfortunately, the low-cost house design majority preparing by not seriously as the housing developer because they only find the minimal margin versus to prepare the exclusive housing. The low-cost house always under grades of housing standard, always show the bad performance in all aspect. The visual ugly and the under grade material accelerate the nation generation degradation. The child is not has a challenge to learn the aesthetical aspect as the basic of all of the etic code. They ever seen the order of thing as the basic philosophy to preparing the order of the mentally of their mind set.

On the other hand, in the IAI – *Ikatan Arsitek Indonesia* chapter, the professional architect is also role their social responsibilities to find the national problems. Through social media, they can socialize their ideas to the lower class in suitable architectural design of their condition. Architects can socialize their ideas easily to find the partner to collaboration to provide the low-cost settlements. In the information era, especially the social media impacts, the media used to covering their ideas of low-cost housing design.

## 2. RESEARCH METHOD

### 2.1 Grounded Theory to Finding the Characteristic of ‘Wong Cilik’

The research study is a part of architecture investigation to express the low-cost house architectural design refers the Qualitative Research as a part of the seven ideas of Groat’s architecture research method (Groat, 2002: 173). The study in the qualitative refers to Grounded Theory Research, to reveal the characterized of low-income people - ‘Wong Cilik’ activities. After data collected, the categories named in to the coding data analysis. And finally the research concluded into the memoing

– to build a new theory (Glaser, 1967). To ensure the data accuracy of research based on phenomenological investigation at several *kampoeng* in Central Java. The one of is *Kampung Mlaten* in Semarang is the first *kampoeng* of rental housing in Indonesia during the Colonial. The *kampoeng* is still exist until today . They divided into several types start from 15 m<sup>2</sup> of housing dimension (Ardhiati, 2013). Post investigation on the Thomas Karsten work in *Kampung Mlaten* in Semarang, inspired the basic design of criteria of housing dimension within open plan multiuse housing.

## 2.2 The Research Finding

The research objectives to find the housing design include to increase the 'Wong Cilik' dignity. The research finding the formulate of the concept house for "Wong Cilik" as "the lower class" people to improve their dignity based on their activities job. The philosophy of their house role is, the content to stay and activities job, so they need the optimizing their own houses.

The formulated of a beautiful house for "Wong Cilik" among others: a) the minimal dimensions, b) the design innovations aimed at reducing costs, c) the efficiency of design, and d) enhance the facade as well as the art expression, and vertical garden. The cost reduction changes to the original design of practical column rectangle into a triangle, and reduce the door frame element, and replace it with a swivel-pivot hinge. The 'open space' design with the service zone at the side of the house is the best solution to maximize the function.

A house like a poetic space refers to Bachelard, is also the dreams of the low-cost income people. By intensive research of the several low-cost settlements, found the criteria of the house contextual of their conditions by the innovation design in: a) the minimal dimension refers to Housing and Developers Association of Indonesia (APERSI) based on post the Constitutional Court determined the number 1 of the Law 2011 on Housing and Resettlement Zone. Yet, the minimal housing dimension in 36m<sup>2</sup> is contrary to the 1945 Constitution.

Post research investigation in several low-cost house settlements formulated their hidden need. They need to explore their dignity as human by own their house. The result investigation is reveal the main criteria of beautiful house for "Wong Cilik" among others: a) the minimal dimensions, b) the design innovations aimed at reducing costs, c) the efficiency of design, and d) enhance the facade as well as the art expression, and vertical garden. And, the best solution of 'Wong Cilik' dignity, create by the vertical of façade as the surface of the aesthetical work and vertical garden.

## 3. RESULT

### 3.1 The 'Beautiful House' to 'Wong Cilik'

The low-cost house is shift the new paradigm. The house is not role as the residence only, but also to expression their dignity, because its content of their dreams, the preferences, responses, and perceptions towards their house and environment.

The design by research to low-cost income offer among other ; a) the minimal dimensions is around 22m<sup>2</sup>, b) the design innovations aimed at reducing costs, with the reduction cost through change the practice column. Yet, the rectangular shape changes into the triadic. The usually need the door frame is reducing by used the pivot hinge. To efficiency of space is created the open plan concept without the wall partition especially the bath room. And, finally to express their dignity is enhance the facade vertically as well as the surface to art expression, and create the vertical garden.

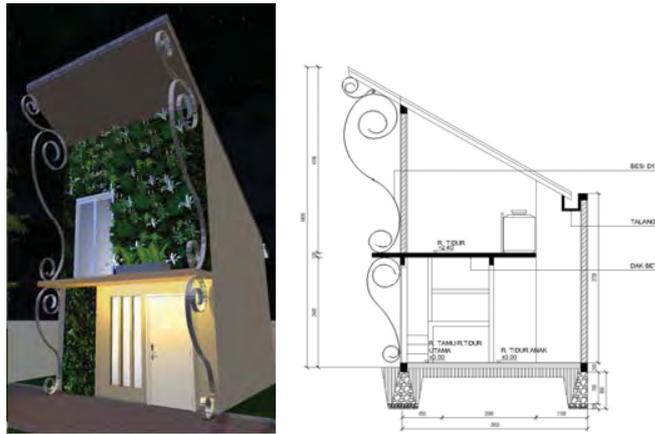
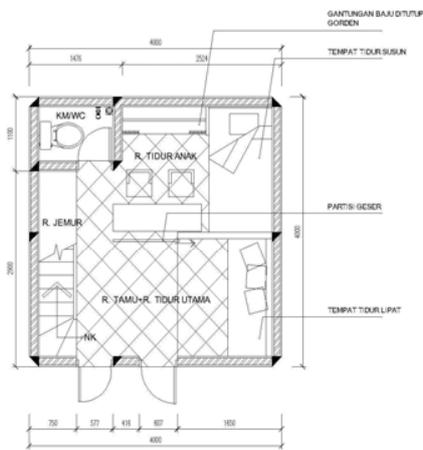
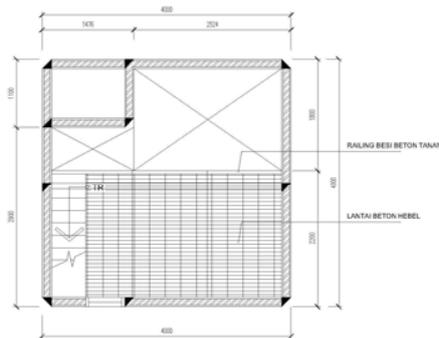


Figure 1: Greening And Beautifying The Housing Façade



DENAH LT. 1  
 SKALA 1:100



DENAH LT. 2  
 SKALA 1:100

Figure 2: The Low-Cost House Plan

### 3.2 Triadic Column Practice to Reduce the Building Material

The housing cost reduction's conventionally by reduce architectural building structures. The normally form of the column as usually in square form change into the triadic form by reduce the amount of the building structure material.



Figure 3: The Triadic Colomn to Reduce the Building Structure Material

### 3.3 Pivot Hinge of Door to Reduce the Architectural's Element

The one of building house will low-cost by reduction cost for the structure material items. The expensive architectural part is the frame door and hinges. The reduction of hinge solution is reduce the frame's door and put the pivot hinges.



Figure 4: The Pivot Hinge to Reducing the Door Frame

## 4. DISCUSSION

### 4.1 The House as the Dignity Expression

The low-cost house is the way to express the people dignity. Its the chalengge to vis a vis the low-cost house as usual. The facade vertically is of the best thing to increase the house performing. The vertically surface is have the opportunity of the house to expressing their hidden need as well as to expresss the art and aesthetic sense. The normally low-cost building façade as horizontally change into the vertically façade to be a pride suggestion like the body upright and gallant. The vertically façade is approach by two stories design to get the visual effect of elegance of the design house. By design the facade vertically, we have the opportunities to create the house greeny by vertical garden and the house beautifying the surface to create something creative like; greening by plants, decorated by mural, mosaic, painting by color, or filled the surface by natural ornamentation as the low-cost people doing their creative process in them life.

## 5. CONCLUSION

The architectural design of low-cost house with innovation design is need to share to 'Wong Cilik' to find the right developer in order to inspire them to provide the house settlements. The social media is the right medium to socialize the design solution. In other side of the architectural idea is include the intellectual of property right. The architect or researcher have obligation to improve the 'Wong Cilik' dignity by create the innovative design, and the government protect them by the intellectual of property right as PATEN or HKI. By using the social media, the architectural research finding will be published as the academia contribution.

The issue published of 'the Beautiful House' to 'Wong Cilik' is the first step to declare the architecture design finding, is a part of the engineering field protect by intellectual of property right of the Architect as Industry Intellectual Property Right – HKI and the innovative design as PATEN. The social media publication is the medium to declare the state of the art of the architect researcher.

## ACKNOWLEDGMENT

I would like to acknowledgment to the low-cost communities in Kampung Mlaten Semarang, and my best friends; Mas Ardi, Bayu Widhitama, Mohammad Fauzi, A'a Agoes, and Mr. Eddy Ganefo the President of Apersi for offering my architecture design the 'Beautiful House' to 'Wong Cilik' become the reality model.

## REFERENCES

- [1] Adams, Laurie Scheider. *The Methodologies of Art*. New York: HarperCollins Publishers, Inc. 1996
- [2] Alexander, Christopher. *The Timeless Way of Building*. New York: Oxford University Press, 1999
- [3] Antoniades, Anthony C. *Poetic of Architecture*. New York :Van Nostrand Reinhold, 1990
- [4] Bachelard, Gaston (transl.) French by Maria Jolas. *The Poetics of Space*. Boston: Beacon Press, 1958
- [5] Glaser, Barney G and Strauss, Anselm L. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Copy Right 1967. London: Adline Transaction. 2010
- [6] Groat, Linda & Wang, David. *Architectural Research Methods*. Canada: John Wiley & Sons, Inc, 2002
- [7] Strauss, Anselm L. *Qualitative Analysis For Social Scientists*. Cambridge: Cambridge University Press. 1987
- [8] Strauss, Anselm L. *Basics of Qualitative Research. Grounded Theory Procedurs and Techniques*. California: Sage Publications. 1990

## Lesehan Culture at Yogyakarta Tourist's Night Space

Klara Puspa Indrawati, S. Ars and Evawani Ellisa, Ph.D.

Department of Architecture Faculty of Engineering, University of Indonesia, Depok 16424  
 E-mail: klarapuspa.indrawati@gmail.com  
 E-mail: ellisa@eng.ui.ac.id

### ABSTRACT

The "informal" establishments of public spaces into tourist spaces by local communities in Yogyakarta indicate the growing tendency of local economic development in tourism industry. Financial problems for obtaining "formal and legal space" have drawn local people, called *angkringan* sellers community, to utilize ineffective public spaces. Located in Wongsodirjan Street, the northern boundary of the Tugu Station, they utilize the area of two opposite sidewalks of the street as the culinary space at night. *Angkringan* creates a unique place as visitors could enjoy and practice *lesehan* culture. This paper discusses how local people modified the empty public space through socio-cultural strategy to create tourist space in Yogyakarta. *Angkringan* adds the repertoire of tourist destinations and counteracts the emergence of malls and shopping centres, which in fact merely afforded by particular consumers and ironically lack of local character. This research supported by in-depth observation conducted between February-May 2012 at *Angkringan Tugu* Yogyakarta. We concluded that the tactic for arranging *lesehan* has been employed as socio-cultural strategy in helping *angkringan* sellers modifying the space to offer low prices foods and drink for long duration visits.

### Keywords

*Angkringan Tugu*, *lesehan*, culture, tourist space, socio-cultural

### 1. INTRODUCTION

Yogyakarta is well known tourist city in Indonesia and has been grown as major tourist destination after Bali in term of visitor numbers. One of the tourist's main access is the line between Tugu Station and Mangkubumi Street connected to Malioboro Street. Here the informal tourist spaces spread out the city offering culinary, relaxation, and gathering pleasure, especially during the night. In Wongsodirjan Street, a street located in the northern boundary of the station, a group of *angkringan* community utilized the under-use pedestrian and transformed it into another tourist line. The street provides the opportunity for the people to informally participate the socio-economic and cultural activities.

The activity begun when the sellers found the pedestrian was less functional as only few people walk on. Later on, this space has successfully functioned as a social space which is affordable for all groups of dwellers of Yogyakarta. Through modification of public space, *angkringans* have been colonized almost the whole area of the two opposite sides on the street. It created the place of culinary with a unique character. Along the side walk, the visitors practice the Javanese social interaction called *lesehan* where people sit on mats. In Wongsodirjan Street, local people initiated the formation process of new tourist destination in Yogyakarta through modification of public space that emphasizing the strength of local culture. This "new kind" of public space meet the people's longing for simple interaction place, a situation that can not be found in formal public tourist space such as malls and shopping centers. In these formal places, there is no people's participation in design process. As a result, they are afar from the spatial practice and daily necessity of local people.

### 2. A BRIEF HISTORY OF ANGKRINGAN TUGU

*Angkringan* is a kind of hawker from Yogyakarta. They are offering cheap foods either hold by *pikulan* (bamboo stick bearer) or carried by moving cart. *Angkringan* term came from Javanese word *angkring* means sit freely and relaxed [1]. The consumers can raise or fold up one leg while sitting on the wooden bench near the stopped cart. The other form of hawker similar to *angkringan* also can be found in Solo and Klaten. Local people in both city call them *hik*, an abbreviation of phrase in Indonesian for *hidangan istimewa kampung*, which means special villager's dishes. Nowadays, *hik* is still well known in Solo, while people in Yogyakarta are more familiar with *angkringan*. The first *angkringan* seller in Yogyakarta did not use moving cart but simply hung the two sets of equipment, including a stool for the seller, tools and ingredients for making beverages, cooked foods and snacks, and an *anglo* or coal stove. The first generations of *angkringan's* equipment are very simple since the sellers have to move frequently.

The initiator of *angkringan* at the area of Tugu Station was Mbah Pairo who came from Klaten and promoted *angkringan* since 1950. In 1969, he transferred his business to his son, Lik Man. Lik Man had been moved several times from Tugu Station to

Mangkubumi Street in 1970 and then finally he moved to Wongsodirjan Street in 1975. Since then, numbers of *angkringan* sellers at Wongsodirjan Street were growing. Hereafter, the *angkringan* sellers gradually changed from mobile into immobile. They set their business at the same place and time everyday. One of Lik Man's worker explained that the reason for moving was because visitors continuously increased and required a larger space. As Mangkubumi Street could not accommodate the business expansion anymore, they move to Wongsodirjan Street. This was the best choice as the street has direct connection to Mangkubumi Street, which is adjacent to Malioboro Street.

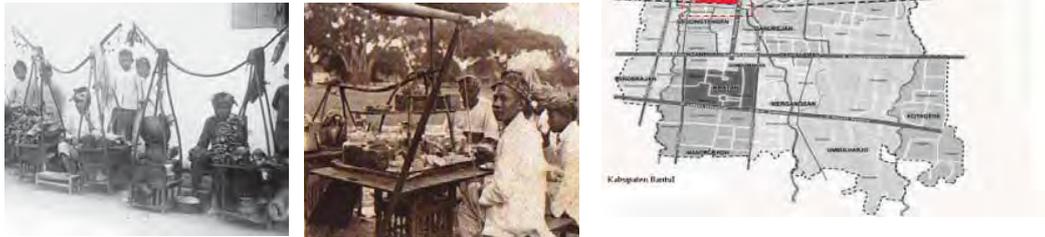


Figure 1: The Old Time Angkringan (left) and Angkringan Tugu Location Map (right)  
 (Source: kaskus.com, ikiangkringan.blogspot.com, cerita-kota-loenpia.blogspot.com, jogjareskrim.wordpress.com)

Wongsodirjan is the street with 6 m width. One side of the street has the sidewalk adjacent to the wall of Tugu Station that creates an empty edge. The opposite side of the street consists of the line of houses. Since its streetscape consists mainly of single-use building (houses) and empty wall with virtually none of the street-level commercial bustle, walking in this street is not appealing and unproductive. William H. Whyte's concept of social life of small urban spaces has stated that blank wall along one street will prevent public activities [2]. Corresponded to that statement, our observations during the day and the night showed that pedestrians prefer not to walk on pedestrian sidewalk but on the edge of the street, seemed to avoid blank station wall.

When Lik Man, Lik No, and Pak Seh located their *angkringan* at this street, they decided to occupy the sidewalk area adjacent to the north wall of Tugu Station. Following Lik Man, Pak Seh and Lik No who also came from Klaten became a new comer of *angkringan* sellers. As consumers steadily increased, other new *angkringan* sellers emerged. Since then, Wongsodirjan sidewalk was totally transformed into *angkringan* district. It is well known as night eating and gathering place that opens from 18.00 until dawn. As sellers did not have enough money to set a permanent kiosk, utilization of public space through negotiations is the best choice. The transformation of empty public space into business space indicated the process of take over from public space into commercial space for the benefit of the collective communities [3]. *Angkringan* communities had transformed the empty street into livable street and increase the mobility of pedestrians.

### 3. LOCAL PEOPLE'S STRATEGY IN DESIGNING TOURIST SPACE: *LESEHAN* CULTURE

#### 3.1 *Lesehan* as the Daily Life

Daerah Istimewa Yogyakarta (DIY) maintained to be administratively and socio-culturally led by Sultan or the King of Java. Formally, Yogyakarta is registered as a city since 1757. The city was laid on the basis of cosmic axis lines between Merapi Mountain at north and Indonesia Ocean at south. The cosmic center of Yogyakarta is placed along Malioboro Street as the main access from city to king's palace [4]. Yogyakarta's long history describes the strong establishment of local culture. This is a well-known city of culture, art, and education. It is also one of the main local and international tourist destinations.

The way of living is one of the keys to discover one place's character. Character is defined as dominant atmosphere in experiencing one place. Space gets its own reality in the context of location, because space is not only signified by physical boundaries, but also by its character to give space its certain meaning [5]. Experience of space can only be felt through the experience of one place's character, such as *lesehan* or the way of sitting in Yogyakarta society. *Lesehan* is the traditional element of spatial formation of architecture in Yogyakarta. The origins of word *lesehan* in Indonesian shows meaning for a way of sitting on the floor [6].

Traditionally inside the house, local people widely practiced *lesehan*. People just started using chair in the 19<sup>th</sup> century and in the beginning, it was limited only for the aristocrat. People usually *lesehan* on mat or *ambén* or a low platform made of bamboo for informal social interaction in the family. It is casual in character and comfort becomes priority. Chair was used when the head of one family needs to formally express their authority to the guest. In *lesehan* culture, we can find two different settings based on its spatial orientation. One called sociopetal or center oriented and the other called sociofugal or periphery oriented. Sociopetal *lesehan* occurs in a long-term activity, such as eating or visiting. Sociofugal *lesehan* occurs in short term

for spontaneous activity. Proxemics theory argues that sociopetal setting will develop interaction, while sociofugal will prevent it [7].

*Lesehan* is popular among local people in their daily life because it is comfortable enough to accommodate the long term of daily activities. *Lesehan* also give chance for variations in sitting position. In fact, before the 19<sup>th</sup> century, the aristocrat practiced *lesehan*. It gave impact to the way of traditional dance that must be performed on the level of the *lesehan* audience [8]. *Lesehan* culture signified the characteristic of local space in Yogyakarta. Furthermore, *lesehan* culture creates a fluid and flexible space arrangement. Unlike chair, there is no specific placement for individuals in *lesehan* formation. *Lesehan* has its own social norms, such as disallow to pass in front of the parents without say permission. This way of sitting not only related to functional aspect, but also to Javanese philosophical aspect about the closeness relation between human and earth. Javanese culture understand floor as representation of earth, the source of life who give existence to human. Human is the earth's offspring, while sky is deity sphere. Javanese terminology of *bumiputra* is the manifestation of this philosophy and generally used to refer Indonesia's indigenous people [9].



Figure 2: *Lesehan* Culture in Kota Gede, Yogyakarta  
 (Source: Bambang Tri Atmojo, 2007)

### 3.2 The Chances

Before discovered by *angkringan* sellers, Wongsodirjan Street is more like barrier rather than street. The sidewalk was one side at the edge of Tugu Station's northern wall with height of 1.35 m. The street gave rise to the feelings of monotony, which repel pedestrian to pass. In the other side of the street, home fences lined along the street. Here pedestrians would feel to be on the expansion of homeowners' private area. The heights of home fences, that are located along the sidewalks, are 100-110 cm. Some houses even erected right in the periphery of street. From the sidewalk, people could see inside of the house through the fence when windows or doors left open.



Figure 3: Wongsodirjan Street Utilization Map Before Occupation of *Angkringan* Sellers (top left), Location of *Angkringan* Storage Area (bottom left) and Panoramic View of Sidewalk in front of Line of Houses (right)

(Source: Klara Puspa Indrawati, 2012)

Lik Man, Lik No, and Pak Seh saw the initial opportunity at Wongsodirjan sidewalk. They demonstrated an understanding of spatial practice that encourages reproduction of sidewalk area. The sidewalk is not just a pedestrian crossing space, but also a social space between street users and the residents [10]. The three initiators of *Angkringan* Tugu District modified the sidewalk in order to optimize its presence, although by contesting new functions to sidewalk function. The spatial occupancy had been seen as the business opportunity for the trio of *angkringan* sellers. Now, *angkringans* do not only visit by people of Yogyakarta, but also tourists from other parts of Indonesia as well as foreign tourists.

*Angkringan* sellers formed their spaces by setting up tents modules with size of 6 m long and 3 m wide. In 2012, there were 11 *angkringan* vendors on the sidewalk adjacent to station wall. Mass media helped promoting *angkringan* sellers at Wongsodirjan Street as one of Yogyakarta culinary area and recommended it as destination for tourists. *Angkringan* offers simplicity and strong atmosphere attracted visitors for gathering at night. *Angkringan* also offers dining and culinary at a low cost.

The local government supports *angkringan*. Each seller gets the opportunity to use area of the sidewalk for free. They only need to report their presence for official registration. The size of the tents constructed according to the economic capacity of the seller. During our observations in 2012, there are 3 sellers who use 3 tent modules, 5 sellers who use 2 tent modules, and 3 sellers who use one module. *Angkringan* operates from 18.00 to 04.00 but sellers start to set up the tent from 12.00. For illumination, lightings are channeled from an old store at the junction between Wongsodirjan Street and Mangkubumi Street. For any lighting used by sellers, they are charged 1.000 Rupiah/day. Every vendor is required to properly manage his/her *angkringan* equipment, including undo the tent and dispose all the trash at the end of street.

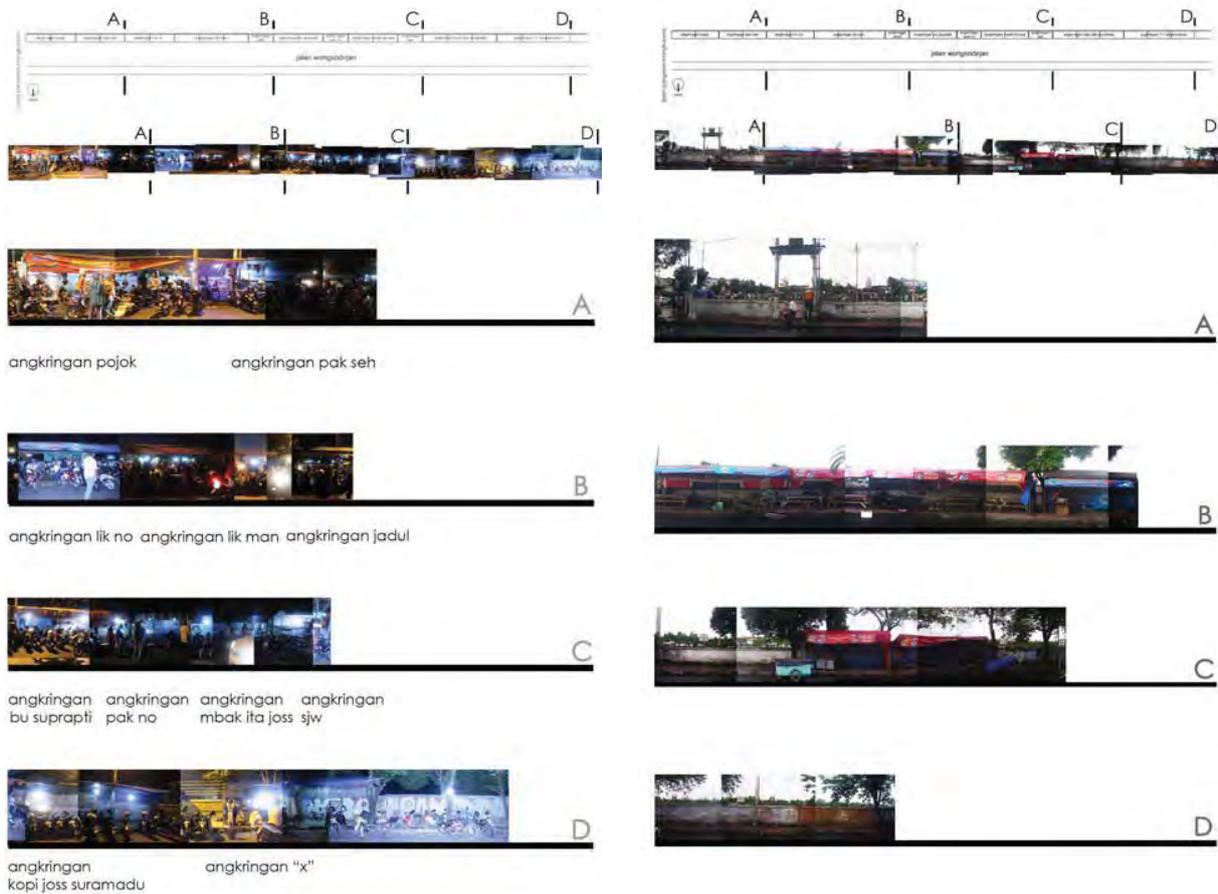


Figure 4: Panoramic View of Angkringan District at Night (left) and Day (Right)  
 (Source: Klara Puspa Indrawati, 2012)

Before leave, sellers store all *angkringan* equipment in shared storage located at the east of Mangkubumi Street. In the morning *angkringans* are totally disappear and the sidewalk can be used again for pedestrian. At noon, *angkringan* cycle starts to move again. Seller erected tent on the 25 cm raised sidewalk. Here sellers and buyers defined the area by the semi fixed

features consist of seller's equipment and simple elements for customers such as benches, tables, and mats. No any seller gains ownership from the plots at the sidewalk except their own temporary tents and mats. Each *angkringan* seller owns an agreement to divide his/her area of occupation.

There are three types of *angkringan* space's formations. First is the formation of a seller area and a buyer area with bench. Second is the formation of *lesehan* where the seller area and the buyer using the mat. Third is the combination of the first and second type. We found that first type used by four merchants, the second type used by six merchants and the third type used by one merchant. If sellers use *pikulan* as the place for serving food and processing beverage as well, they will provide 20-30 cm wide and 70 cm raised serving table rounded to *pikulan*.



Figure 5: Wongsodirjan Street Utilization Map After Occupation of *Angkringan* Sellers (left) and The Second Type of *Angkringan* Formation (right)  
 (Source: Klara Puspa Indrawati, 2012)

This formation enabled customers to enjoy meal at the same level with the sellers and create the same interaction level between seller and buyer. This also represented the original formation of *angkringan* of which the seller and buyer formed intimate interaction. However, at Wongsodirjan Street, merchants more prefer to choose the second type or *lesehan* using the mat. By *lesehan*, customers enable to freely sit cross-legged, a situation impossible to be done using a bench. Mat is more flexible for serving different group of customers, so that more customers can be accommodated. Without tables and benches, *lesehan* also reduced the cost. During peak hours when *angkringan* crowded, customers will create groups of circular formations.

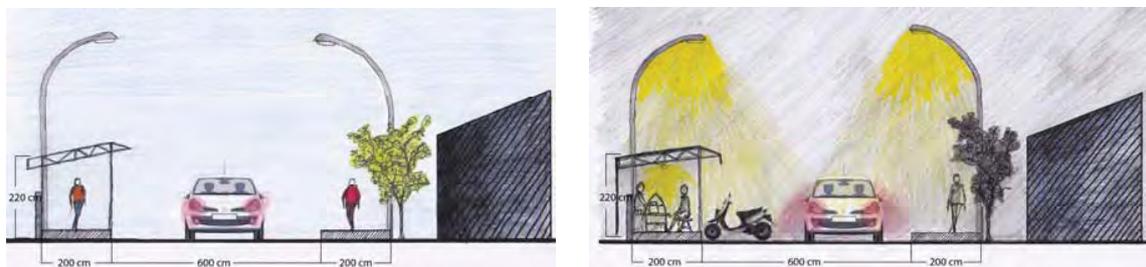


Figure 6: Section of *Angkringan* District at Day (left) and Night (right)  
 (Source: Klara Puspa Indrawati, 2012)

### 3.3 *Lesehan* as The Strategy for Spatial Conflicts

Visitors recognized *angkringan* at Wongsodirjan Street as *Angkringan Tugu*. The special menu which attract local and foreign tourists are *sego kucing* (literally means rice for cat) or cheap small portion of rice and *kopi joss* or coffee dyed by hot charcoal. This area gains popularity by the growing number of visitors, especially during weekends and holidays. In 1990s, when visitors increased and they often come as groups of four people or more, *angkringan* needed expansion. As merchants relied on tables and benches, it became difficult to cope with the increasing numbers of customers anymore. This situation triggered sellers to consider for using the area located on the opposite side of the street. However the problem is that the area proximately located just in front of line of houses. Utilizing these spaces would raise conflicts as it would annoy the residents whose properties need to be directly accessible to the street.

To solve the problem, the seller's applied four tactics. First is that as long as in the morning until noon there is no anything left over, they could utilize the space for extending the *angkringan* space. Second is that sellers need to quickly form and remove the space, while at the same time they also need to accommodate large numbers of customers. For that reason, sellers use roll mat, which is easily stretching along the sidewalk in front of the houses. Third is that mats are only used when large groups of visitors are coming. Forth is that to respect the rights of homeowners, sellers avoid laying mats at the certain position, of which it is directly adjacent to the door. Using these four tactics, sellers could save the cost since there is no need for purchasing

tables and benches. Roll mats also enable the sellers to flexibly arrange and leave enough spaces for the homeowners enable to directly access to the street. In William H. Whyte's analysis, we found people's effort to create a proper sitting position by moving their chair from one place to another place [11]. However by practicing *lesehan* on mat, the visitors can be more flexible in manipulating their position. *Angkringan*s only operates during the hours when the homeowners already at homes, so that eventually the conflict can be avoided. Among the seller, there is informal agreement that they may extend the space expansion for customers, right across their tents at the opposite side of the street within the same area as their tent's border.



Figure 7: The Expansion for Customer's Spaces (left) and Section of *Angkringan* District at Night After Expansion (right)  
 (Source: Klara Puspa Indrawati, 2012)

Expansion of the customer's spaces are no longer defined by the border of the tent, but by the space formed by mats and bodies of *lesehan* customers on the sidewalk. Soon after the visitors come, the seller immediately spread the mat along the sidewalk and gave instructions to the visitors to take their positions for *lesehan*. As visitors need to adjust their own space in accordance to the numbers of visitors, *lesehan* create the fluid and flexible space. Interestingly, *lesehan* also create strong character of *Angkringan* Tugu and make it more popular. *Lesehan* offers visitors to immerse themselves in groups. While for Javanese sitting on an armchair in the house described the owner status, enjoy *angkringan* through sitting on a bench or *lesehan* create the ambience of relax and informal. The identity of each visitor submerged in the form of *lesehan*.



Figure 8: Scenery of *Lesehan* Culture at *Angkringan* Tugu District During Night Time  
 (Source: Klara Puspa Indrawati, 2012)

As in other typical street foods served by any street hawker or *kaki lima*, people doubt about the hygiene level at *angkringan*. There is no enough lighting provided at *angkringan*, so that at night the atmosphere is not bright enough to clearly recognize the figures and faces of customers. As a result, customers do not pay much attention to the cleanliness of *angkringan* area. To attract and get attention of customers from the main streets, *lesehan* are now expanding until Ratih Guesthouse at Pangeran Mangkubumi Street. Although the street scale is smaller, *lesehan* at Wongsodirjan Street is more spacious and comfortable. Overwhelmed by shade and vehicles in the parking area, the tent formed space with good ambience. The space extension in the opposite side of the street is entirely open and flexible. Practices of *lesehan* sitting at this space of expansion created two kinds of setting. First is converge (sociopetal) and the second is lined (sociofugal). One night we observed that in the *Angkringan* Tugu, we found 39 groups of customers, 14 groups of them applied the sociofugal setting and 25 groups applied sociopetal setting.

Proxemics study that sociopetal setting encourages interaction while sociofugal reduce the interaction was not effectively fully applied in the expansion space of the *Angkringan* Tugu. Among customers, who apply both sociofugal and sociopetal practice setting do intensive interaction with the group. Both settings were chosen based on considerations, such as comfort and ambience. Customers of *lesehan* prefer more sociopetal setting than sociofugal. Customers who sat in sociopetal setting are customers of 2 to 8 persons. They usually choose sociopetal setting in order to establish more enclosed group. Crowded and the surrounding environment is not their concern. Each group focuses on the interaction within the group while enjoying his/her dishes. The group eventually bonded togetherness. Within more enclosed space, individuals within group are not severely affected by the crowded and the noisy speech of others. At the most crowded, distance between groups could almost close to 10 cm or intimate distance. At this intimate distance, the sound of other group will be heard very clearly. But this is

not a problem. Each individual in the group merely focuses on the speech in the circle group and she/he just ignored the conversation outside the group.

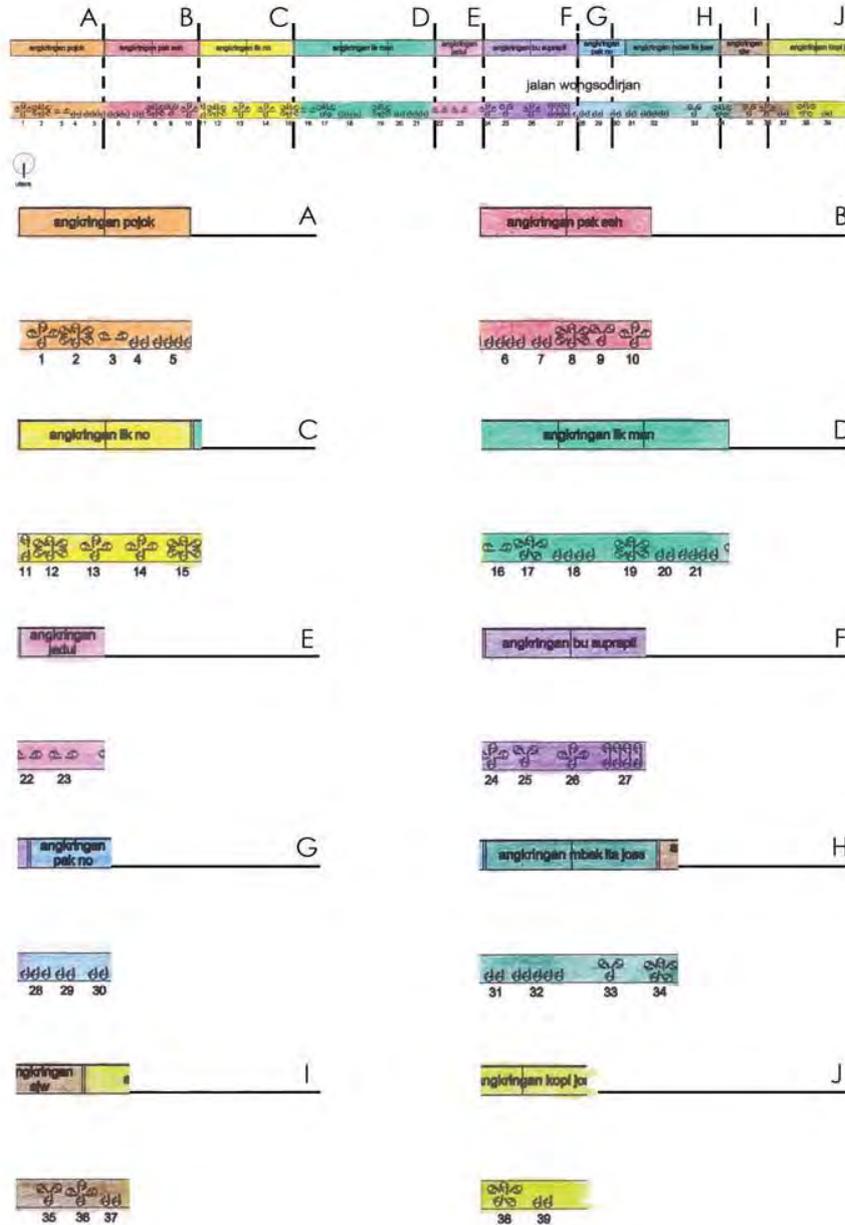


Figure 9: Diagram of *Lesehan* Plot for Each *Angkringan*  
 (Source: Klara Puspa Indrawati, 2012)

*Lesehan* customers are sitting on the floor in groups of 2 to 5 persons with sociofugal setting. We found 8 customer's groups consisted of two people who usually are a couple. They chose the sociofugal *lesehan* because they can sit more comfortably by leaning on the boundary wall of Tugu Station in one side or fence in opposite side of the street. The *angkringan* crowded did not reduce their comfort, as the communication between couples remained intense. From 39 customers we had observed, we found that the average distance between customers are 73 cm or in the range of social distance. This is a convenient distance for gathering activities. When a group determined the space and its distance to other groups on other side, they do not take into account the space for other groups who would visit. The upcoming groups will adjust the remaining available space. In fact, during holiday season, the group is not only sitting adjacent to other groups sit in left or right side, but also in front of or behind. Cheap food and drink and comfortable *lesehan* sitting attracted visitors to enjoy the ambience of the place. *Angkringan*

is a simple gathering place for an unlimited duration. Customers are allowed to stay until *angkringan* closed with no requirement to buy more food or drink. By purchasing any food or drink, visitors can use the space as long as they like. The efforts of *angkringan* sellers to expand their *lesehan* space is not solely driven by economic motivations, but rather response of the demand for inexpensive dining, drinking, and hanging out.

*Angkringan* generated tourist place which more emphasis on the social significance. This is because customers do not only spend time to eat and drink. It was the social interaction at night that became the major attraction of the place. *Angkringan* sellers serve almost similar food. The main menu is varieties of drinks offered by sellers. It is the drinks that accompany visitors during the long duration of interaction among customers. *Angkringan* Tugu creates economic opportunities for many people, such as a parking attendant and street artists. Various street arts by street artists also take parts to shape the evening festivities at the street. The definition of architectural space formed by the body of the customers physically weak, but it can be understood and operated by users [12]. Visitors who practiced *lesehan* along the street both in front of the Ratih Guesthouse at Mangkubumi Street and Wongsodirjan Street depict a strong relationship. Wongsodirjan Street is an interlude space for both sidewalk of *angkringan*. Passing passengers of motorbikes and other vehicles as well as people who walk will discover the landscape of tourist's night space along the sidewalk. The wall and the fence form the space enclosure. They also functioned as a backrest for customers who sit *lesehan*. The appearing lights of passing vehicles help to create the missing illumination. Both sides of the sidewalk transformed into a stage. Here people enjoy performance of various activities of social interactions, economic, and cultural.

#### 4. CONCLUDING REMARKS

Local traders of Yogyakarta initiated the process of place making of *Angkringan* Tugu and created tourist's night space that is accessible to all. *Angkringan* sellers emphasize the local culture of *lesehan* as the strategy to transform the "lost space" of Wongsodirjan Street into "finding place". Local inhabitants and tourist enjoy the atmosphere of Yogyakarta at night in an ephemeral space formed by simple open strip bordered by walls and fences. *Lesehan* also represent the culture of Yogyakarta. Therefore, *Angkringan* Tugu became one of the main destinations for tourists. *Lesehan* is a common seating practice among local residences which emphasizes the significant meaning of flexibility, informality, cosiness, familiarity, and confirmation of human existence on earth. *Lesehan* also attached to *angkringan* character as a kind of temporary business. We argue that the seller's initiative to develop the tourism space was not only enhance the 'pro-poor' local economy but also enrich the space for social and cultural aspects. Such bottom up small scale business space has triggered an emergence of attractive culinary street. We also assume the temporary *angkringan* district and existing residential place will create a fascinating mutual socio-economic place in Yogyakarta's main axes since the home owners also play role as consumers and *angkringan* sellers keep the pedestrian area clean after their night occupancy. In broader scale, it offer unique night sidewalk and open space scenery which is defined by the bodies of *lesehan* visitors.

#### REFERENCES

- [1] R. B. Santosa. (2012, May 16<sup>th</sup>). Personal Interview
- [2] William H. Whyte (Filmmaker). (1988). *Social Life of Small Urban Spaces*. [Videotape]. New York: The Municipal Art Society of New York.
- [3] M. Foucault, *Des espaces autres (Of other spaces)*. [Lecture to Cercle d'études architecturales]. Paris, 1967
- [4] R. B. Santosa, *Omah: Membaca Makna Rumah Jawa*. Yogyakarta: Bentang, 2000
- [5] C. Norberg-Schulz, "The Phenomenon of Place", in *Theorizing A New Agenda for Architecture: An Anthology of Architectural Theory 1965-1995*, K. Nesbitt, Ed. New York: Princeton Architectural Press, 1988, pp. 414-428.
- [6] *Kamus Besar Bahasa Indonesia Dalam Jaringan*. (n.d.). March 21, 2013. <http://pusatbahasa.kemdiknas.go.id/kbbi/>
- [7] E. T. Hall, *The Hidden Dimension*. New York: Anchor Books, 1969.
- [8] R. B. Santosa. (2012, May 16<sup>th</sup>). Personal Interview
- [9] *Kamus Besar Bahasa Indonesia Dalam Jaringan*. (n.d.). April 15<sup>th</sup>, 2012. <http://pusatbahasa.kemdiknas.go.id/kbbi/>
- [10] H. Lefebvre, *The Production of Space*. Oxford: Blackwell, 1974.
- [11] William H. Whyte (Filmmaker). (1988). *Social Life of Small Urban Spaces*. [Videotape]. Santa Monica, CA : Direct Cinema Ltd.
- [12] I. de Solà-Morales Rubio, "Weak Architecture", in *Architecture Theory Since 1968*, K. M. Hays, Ed. Cambridge: MIT Press, 1987, pp. 614-623.

## Bro: An Appropriate Design to Unify People, Places, and Traffic in the City Centre Plaza of Malang City

Imma Widyawati Agustin<sup>a</sup>, Hisashi Kubota<sup>b</sup>, Happy Agianata<sup>c</sup>

<sup>a</sup> Lecture at Department of Urban Regional Planning, Brawijaya University, Jl. MT. Haryono 167, Malang City, East Java, Indonesia, 65145  
immasaitama@ub.ac.id, Tel. +62-81333128894

<sup>b</sup> Professor at Graduate School of Science Engineering, Department of Civil Engineering, Saitama University, 255 Shimo-Okubo, Sakura-ku, Japan, 3388570

<sup>c</sup> Undergraduate Student at Department of Urban Regional Planning, Brawijaya University, Jl. MT. Haryono 167, Malang City, East Java, Indonesia, 65145

### ABSTRACT

This paper is focuses on an inclusive, vibrant and convivial street environment in the city centre. City centre is an important area because many people come to work in the city centre. There are some problems in the city center such as full crowded, full of skyscrapers, air and noise pollutions, daily traffic jams, and unhealthy place to live-in especially for children and elderly people. Every morning and evening rush hours cities become packed with vehicles. This study investigates this problem by combining qualitative and quantitative methods with three steps: Selection of appropriate sites to be included in the operational assessment; Collection of observational data of pedestrian and driver behavior; and Statistical analysis of the data. The new design created using 3D. The objective of this research is to examine the possibility of BRO works, and the main purpose is to stimulate economic activity through increased pedestrian activity when it is really implemented. This study shows that the design of BRO can be apply in the city centre of Malang to reduce vehicles speed and it makes comfortable for pedestrians, calm and clean, easy to move by public transport, kind to children and elderly people, easy to cooperate with citizens and visitors.

### Keywords

Links; Design; BRO; City-centre; Non-segregation

## 1. INTRODUCTION

Streets are complicated place because they must serve a variety of functions, particularly those related to the movement and traffic circulation, interactions, exchanges, and other social and community activities. Streets are not only complicated. They are also immensely important. In Europe, and even more in the USA, streets represent perhaps 80% of the public realm of the urban environment (Hamilton, 2010). Streets have five principle functions: place, movement, access, parking, and drainage, utilities and street lighting (MfS, 2007). These functions are derived from *Paving the Way* (CABE, 2002). Street design should be inclusive. Inclusive design means providing for all people regardless of age or ability. There is a general duty for public authorities to promote equality under the Disability Discrimination Act 2005 (DDA, 2005). Designers should refer to *Inclusive Mobility*, *The Principles of Inclusive Design*, and *Guidance on the Use of Tactile Paving Surfaces* in order to ensure that their designs are inclusive (DfT, 2002; CABE, 2006; DETR, 1999). The specific conditions in a street will determine what form of crossing is most relevant. All crossings should be provided with tactile paving. Further advice on the assessment and design of pedestrian crossings is contained in Local Transport Notes 1/95 and 2/95 and the *Puffin Good Practice Guide* (DfT, 1995; CSS, 2006). Related to the LOS of the road, there is a relationship between land use changes and the LOS of the road (Budi et al., 2012).

City centre is an important area in the City because many people come to work in the city centre. It consists of stores, government building, banks, and cultural attractions. There are some problems in the city centre such as full crowded, full of skyscrapers, air and river pollutions, daily traffic jams, and unhealthy place to live-in especially for children and elderly people. Every morning and evening rush hours cities become packed with vehicles. If city centre can not grow anymore and it also so many problems, citizenry will be move to the rural-urban fringe because this area is not so far from city centre and it has many positive advantages compare with city centre (Agustin and Kubota, 2012). Related to this condition, here are two solutions: firstly, we create an appropriate strategy for rural-urban fringe area (Agustin and Kubota, 2012). Secondly, we create BRO design to improve the design of existing in city centre. The design of BRO in this research adopted TDO concept by Kubota (Kubota et al., 2006). It is a little different because this research combines shared-space concept and TDO concept. This research investigates city centre's problem using combination qualitative and quantitative methods with three steps: Selection of appropriate sites to be included in the operational assessment; Collection of observational data of pedestrian and driver behavior; and Statistical analysis of the data.

The objective of this research is to examine the possibility of BRO works, and the main purpose is to stimulate economic activity through increased pedestrian activity when it is really implemented. Firstly we discuss about the definition of BRO (Berbagi Ruang Omotenashi). Secondly, we identify an appropriate location for the application of BRO. Thirdly, we create a new design to manage traffic speeds and improve the pedestrian experience by narrowing the carriageway, using tighter geometry, de-cluttering the street, providing street seating etc. Then, the outcome of this research can be used by city government to creating a new design of street for the sustainability and livability of the city centre in the future.

## 2. METHODOLOGY/ EXPERIMENTAL

In this research, we used combination between qualitative and quantitative methods with three steps: Selection of appropriate sites to be included in the operational assessment; Collection of observational data of pedestrian and driver behavior; and Statistical analysis of the data. The new design created using 3D.

The location of the study is the city centre of Malang City, East Java, Indonesia. The present study selected Klojen Sub-district and one site, which have a total area of about 8.83 Km<sup>2</sup>. In 2012, there were 106,017 inhabitants and population density is 12,006 inhabitants/km<sup>2</sup> (Statistic of Malang City, 2012). The study area located between 112.06° - 112.07° (East longitude) and 7.06° to 8.02° (South latitude). The study area has a topography that is most flat (96.3 per cent) with slope 0 per cent to 15 per cent and a height of 380 meters to 667 meters above sea level. Detail of the location of three sites can be seen in Figure 1.



Figure 1: The location of BRO design

One site and 6 links were selected based on site visits and site maps (which detailed the street layout and key characteristics). Firstly we make photo analysis to identify characteristic of the sites and the links in two categories: no activity and full activity. Secondly, we make a cross-section of each links in accordance with the existing condition in two categories: no activity and full activity. Thirdly, we mapped public transportation routes in accordance with the existing condition that passes through the study area. Then, we try to improve the existing design with the new design of street, more livable for pedestrian in the city centre. The research design can be seen in Figure 2.

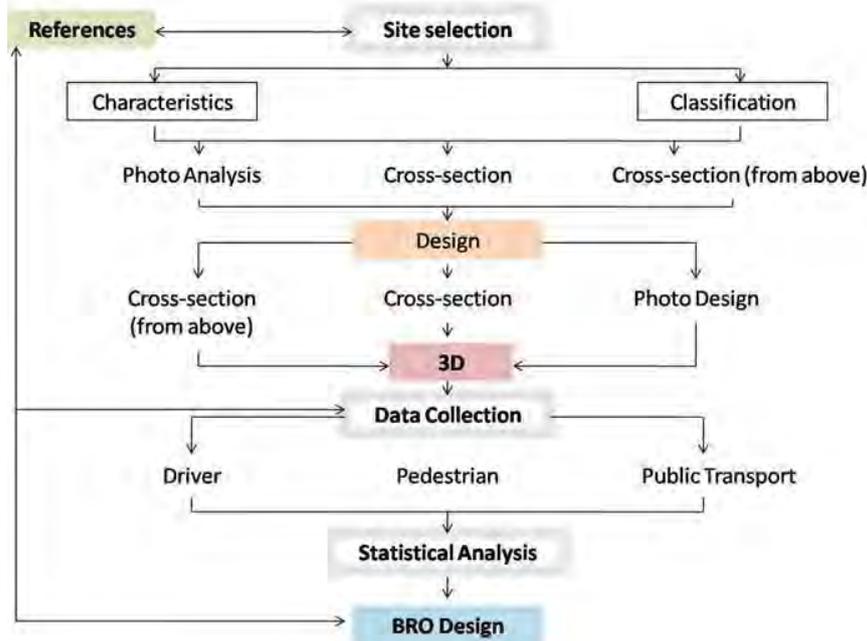


Figure 2: Research design

### 3. RESULTS AND DISCUSSION

Analysis of the characteristics of the street evaluate patterns and conditions of the street network, in which street network is an infrastructure that has an important role in the region, and the street as well as the access link from one place to another. Various analysis were conducted to determine how important the function of the street to support the accessibility and the mobility of a human activity. Here is the analysis of the condition of the street network in the city centre plaza area of Malang City, East Java, Indonesia (Table 1).

Table 1 Characteristic of streets in the study area

Sites	Links	Characteristics	Analysis
City centre plaza area 	Jl. SW. Pranoto	<ul style="list-style-type: none"> <li>- hierarchy of the street is secondary local</li> <li>- total of street reserve is 6.5m</li> <li>- the users are pedestrian, vehicle, motorcycle, and on street parking</li> <li>- there is no complementary street</li> </ul>	Based on the hierarchy of the street and street users, there is needed a plan to 'street design' for users in the area of City centre plaza, so that it can be create a comfortable community. Street design conducted by
	Jl. Merdeka Utara	<ul style="list-style-type: none"> <li>- hierarchy of the street is secondary local</li> <li>- total of street reserve is 12m</li> <li>- the users are pedestrians, vehicle, motorcycle, and on street parking</li> <li>- there are complementary street ie traffic signs</li> </ul>	
	Jl. Merdeka Selatan	<ul style="list-style-type: none"> <li>- hierarchy of the street is secondary local</li> <li>- total of street reserve is 5.5m</li> <li>- the users are pedestrian, vehicle, motorcycle, on street</li> </ul>	

Sites	Links	Characteristics	Analysis
		parking and some illegal activities - there are only a few complementary street ie street signs	observing street users and the types of activities that are in the area of City centre plaza.
	Jl. Merdeka Barat	- hierarchy of the street is secondary local - total of street reserve is 10m - the users are pedestrian, vehicle, motorcycle, and on street parking - there are complementary street ie traffic signs	
	Jl. Merdeka Timur	- hierarchy of the street is secondary local - total of street reserve is 12m - there are complementary street ie street signs	
	Jl. Basuki Rahmat	- hierarchy of the street is secondary collector - total of street reserve is 10m - there are complementary street ie street signs	

The majority of LOS in existing conditions for some links increased to get better when tested using BRO design (Table 2). The capacity of on-street parking also has improved when tested using BRO design (Table 3).

Table 2 LOS of the city centre plaza area of Malang City

Sites and Links	Capacity (C)	Volume (V)	V/C	LOS (Existing)	LOS (Design)
City centre plaza					
Jl. SW. Pranoto	2539,92	1889	0,74	C	A
Jl. Merdeka Utara	5251,07	2280	0,43	B	A
Jl. Merdeka Selatan	2625,53	776	0,30	B	A
Jl. Merdeka Timur	4623,22	2176	0,47	C	A
Jl. Merdeka Barat	5251,07	985	0,19	A	A
Jl. Basuki Rahmat	4773,70	2054	0,74	C	A

Table 3 Capacity of on-street parking in the study area

No.	Link	Angle (n°)	Existing				Design					
			S (Plots)		D (hour)	S/m (vehicle/h)		S (Plots)		S/m (vehicle/h)		
			MC	LV		MC	LV	MC	LV	MC	LV	
City centre plaza area												
1	Jl. SW. Pranoto	90	107	56	0.5	214	112	0	107	27	214	54
2	Jl. Basuki Rahmat	0	29	113	2	14	60	0	29	113	14	20

BRO is designed specifically for the vehicle with low speed. Pedestrians have the same privileges to the vehicles. Several characteristics of BRO design are: (1) Elimination or removal of separation between motorcycle/vehicles, pedestrians and other street users; (2) Elimination of the traditional distinction between footpath and street, thus providing more space for pedestrians and other street activities (street restaurant, music, etc); (3) The device street such as curbs, lines, signs, signal is removed. It is replaced with integrated utilization, which is oriented to the public space so, walking, biking and driving the car into a controlled activity and instead holding a 'BRO' point of entry and exit to the city centre. BRO design is contradicting to the principle of segregation, the idea of separating functions and different users in the city. We put some design elements such as street furniture, artwork and other plants or flowers around the space. It encourages the speed of vehicles being slow.

Table 4 Design concept of BRO in the city centre plaza of Malang City

Sites	Concept
City centre plaza	<p>Travel way</p> <ul style="list-style-type: none"> <li>▪ Limiting the width of travel way only for 6 meters.</li> <li>▪ The use of paving materials as its pavement. There is no asphalt.</li> <li>▪ There is a difference in color between pedestrian and travel way.</li> <li>▪ There is no difference in 'high levels' between pedestrian and travel way.</li> </ul> <p>Pedestrian</p> <ul style="list-style-type: none"> <li>▪ There is no difference in 'high levels' between pedestrian and travel way.</li> <li>▪ Widening the pedestrian way, the widest possible use of the remaining existing travel way narrowed.</li> <li>▪ There is a difference in color between pedestrian and travel way.</li> </ul> <p>Ornament</p> <ul style="list-style-type: none"> <li>▪ There is added planter on the right side of the street.</li> <li>▪ On-street parking is eliminated. Car/vehicle can stop within a specified period.</li> <li>▪ There is added street lights on both sides of public space</li> <li>▪ There is added pots of flowers on pedestrian</li> <li>▪ There is added public seating in the area of public</li> </ul>



Figure 4 Photo design and 3D of Jl. SW. Pranoto

New design of Jl. SW. Pranoto can be seen in Figure 4. There is no difference in 'high levels' between pedestrian and travel way. Public transport and motorcycles have their own lanes. Their lane is different with private car lanes. This is intended to avoid congestion. The design of the cross-section and longitudinal section of the concept of BRO in City centre plaza sites can be seen in Figure 5.

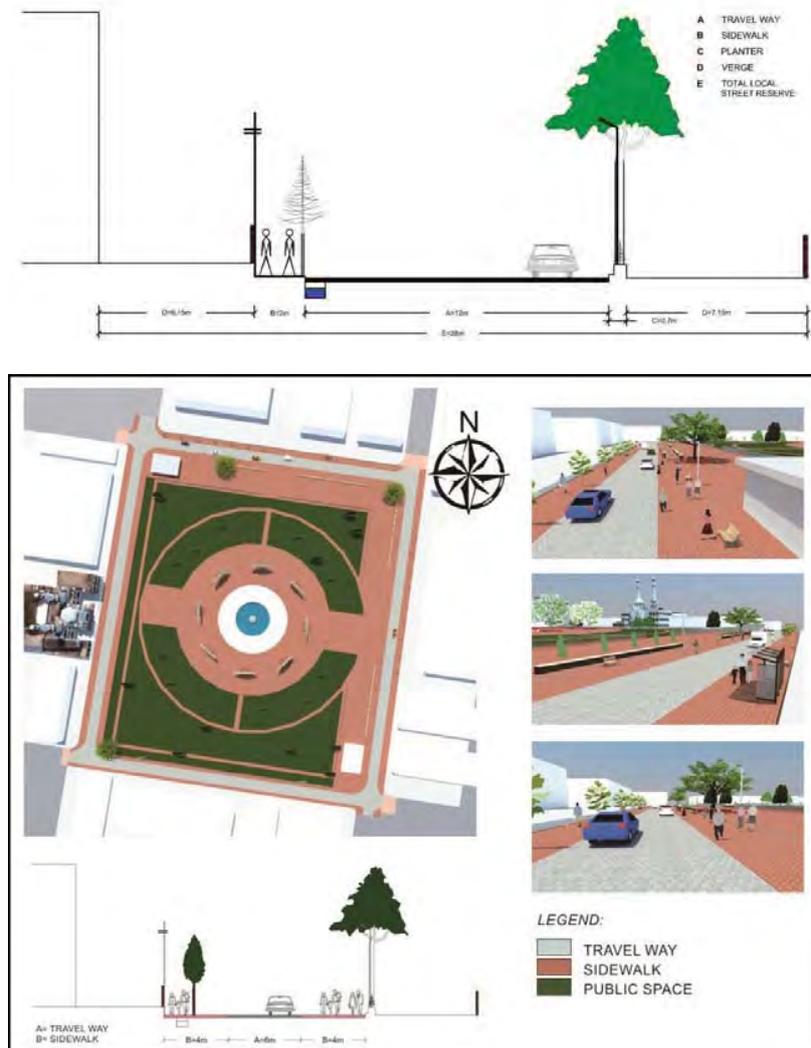


Figure 5 The design concept of BRO and cross-section of BRO design in the City centre plaza

### 3. CONCLUSION

The design of BRO can be apply in the city centre plaza of Malang City to reduce vehicles speed and it makes comfortable for pedestrians, calm and clean, easy to move by public transport, kind to children and elderly people, easy to cooperate with citizens and visitors. This design is safe. This is due to both motorists and pedestrians are encouraged to be more careful with the surrounding environment and to each other. Example: the driver will instinctively slow down and make eye contact with pedestrians in the vicinity.

The authors hope that this study will give a new idea that can be used by other researchers and city government to creating a new design of street for the sustainability and livability of the city centre in the future

### 4. AKNOWLEDGMENT

The authors wish to express their gratitude to all members of the urban regional planning studio in University of Brawijaya and also UTG laboratory in Saitama University for their cooperation and support.

## REFERENCES

- [1] Agustin, IW., Kubota, H., (2012), An Appropriate Strategy to Anticipate Fringe-Settlements Development in the Rural-Urban Fringe Area, J. Basic Appl. Sci. Res., Volume 2, Part V, pp. 10612-10619(10), TextRoad Publication.
- [2] Agustin, IW., Kubota, H., (2012), Changing Physic, Changing Pattern, and Conflict of Rural-Urban Fringe Using a Combination Model, J. Basic Appl. Sci. Res., Volume 2, Part V, pp. 12722-12730(12), TextRoad Publication.
- [3] CABE and ODPM, (2002), Paving the Way: How we Achieve Clean, Safe and Attractive Streets, Thomas Telford Ltd, London.
- [4] CABE, (2006), The Principles of Inclusive Design, London.
- [5] Communities and Local Government, (2007), Manual for Streets, Thomas Telford Ltd, London.
- [6] County Surveyors' Society/Department for Transport. Puffin Good Practice Guide, (2006), available to download from [www.cscnet.org.uk](http://www.cscnet.org.uk).
- [7] Disability Discrimination Act., (2005), TSO, London.
- [8] DETR, (1999), Guidance on the Use of Tactile Paving Surfaces, London.
- [9] Department for Transport, (2002), Inclusive Mobility A Guide to Best Practice on Access to Pedestrian and Transport Infrastructure, London.
- [10] Department for Transport, The Assessment of Pedestrian Crossing, Local Transport Note 1/95, (1995), TSO, London.
- [11] Department for Transport, The Assessment of Pedestrian Crossing, Local Transport Note 2/95, (1995), TSO, London.
- [12] Hamilton, B., (2010), Shared Space and Street Design, City Planning Institute on Japan, June 25.
- [13] Kubota, H., Uemura, T., Kojo, M., and Sakamoto, K., (2006), Transportation Demand Omotenashi (TDO): an Idea and an Analysis, 考察 管理からおもてなしへ土木学会 土木計画学研究・論文集 23:711-716.
- [14] S.W., Budi, Surjono, S., Harnen, (2012), The Influence of Trip Attraction on the Road's LOS at Traditional Market Land Use. JAEBS, Volume 2, pp. 92-96.

# The Role of Indigenous Community in the Production of Street Space Use Justice

Antonius Karel Muktiwibowo<sup>a</sup>

<sup>a</sup>Faculty of Engineering, Architecture Department, Udayana University  
 Kampus Bukit Jimbaran Tel : (0361) 703384  
 E-mail : antonimation@gmail.com

## ABSTRACT

Among the recent research and theories in urban planning, it is argued that street is a public space that should have equal access for the city inhabitants to use it. However, this character of street 'publicness' is always being contested. The various users, occupation and control of street use have become a daily practice of urban life, especially in developing countries, which consider street as a place of a person's livelihood beside its main function as a path or transportation access space. This creates a street space contestation which demands for space justice. It is argued throughout this paper that municipality with a top-down governance approach has difficulty to create and manage public space equality. At the same time, indigenous community is capable to control street space activities and users by adopting the traditional value to create 'justice' in community practice. This argument is accessed through an examination of empirical qualitative data of Denpasar Street life, Bali.

## Keywords

Public space, justice, governance

## 1. INTRODUCTION

*"Public space is, in this sense, the space of justice. It is not only the space where the right to the city is struggled over; it is where it is implemented and represented. It is where Utopia is both given spatial form and given lie to. Utopia is impossible, but the ongoing struggle toward it is not."*[1]

A street, a Public Space, is an important urban element of physical, economic, social, culture and identity[2-5]. Especially in Denpasar, a street has been used daily as a transportation path but also as economic and social life. It is inevitable that the use of street space being contested everyday. Madanipour [6] argues that street as an urban public space should be accessible and consumed [7] for everyone than the challenge has developed into a more complicated matter such as degree and control of accessibility, which is disputed. Newman [8] states that local municipalities have this responsibility to maintain the users and function of streets for transportation circulation[9]. When local officials want to segregate activities and localized activities as its urban planning direction, it will face another problem of maintaining street space as social space [10]. This section will focus more into the power and authority to govern public space in a democratic practice that people should have the right to participate and express their voice in public space [11; 12]. Therefore, questions of this section are which actor who has the main role to participate in street use justice, and followed by a question of how they can manage it?

The municipality power to define and redefine public space will be contested in this section. The lack of common municipality engagement in the community in a matter of budget limitations and other provincial procedure for off-office work makes another negative perspective of present Denpasar official. In Denpasar, the community creates a specific agent of space control that can determine access and activity in their territory area (*Pecalang*) this phenomena has occurred as a response of low space control into the increasing awareness and participation of indigenous people to repossess and classify the existence of public space into community space. It creates civic space which is still accessible for everyone, but it is controlled and maintained by indigenous/ local residents group. One obvious advantage of community participation is the high level of attachment of place, in this case a street space. Balinese attachment of space as an element of territoriality behaviour[13] determined by inherited value and identity relation of individual and related family experience of space. Geertz[14] stated that the history of the development of Denpasar city that resulted from several compounds of family-interrelated kinship make a specific urban space is being valued as family-personal space. Then the question of how to create a democratic space of historically 'private' communal space should be accompanied with the interdependent question of who will guarantee the regulator fairness, authority, and balance of management and maintenance of street space in a sustainable manner.

This sub-section is organized into three sections that will examine and discuss thesis argumentation of the role of indigenous community groups and organization in the production of equal public space and how they can manage this 'justice' in a sustainable urban practice. The first section focuses on the native norm and community classification called '*krama*' of society to maintain community justice. It is a traditional classification to create a society order. The fairness of this native power to control street space is discussed in the second section which explores '*gayah*' as the traditional social concept that can bind

the justice in community responsibility. The last section describes the effort of indigenous community to preserve the traditional value and norm as a guideline for its sustainability.

## 2. SOCIETY CLASSIFICATION (OR SEGREGATION) FOR JUSTICE

In Traditional Balinese society and also Denpasar community, it is well-known and applied the social community classification called 'krama' [15; 16]. It is based on religion, ingenuity, local-based identity, caste, economy and ethnicity differences. It consists of three types of *Krama*. *Krama* is for indigenous local residents with Hindu's religion; *Krama Tamiu* is for Hindu's residents but not originally (inherit) from local community/place and time for other residents who is not included in class of *Krama* and *Krama Tamiu*. To simplify things, in the common daily practice, Balinese often called this categorization of residents as *Warga Adat (Krama)*, *Warga Dinas* (officially registered as resident but not inherit an indigenous identity) and '*Bukan Warga*' for others. This traditional classification is written in indigenous social norm and regulation called 'awig-awig' [17]. Beside the classification of residents it defines the other society regulation and norms that related to everyday life in public space, in the human relation and the creation of balance relationship between society, the environment and God which known of '*Tri Hita Karana*', a Balinese concept of life. The differentiation of rights and duties in every member of society is detailed written in this indigenous document while it is also stated that the existense of society norm that unwritten in 'awig-awig' also have their *de-facto* power to regulate communities.

*One must therefore construct the objective class, the set of agents who are placed in homogenous conditions of existence imposing uniform conditionings and producing homogenous systems of dispositions capable of generating similar practices; and who possess a set of common properties, objectified properties, sometimes legally guaranteed (as possession of goods and power) or properties embodied as class habitus (and, in particular, systems of classificatory schemes) [18:101].*

The social creation of classification should be valued as a positive community action towards social justice. It should be comprehended that justice not solemnly relates to equality that everyone should have the same amount of resources. Social justice relates to equity, equality and welfare [20]. The competition of street use that leading to horizontal conflicts are often resulted from the misinterpretation of public space for freedom of use by the public. Highly accessed space that defines publicness of space is no permanent relation to the ability to control. There are many debates through the act of public space occupation, possession and privatization [10; 21] that eventually potentially produce horizontal conflict. Creating justice in public place requires an agency that can maintain the justice of use and act of territorialisation. This must be a persistent action not just a scheduled or a random process of control. As stated by one of the street vendors,

*'We usually sell our groceries right here (on the street) start from 5 to 6.30 am. These are our daily activities working hours that we are organised in conjunction with other vendors and parking man, as well as we share a sum of money to pay parking man as they lose some space for motorcycle parking. We are here working and cooperate in cooperation with our living, to earn money to buy some food and pay our child's school fee for our family at home not more... We know that government prohibits us to sell our stuff on the road, but they rarely come here to control us, .. And if there will any plan of inspection for several municipality reasons (... i.e special inspection from higher municipality, president or other important national events), we know a day before from Pecalang that always came here three times a day, it has happened so we can organise and help them by following the regulation (temporary). Anyway, we know the officials quite well; we are friends...'*

In this statement, it stated that municipality conducts street inspection irregularly. As it is becoming common understanding in the Denpasar community that the governance of a neighbourhood (including the street space) is their basic right as hereditary the space and resources is their belonging therefore the benefit and cost of territorial resource management better become their authority. Municipality aware of this understanding and minimize their presence to avoid states-community, a Top-Down conflict. Controlling street activity is a huge challenge in economic and mainly socially interconnected problems, and irregular control of the street space is an inappropriate one.

Based on reviewing municipality and community empirical dispute about right to manage street, It can be summarized that municipality seems to have a (save) neutral position, which also can be categorized as the lack of direct actual action as it tight relation to law enforcement, regulation, justice and bias of political security. On the other hand, community (indigenous) groups have their grounded and in depth comprehension through every second of street or social events and identification of street users in their environments.

Community classification such as differentiation of local and non-local residents is not merely social segregation but a way of managing right and responsibilities. As local residents more responsible to their territory through everyday activities such as cleaning, offering, praying over all community public space than they have more right, the feeling of belonging than another, as empirical data also shown that non-local (especially) vendors have a low level of public space environment quality even more they make destructive action by littering or polluting neighbourhood.

Classification based on religion also has its own importance to maintain social justice harmony. Denpasar community consists of 63% Hindus, 29% Islam, and other religion such as Catholic, Protestant, Buddha below 4% each [22]. It is indicated in census data that the proportion of Hindus community (indigenous one) still dominates the population followed by Islam's community in the second. These two groups of religion take a strong position in the governance of the city. The Hindu represents indigenous and Islam represents the municipality (or nationality) as an Indonesian biggest majority religion, a religion that has full financial and political support from central government. On the level of street neighbourhood, Denpasar community landscape, these groups of community based on religion create their individual community cohesion and exclusion indicated by their particular symbol, attitude, language and activity system. As stated before in *Awig-awig* (indigenous regulation), that non Hindu's community classified as *tamiu* (community guest) that have different right and responsibility with Hindus (the indigenous) which is practically conducted successfully in the present societies. Balinese Class domination is based on Tri Hita Karana concept, to share and maintain a relationship with others. This is the key of creating social class justice. Classification in a Balinese democratic society means the right of the majority to serve and support the minority class right and activity which resulted in a respect of minority to majority that lead to social order.

Community classification as a part of Place-based justice is a requirement of social order. Indigenous community (Hindus) with their social value of creating balance between human, environment and god have positioned themselves in the process of sharing community resources and right and duties, benefit and cost. For example, Hindus community will be more responsible in maintenance and cost of their public space, especially sacred public space as it is related with their daily worship. It is also found in the empirical data that several street vendors are classified by their interrelationship with home, shop, temple owner of the street. For a Place that considered high local-sacred valued it is inhabited by Hindus community that has certain knowledge for place worship and offering. Classification of actors who reflected in character of street use, creating a definition of locality, an initial indication of private (certain group) place in public space. Classification of community is made to maintain the conflict, which not certainly means segregation but more into the appropriation of the community members right, action and activities around a specific territory. Justice can be achieved without fear with understanding people through respect for certain inherited value.

### 3. COMMUNITY PARTICIPATION PROGRAM FOR EQUALITY

In Denpasar, there is a social participation concept called '*Ngayah*'. It is a term for an individual, family representative, or group of people to work and spend their time for any community event based on scheduled affair or unscheduled one such as family birth, marriage, funeral ceremony, temple birthday and other event ordered by community leaders. It is usually unpaid job and consume a specific amount of time with a definite consequence for opposing this social activity, that is being secluded and confronted with physical and social punishment. For example, a Balinese person that in purpose avoids a series of '*Ngayah*' then when there is a ceremony related to that 'naughty-lazy' resident than the community can embargo that specific event, street access and even social access to the religion leader who related with. As Made, a Balinese resident said.

*'.. Everyone must attend and involve in every 'ngayah' session, if they are not joining this social work for several times, it is against our community norm and social fairness, which also implies disrespect to God and Prajuru Banjar (community leader) and societies, especially if they not come when there is a 'Ngayah' for funeral ceremony. We can punish them with boycott their funeral ceremony when the days it comes. Not allowing their dead body to enter and pass through our neighbourhood street... we should help each other, that's the key... if they want to replace 'Ngayah' with money, I also have money. And if everyone wants to play .. So who will help this ceremony to be happening .. No other reason, but they have to join 'Ngayah' whenever and wherever... as we do it for parahyangan, pawongan, and palemahan... (God, community and place)..'*

From the interview statement, it can be concluded here that some factor influencing the degree of participation in a community is good leadership, which reflected in degree of obedient and respect to the leader (Balinese leader: *prajuru banjar* and God), community (social) punishment and equality besides materialism (money). The interesting finding of Balinese community equality is the effort to avoid the materialism factor in community governance. Money as the top rank of the social practice generators is not generally applied to this empirical study result. When community aware that the materialism can distract the successfulness of governance then immaterialism (value, religion, god, social norm) can be used as a generator to create a community order. One way to minimize social class status is by treating them socially equal. Rich, poor, high caste, low caste, active or not busy residents have the same obligation to conduct '*Ngayah*' community (unpaid) work.

Social consequences become an important factor of community participation. It ensures the equality of responsibility corresponded to the various differences of community equity and welfare. It is claimed that punishments have a greater impact if it is a social / community –based, immaterial one. When the community has the equal consequences of participation then awareness of active responsibility can be built as well as reduce social class distinction.

#### 4. SUSTAINABILITY OF ACTIVE COMMUNITY PARTICIPATION

Judd and Fainstein [23] argues social, environmental, institutional and economic defines sustainability, which is influenced by level of care, democracy and justice. Based on the empirical finding, It is found that sustainability also shaped by three other elements such as transformability, commonality, and dedication to immaterial value. Bourdieu (social) class and capital argue this communal power called social capital is an important factor for small based enterprises, and consequently. It is reflected on the degree of cohesiveness that constitutes people's perception, right, and exclusivity.

Transformability is the ability of the community to adapt, adopt and adjust their social behaviour with the change of individual and resource development. Transformability will relate to the fluidity of regulation and regulator to manage society. Awig-awig as indigenous community regulation is not a solid regulation and is kept, transformed and adjusted following the variety of stakeholders, therefore, there is no identical awig-awig around Bali. One media that had been found in the research is a de facto (legal) communal meeting called 'paruman' which can produce additional norm and regulation instead of inherited one to adapt the change of resources. With direct voice, idea and expression from all community's inhabitant, the regulation product of 'paruman' is a result of democratic approach. Although there are differences and debate of ideas and power as it heard and witnessed by all, it is one way to create sustainability of participation that guarantee the equality to express voice. Another common understanding of community is that awig-awig has created from a generation that has huge difference to the recent community condition. Therefore, it should be modified democratically for community good will.

The second factor of sustainability is the proud, respect and attachment of indigenous value. In this case concept 'Tri Hita Karana' balance relation with God, human and environment which is a fundamental concept but easily applicable to everyday practice. Other indigenous practices such as traditional event, ceremony and activities that being preserved nowadays is the other evidence of relativity with a traditional concept can bind cohesiveness of society, which develops a greater degree of people attached to the physical and social environment. In a simplify way that expressed by the respondent that express confidence of Balinese people to preserve this tradition as it is not only a physical tangible product but more into social valuable entities. Leaving tradition and indigenous value does mean leaving the physical attribute of a locality which is not difficult to conduct, but leaving the social relation, value, meaning memory with friends and relatives still a greater factor to be preferred.

Classification, Caste and leadership are other keys of sustainability factors. Community classification is socially constructed based on individual possessed resources and hereditary. It exists, therefore, should be consumed carefully in the perspective of social justice. Dominancy of power and class is used to maintain equity and community welfare. As awig awig states the difference right and responsibility of every class of the community, it should be applied to balance of right and responsibility in analogy of the balance of social benefit and cost. To achieve this, social solidarity is a key factor together with the ability to actively control and manage this solidarity among the community.

#### 5. CONCLUSION

Diversity of and class in the community are an on-going social construction process through variety, similarity, the cohesion of identity. Generalizing community diversity into an equal identity of the community will face some difficulties in the process and product of justice. The indigenous Balinese classification called 'Krama' is not merely a segregation tool for community difference but as an indicator to achieve social justice in distributing community rights and resources. Balinese aware with this unavoidable class difference, therefore, several regular community events were conducted called 'paruman', community meeting and 'Ngayah', a community social work, with equality of class and social punishment for noncompliant one. It is a social activity that reflects an active community participation towards their environment, neighbourhood space and God. These indigenous values and activities have the important factor that should be kept for its sustainability such as transformability, respect and attached values.

#### REFERENCES

- [1] D. Mitchell, *Right to the City: Social Justice and the Fight for Public Space*. Guilford Publications, 2012. pp :235
- [2] A. Rapoport, *Urban and Regional Planning Series*. Pergamon Press, 1977.
- [3] I. Altman, J.F. Wohlwill, A. Rapoport, . *Environment and Culture*. Springer, 1980.
- [4] N.R. Fyfe, " *Images of the Street: Planning, Identity, and Control in Public Space*. Routledge, 1998.
- [5] B. Lawson, *Language of Space*. Taylor & Francis, 2001.
- [6] A. Madanipour, *Whose Public Space?: International Case Studies in Urban Design and Development*. Routledge, 2010.
- [7] A. Chakrabarti, A. Thakur, "The Making and Unmaking of the (in)Formal Sector." *Critical Sociology* 36, no. 3, 2010, pp: 415-35.
- [8] O. Newman, *Defensible Space: People and Design in the Violent City*. Elsevier Science & Technology, 1973.

- [9] Bailey, Keiron, Benjamin Blandford, Ted Grossardt, and John Ripy. "Planning, Technology, and Legitimacy: Structured Public Involvement in Integrated Transportation and Land-Use Planning in the United States." *Environment and Planning-Part B* 38, no. 3, 2011, pp: 447.
- [10] R.H. Barnes, A. Gray, B. Kingsbury, *Indigenous Peoples of Asia*. Association for Asian Studies, 1995.
- [11] Perda, "Peraturan Daerah (Perda) Provinsi Bali No 06 Tahun 1986." edited by Pemerintah Daerah Provinsi Bali, 1986.
- [12] F. Hernandez, P. Kellett, L.K. Allen, *Rethinking the Informal City Critical Perspectives from Latin America*. New York: Berghahn Books Inc., 2009.
- [13] I. Altman, *Human Behavior and Environment, Advances in Theory and Research*. edited by Altman and Rapoport: Plenum Press, 1980.
- [14] H. Geertz, C. Geertz, *Kinship in Bali*. University of Chicago Press, 1978.
- [15] C. Warren "Community Mapping, Local Planning and Alternative Land Use Strategies in Bali." *GEOGRAFISK TIDSSKRIFT* 105, no. 1, 2005, pp: 29.
- [16] L. Cuba, D.M. Hummon, "A Place to Call Home: Identification with Dwelling, Community, and Region." *The Sociological Quarterly* 34, no. 1, 1993, pp: 111-31.
- [17] CIB Report: "Sustainable Livelihoods in the Informal Settlements." *CIB Report: Publication 302* (April 2005)..
- [18] J. Duruz, S. Luckman, P. Bishop, "Introduction: Bazaar Encounters: Food, Markets, Belonging and Citizenship in the Cosmopolitan City." *Continuum* 25, no. 5, 2011, pp: 599-604.
- [19] J. Agergaard, V.T. Thao, "Mobile, Flexible, and Adaptable: Female Migrants in Hanoi's Informal Sector." *Population, Space and Place* 17, no. 5, 2011, pp: 407-20.
- [20] A. Malik. "Identifikasi Kemacetan Lalu Lintas Di Kawasan Paal 2 Dan Pusat Kota Manado." *SABUA* 3, no. 1, 2012.
- [21] BaliPost, "Jalan Layang, Solusi Jangka Pendek." <http://www.balipost.co.id/mediadetail.php?module=detailberita&kid=21&id=9925>.
- [22] BPS, "Bali in Figures 2010." edited by Statistics of Bali Province. Denpasar: BPS - Statistics of Bali Province, 2010.
- [23] P.D.R. Judd, S.S. Fainstein, *The Tourist City*. Yale University Press, 1999.

## Toward Resilience Urbanization: The Shared Roads as a Mean for Enlarging the Public Spaces.

Mahmoud Yousef M. Ghoneem<sup>a</sup>

<sup>a</sup> Architecture Department, Faculty of Fine Arts  
Helwan University, Cairo, Egypt  
Tel: (002) 01123640401  
E-mail : mahmoudghoneem@yahoo.com

### ABSTRACT

More than half of the world's population now lives in cities, making the creation of a healthy urban environment a major policy priority. The city or urban area is a set of infrastructure, other structures, and buildings that create an environment to serve a population living within a relatively small and confined geographic area. The lives and livelihoods of the population are supported by interrelated systems around which the urban area and society function. Most public space in urban areas is provided by streets. Well designed streets can offer opportunities for recreation, social interaction and physical activity. Poorly designed streets can be indifferent or unwelcoming, contributing to community severance, reducing social cohesion as well as suppressing levels of walking and cycling. They can also have a negative impact on local economic performance. In the City of Cairo and According to the World Bank Report Cairo Consider One of the most crowded cities that assumed there is a lake of public spaces which has a great impact on the social activities and the local economic performance. That what led me to propose the need for integrated concept to enlarge the public spaces within the city. The shared space is an existing streets or places designed to improve pedestrian movement and comfort by reducing the dominance of motor vehicles and enabling all users to share the space rather than follow the clearly defined rules implied by more conventional designs. The main objective of this paper is to increase the public spaces within the cities inner districts without affecting the traffic and the infrastructure and to improve the road safety by encouraging negotiation of shared areas between different road users. An analytical study was done on the city of Cairo, in order to understand the society needs using SWOT analysis to evaluate the efficiency of the different solutions. The study found that Shared Spaces does not offer a ready recipe for the organization, design and equipment of public space. Individual problem situations demand tailored solutions. Nevertheless, there are a number of general basic principles for the design of people space. To promote socially conscious behavior, the design should be based on local characteristics and one should use as few as possible traffic engineering and regulation elements. Priority signals should be replaced by human interaction.

### Keywords

*Urban, resilience, shared roads, public spaces, Cairo.*

### 1. INTRODUCTION

More than half of the world's population now lives in cities, making the creation of a healthy urban environment a major policy priority. The city or urban area is a set of infrastructure, other structures, and buildings that create an environment to serve a population living within a relatively small and confined geographic area. The lives and livelihoods of the population are supported by interrelated systems around which the urban area and society function.

Recently cities are getting larger and denser, but they are balancing processes of out-migration, suburbanization, and the creation of extended urban landscape that combine cities, towns, and interspersed rural landscapes into a functioning whole. Other cities are decreasing or only maintaining their population, but even they are engaged in efforts at transforming their structure and function in order to maintain their vitality. Whether they are growing or not, cities and their associated regions are competing to be regional, national, and international hubs.

Most public space in urban areas is provided by streets. Well designed streets can offer opportunities for recreation, social interaction and physical activity. Poorly designed streets can be indifferent or unwelcoming, contributing to community severance, reducing social cohesion as well as suppressing levels of walking and cycling[5]. They can also have a negative impact on local economic performance.

**The main objective of this study is** to determine enhance ways to increase the public spaces within the cities inner districts without affecting the traffic and the infrastructure and to improve the road safety by encouraging negotiation of shared areas between different road users.

**Greater Cairo city center was chosen as the main case study** because Cairo According to the World Bank Report Consider One of the most crowded cities that suffering from lacking of public spaces which put pressure on land, services and increase settlement inside the city, that has a great impact on the social activities and the local economic performance.

### Questions the Research Answers:

This study aims to demonstrate to what extent urban strategies can be helpful for solving the urban problems that related to the continuously growth inside the cities. And how those strategies can be useful in developing better plans for managing urban public spaces . To that end, it proposes a hypothetical solution depending on urban resilience management strategies. The main research questions are formulated as follows:

- What is the resilience urbanization strategy?and what is its importance?
- What is the importance of the open public spaces? And is it possible to enlarging / expanding them within its existing boundaries?
- What are the shared roads and its importance?
- How shared roads can be useful in providing the concept of sustainability inside cities?
- Why the Greater Cairo City needs urban resilience strategy?

## 2. WHAT IS THE RESILIENCE URBANIZATION STRATEGY? AND WHAT IS ITS IMPORTANCE?

Change is a constant in our world especially with the rapid calls for Urbanization and not all communities are dealing successfully with the issues of growth. Some communities must manage the issues that derive from decline.

Urbanization is both an opportunity and a challenge and according to that, many urban management strategies appeared to dial with the city dynamic growth impacts and its consequences':

1. **Urban growth management strategies** that consist of the various tools used to manage the amount, type, extent, rate, and quality of urban development. In other words, these tools can be used to manage how much growth occurs, what kind it is, where it occurs, how fast it happens, and with what impacts.
2. **Urban disaster recovery management** that takes steps to anticipate and mitigate the impact of disasters, incorporating monitoring and early warning technologies to protect infrastructure, community assets and individuals, including their homes and possessions, cultural heritage, environmental and economic capital, and is able to minimize physical and social losses arising from extreme weather events, earthquakes or other natural or human-induced hazards.
3. **Urban resilience strategy** can be define as guidelines & action plan that help the cities to be able for respond, implement immediate recovery and quickly restore basic services to resume social, institutional and economic activity after any threatens or crises. And we can Consider the city where people are empowered to participate, decide and plan their city together with local authorities and value local and indigenous knowledge, capacities and resources. a resilient city.

According to above we can define Resilience as a prevailing theme of the discourse on disaster preparedness, response, recovery and mitigation; it is a measure of the system's capacity and the ability of these systems to absorb changes that caused from the different variables.

Without doubt, resilience is an evolving concept. Understanding resilience perspectives from multiple fields requires further research. In my study, I share the perspective that resilience has multiple levels of meaning: as a metaphor related to sustainability, as a property of dynamic models, and as a measurable quantity that can be assessed in field studies of urbanization. The concept of resilience is useful for urban designers who strive to create cities that are adaptable to changing conditions and needs.

## 3. WHAT IS THE IMPORTANCE OF THE OPEN PUBLIC SPACES? AND IS IT POSSIBLE TO ENLARGING / EXPANDING THEM WITHIN ITS EXISTING BOUNDARIES?

Great cities all over the world became featured with some common urban features, which is clearly could be noticed in the main urban components of the centers of great cities, those components may be not exist in the rest of the city, such as the historical heart that represent the oldest part of the city, CBD, the main stations for public transportation networks, and many other urban components, the public spaces are considered as one of the common urban components in the great cities centers at the same time they don't exist as the same as in the rest of the city, such as central parks, specialized gardens, pedestrian grand plazas and squares which may include national symbols concerned by the citizens of these countries, those unique public spaces represent the social life of a great city and considered as a measure of its vitality. [7]

The public spaces of the great cities centers became logistic nodes acting new urban roles and functions. Nodes where pedestrians are being collected and distributed to different destinations within the city center or its borders by using Entrances and exits of main public underground transports networks, The main train station or to be linked to its Main bus stations, which are good connected to the public spaces[2], these nodes providing the common urban roles of the public spaces besides its new role, the common roles were appropriated to the new fast rhythm, the public spaces became more complicated and contains some specified spaces inside the main public spaces, those new specified spaces usually private but their exists help the main public space to act its new role as a logistic node besides its original urban roles.

In the current City center the public spaces in which the pedestrian participate to the different social and leisure activities limited only to the pavement which its width can be (3-4) meter long in the best case. These public spaces can be temporarily expanded horizontally (including the street/ road – which will increasing the public space about 8-12 meter) to absorb the huge

agglomerations of people in the national events, festivals, which will affect the future design of those spaces and the surrounding pavements, streets to be flexible to meet the multi-functions uses the best concept for that is the Share roads and shared spaces that intend to increase the public spaces within the cities inner districts without affecting the traffic and the infrastructure and to improve the road safety by encouraging negotiation of shared areas between different road users.

#### 4. WHAT ARE THE SHARED ROADS AND ITS IMPORTANCE?

The concept of designing public roads, junctions and spaces as so called Shared Spaces/ Roads is increasingly popular in recent years and is seen as a chance to reduce the car-dominance in cities throughout Europe. It creates extra urban flow paths.

**Shared Road** is a term used to describe an emerging approach to urban design, traffic engineering and road safety in Europe and, increasingly, in North America. It was identified a common thread in the approach of a number of countries on how to reduce the adverse impacts of traffic in towns.

However, shared road could also be seen as the default mode before the separation of vehicles and pedestrians became the accepted approach to designing public spaces. It was the status quo ante for most streets and public Spaces before the introduction of segregation during the last century. Streets that encourage sharing of the space are not new. Many historic streets operate as shared spaces, particularly narrow streets in historic core zones and residential districts. Visit any Italian hill town, such as Siena, or smaller Mediterranean settlements, and shared space will be evident in any traditional streetscapes where modern traffic engineering has yet to have an impact. Even today in the UK, almost all car parks, courtyards, mews developments, market places, village squares, campsites and country lanes involve the informal sharing of space for different uses and by different modes of movement. [3]

In shared Road designs, the segregation between motorized and non-motorized traffic is removed, creating an integrated space without traffic signs or signals, curbs and road markings. Instead, traffic flows are controlled by social interactions and supported by infrastructure measures like colored road surfaces and the thoughtful placement of road furniture.

Shared roads are not, ultimately, defined by the design or configuration of the built environment. Design and detailing are important, but only as a catalyst to changing the way in which people interact within the public realm.

##### **The Shared Road design team:**

Shared space schemes tend to have wide-ranging objectives beyond more traditional single-issue such as traffic management schemes – objectives such as inclusiveness, street vibrancy and regeneration.

It is therefore beneficial to assemble a multi-disciplinary project team which, in addition to the project sponsors, could include the following, for example: (Highway/traffic engineers - urban designers - town planners / conservation officers - landscape architects - accessibility/mobility specialists - maintenance team managers - lighting engineers – contractors).

##### **General Design Consideration for shared roads:**

Shared road does not represent a particular type of street. It is more a broad set of design approaches aimed at encouraging sharing as a way of improving the street's place function. It can achieve this, in part, through minimal use of traffic signs and other traffic management related street furniture. Traffic signals are often removed, with indications of priority at minor junctions omitted. These changes modify the way the street operates by creating an environment that encourages drivers, pedestrians and cyclists to behave in a more co-operative manner.

The surface level is often intended to remove a physical and psychological barrier to pedestrian movement. It can also indicate to drivers that pedestrians are not confined to the footway and that they can expect to encounter them in the whole of the street.

**Data must be collected before and after the reconstruction to a Shared Road[4]** because as we have explained previously, Shared Roads are rather a design guideline with multiple different ways of interpretation instead of a ready-to-use design which is implemented the same way in all projects. Thus we must admit that the findings for a specific project are not necessarily transferable to any other Shared Space. It can, however, be used as the basis for verifying and refining existing guidelines.

1. **A classical traffic survey** must be conducted counting the vehicular flow and the number of pedestrian crossings at different times of the survey period.
2. **The Road users** must be classified into pedestrians, bicycles and cars and tracked during their time inside the origin/destination measurement lines.
3. **Space usage** must be identified rather it is a commercial, Administrative, Government zone or Residential District.
4. **Speed distribution** is important indicator that investigates the speeds and flows of both the pedestrian and motor vehicle.
5. **Safety aspects** that focus on the interaction between and within motorized and non-motorized traffic, using indicators of time as objective and quantitative measure to reduce the severity of conflicts.

#### 5. HOW SHARED ROADS CAN BE USEFUL IN PROVIDING THE CONCEPT OF SUSTAINABILITY INSIDE CITIES?

Good quality living environments reduce stress and make life more pleasant through providing sufficient indoor and outdoor space with few personal hazards, minimum noise, a location close to family and friends and easy access to desired services,

recreation and facilities for safe participation for the different social activities. All those facts must have parameters and indicators to be measured, that what led to the concept of sustainability which in its main Concept is how to provide the needs of the present without compromising the ability of future generations to meet their own needs.



**Figures 1, 2:** All today habits and busy lives can make us forget that urban spaces and pavement can be more than a path along which to deliver between two points. We can enhance our perception to help in revitalize our town centers, boost economic performance, support regeneration and build community pride and social integration and interaction. The Sharing Roads allows having multi uses activities in the same space (vehicles road, cafe, play yard) but not at the same time except in some places not used by children.

**5.1 The Benefits and potentials of the shared roads that providing the sustainability:**

Sustainable development which is the a process which enables all people to realize their potential and improve their quality of life in ways which protect and balances the Environmental, Social and Economical parameters / issues.

**5.1.1 Environmental Benefits:**

1. **Improving the Air quality with** Reducing traffic congestion for vehicles; which is the main cause of the air pollution with high rates of greenhouse gases emissions caused from the incomplete combustion of vehicle exhaust gases, which in turn affect air quality and public health and ecological footprint in the end. Not only that but also that led to increase the temperature inside the center of the cities which known as the urban heat island effect phenomenon.
2. **Reducing the Noise pollution** which the temporary or permanent hearing loss is the best know health impact, although high noise levels are also known to be one of the critical stress factors that cause blood pressure, heart and respiratory rates, central nervous system and influence mental disorders and social pathologies.
3. **Reducing the Visual pollution** that caused from cars smug that attached to buildings' facade. And reduce the distribution of the suspended particulate matters that causes the foggy vision and increase the effect of the dust dome.
4. **Increasing the Greening spaces & Trees** providing vital effects :
  - Reducing the Air pollution and the Co& Co2 gases ratio in the air.
  - Air Quality can be improved through the use of trees, shrubs and turf. Leaves filter the air we breathe by removing dust and other particulates.
  - Trees and other vegetation can mitigate the urban heat island effect because they shade buildings, intercept solar radiation and cool the air by evapotranspiration. trees reduce evaporative emissions from vehicles and other fuel storage.
  - Finally trees and vegetation can help in reduce noise, which is highly valued in urban areas. They also provide shade from harmful ultraviolet radiation, particularly in open spaces.

**5.1.2 Social Benefits:**

1. Every street represents a balance between **movement** (the capacity to accommodate through traffic) and a sense of **place** (the quality which makes a street somewhere to visit and spend time in, rather than to pass through). Shared space is a way of enhancing a street's sense of place while maintaining its ability to accommodate vehicular movement.
2. **Increasing the social communication and connectivity** as a result of providing more spaces and locations close to family and friends. And easy access to desired services, recreation and facilities. For safe participation to the different social and leisure activities.
3. **Support town centre** regeneration by providing a high quality civic space in the town centre suitable for flexible uses. Particularly where there is a level surface that can allow the street to be used in different ways. For example, street cafes and the like may be present during the day, while at night the area occupied by daytime activities could be given over to

people visiting night-time entertainment venues. A Street could also host regular street markets or occasional events such as street theatre.

4. **Enhancing** livability and quality of life.
5. Death and injuries from motor vehicle accidents have become an increasingly significant component of all premature death and injuries in urban centers. The **shared roads increasing the ratio of Safety** with improving pedestrian movement by reducing the dominance of motor vehicles and determine a certain times for motor vehicle to use the shared roads and reduce the speed limit as well and encouraging drivers to behave more accommodatingly towards pedestrians. [1]
6. **Providing safe environment** for children to play and communicate.
7. Redevelop the link to have the feel of an urban square in which people will want to **spend time** but maintain bus movement in the town centre.

#### 5.1.3 Economic Benefits:

1. Reducing the risks caused by motor vehicles accidents and high speed. And increasing the participation of the new public space (provided by the shared road) users and the district inhabitants inside the city center commercial zone. That will increase the opportunity for enhancing the Economic Sector performance.
2. Increasing property values.

### 6. WHY THE GREATER CAIRO CITY NEEDS URBAN RESILIENCE STRATEGY?

Cairo According to the World Bank Report Consider One of the most crowded cities that suffering from lacking of public spaces which put pressure on land, services and increase settlement inside the city, that has a great impact on the social activities and the local economic performance.

Cairo downtown (city center) includes the central business district which set between the main squares of Cairo city - Ramses, Ataba, AbdulmonemRyad, Abdeen and El Tahrir on area of 88 hectares. And this area considers the most crowded district in Cairo. **Cairo city center suffers from many problems that affect livability and quality of life:**

1. High residential density in main existing agglomeration.
2. Rising traffic congestion in Cairo city center cause increasing of heat / GHG emissions and air pollution that have bad effects not only on the pedestrians or social activities contributors but also on the residents who lives inside city center.
3. The high land value of the city center prevents the urban designers and the governmental authorities from expanding or making use of already vacant sites for Public Spaces.
4. The public spaces of Cairo city center attracted many informal commercial activities such as street vendors; that affect the commercial performance and reducing the pedestrian walk side and plazas that prevent them from participation to the different social and leisure activities and even walk.(see figure 4)
5. Many of the motor vehicle streets/ roads not used efficiently which is the main reason for the High traffic congestion-the street/ road can be five lanes but only just three or two lanes are used. According to the occupation of two lanes for parking and may be another one or two for the Invasion of the street vendors. That indicates the essential need for management strategy that not only reducing the traffic congestion but also to make space defragmentation to provide safe and fare share for every use without making any conflicts that cause fatal consequences.(see figure 5)

#### 6.1 The Main Objectives for applying a resilience strategy to Cairo city center:

1. Achieving all the (Environmental, Social and economical) benefits that the shared roads provides.
2. Increase safely public open spaces area within the city.
3. Reduce the traffic congestion and its consequences'.
4. Reduce the pollution ratio in city center with increasing friendly environmental activities.
5. Increasing the social connectivity and communications and the opportunity for enhancing the economic sector performance.

#### 6.2 Using the SWOT analysis to evaluate the Public spaces in Cairo city center:

There are many opportunities can be achieved with applying a resilience strategy depending on the concept of shared road. ThisSWOT analysis depends on the observations were noticed last summer by several times life visits to the greater Cairo city center public spaces, the Main issues of evaluation were:

1. Public transportation and the infrastructure.
2. The Proposed expand public spaces.
3. The urban structure and the current public spaces.

#### The conclusion of the SWOT analysis showed the follows:

1. As a result of the low area of public spaces the green areas were too low also.
2. The squares and plazas were mainly designed for Motor vehicles.
3. The pedestrian pathways are new to the Cairo city center, some few local streets were converted to share roads, but that wasn't efficient enough to respond the need for the public spaces.
4. Unusual spaces were converted to be used as public spaces, like the wide pavements of the bridges along the river Nile from city centre to west areas of the city, the pedestrian use these pavements as a terrace providing a panoramic views of Cairo city centers, with street food, drinks vendors who offers chairs for money.

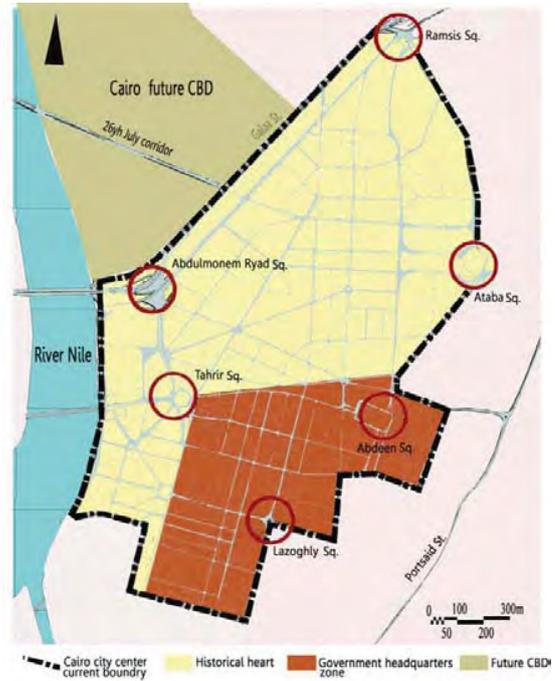
- Most of the public spaces became more complicated as main public spaces with other minor spaces mostly semi-private or private spaces.



**Figures 4:** Traffic Congestion and informal commercial Invasion forcing the pedestrian to walk in the street-Typical scene in city center roads.



**Figures 5:** Traffic Congestion according to reducing the street width with car parking in its both sides.



**Figure 3:** Cairo downtown (city center) includes the central business district which set between the main squares of Cairo city - Ramses, Ataba, Abdulmonem Ryad, Abdeen and El Tahrir on area of 88 hectares.

Table 1: The SWOT analysis to evaluate the current situation of the Public spaces in Cairo city center

	Strength	Weakness	Opportunities	Threats
<b>Public transportation and the infrastructure</b>	<p>Providing good public transport means connecting the city center public spaces to the rest of the city. Especially the underground train (Metro).</p> <p>Providing the city with an integrated infrastructure serving the public spaces is supporting the current urban roles of those public spaces.</p>	<p>Most of the public spaces in the city center were designed according to the concept of segregation between motor vehicle and pedestrian to meet the needs of motor vehicle. Streets and squares were mainly designed for motor vehicles.</p> <p>The inadequate of cars parking in the city centers is preventing wide sectors of society to use the public spaces.</p>	<p>The future governmental plans of the city center supported the services of the public spaces, such as offering new public transport lines to connect the main public spaces to the rest of the city. And using electric cars for reaching the new shared roads inside the city center.</p>	<p>High traffic congestion in Cairo city center and concentration of the central governmental/ and business facilities gives indication that it is very hard proposing to reduce the motor vehicle flow in city center.</p>

<p><b>The Proposed expand public spaces</b></p>	<p>There are various alternatives in case of converting number of streets to enlarge / expand the Public Spaces Whether to be shared roads or completely pedestrian streets.</p>	<p>The annual increasing rates of the land prices besides the inadequate of providing enough areas for the existing needs for public facilities like cars multi-story parking.</p>	<p>The existing plans of converting more tracks paths into pedestrian public spaces.</p> <p>The progress in the drilling and underground constructions support the possibility of offering more spaces for some land-uses like cars parking to be underground which will offer more spaces for public spaces.</p>	<p>The difficulty of providing safe and fare share for every use without making any conflicts.</p>
<p><b>The urban structure and the current public spaces.</b></p>	<p>Most of the city center public spaces enjoyed remarkable livable unique sites which considered as hubs for variant activities and services like the underground entrances, bus stations... etc.</p>	<p>The current landscape design, street furniture of the public spaces is not suitable for the current urban roles of those spaces.</p> <p>Can't Act several variant activities at the same public space smoothly and efficiently.</p>	<p>The possibility of using new architectural urban concepts to offer new extra spaces like using public institutes roofs and many other ideas.</p> <p>The new growing urban roles will help to evaluate the future plans to offer innovative public spaces.</p>	<p>The growth of the future need of the common land-uses of the city center may affect the current public spaces to be reduced.</p>

### 6.3 Assessing existing Shared Roads experiments inside Cairo Downtown:

Cairo Downtown already has a few pedestrian streets such as Al-Alfi, Al-Borsa and Al – Mu’izz streets, and there are already proposals to apply shared roads and places vision to more downtown streets. The following tables will present three experiments for the shared road inside Cairo downtown; showing the advantages and disadvantages to each of them, to stand on the main obstructs that those experiments are facing and draw the main guidelines for applying the shared roads in correct and efficient way:

Table 2: Al-Alfi, Al-Borsa and Al – Mu’izz street analysis and Assessment, Downtown, Cairo city center.

#### Al – ALFI Street:

Overview Description	Assessment
<p>Al-Alfi Street located in the northern boundary of Cairo city center, within the Historical Khedivial Cairo Zone. It was originally designed as a vehicles and automotive street, it is (12-15 m) in width and (approx. 200 m) long, and it extends from Orabi square on the west to Al- Azbakya garden on the east. 12 years ago a part of this street (approx. 100 m) converted into a pedestrian street, it includes various entertainment activities of fast food, Cafes and Cabarets.</p> <p>The Flooring and Pavement material is manly of concrete. Seats are provided and distributed along sides with rows of shrubs, and the Cafes furniture extend to outdoor without specific order.</p>	<ul style="list-style-type: none"> <li>▪ The Street is ineffective because it locates far distance from the commercial area (on the northern boundary of the city center) and the lack of adequate commercial services, and palaces on a small number of fast food restaurants, which mainly serve its surrounding area at day time.</li> <li>▪ The lack of proper social atmosphere due to the presence of casinos and cabarets which attracts limited categories of adults, that Prevents families with children from participating in social activities at night. Moreover the number of seats is insufficient, poor lighting in the night and less security.</li> </ul>

Figures 6: Converting some downtown streets into pedestrian promenades was promising idea. The Cairo governorate support it time ago to reduce pollution and traffic congestion in the city centre. This resulted to have wide and safe pedestrian social space on sections of Al-Alfi and Saray Al-Azbakiya streets. However nowadays the removal of many unused fixed element can provide extra spaces. Moreover changing some shops uses and activities can provide more social interaction. Al-Alfi Street.



#### Al – BORSA Street:

Overview Description	Assessment
<p>Al-Borsa Street located in the heart of Cairo downtown, within the Historical Khedivial Cairo Zone. The area known as Al-Borsa, named after the Egypt’s stock exchange building located at its heart, consists of a network of pedestrian streets. It has plethora of outdoor cafes that consider a popular respite from the noise and traffic of the city. It was originally designed as a vehicles and automotive street, it is (8-10 m) in width and (100-200 m) long.</p> <p>The Flooring and Pavement material is dark raw basalt interlocked tiling and concrete tiling in some areas, Seats are not provided but specific places for car parking are determined, and the Cafes furniture</p>	<p>Although there are many cafes and which represent a suitable atmosphere for old men and youth to participate in many social, cultural and political activities, but it is not suitable for children or women to engage in any social activities in such a place according to our traditions and habits.</p>

extend to outdoor without specific order. And There are direct and indirect lighting units are well distributed but still not sufficient for night social activities.



Figures7: The area around the stock exchange is congested with cafes making lively scene especially at night time. Moreover private car parking and restricted roles in managing the time between vehicle and pedestrian make it safe to socialize in this area. Different shots to Al-Borsa street, Downtown, Cairo.

### Al – MU’IZZ Street:

Overview Description	Assessment
<p>Al-Mu’izz Street located in the western Side of Cairo city center, within the Historical Medieval Cairo Zone (UNESCO World Heritage Site).the street was designed as the spine of the gated city (one kilometer long is adomed with monuments of different historic periods), al-Mu’izz street is a typical medieval street that had been developed along a thousand years, narrow in section, with spontaneous varied widths and heights, creating interesting vistas and views along its path. It was originally designed for pedestrians, light vehicles and carriages (horses and cattle), the narrow and sinuous street has been transformed into an over-populated typical residential/commercial district due to the change in demographic characteristics of its users.</p> <p>Main activities – besides residential – are Specialized crafts and small trades of jewelry, copper, leather, clothes, herbs; each activity located in a specific section of the street.</p> <p>The newly flooring material is dark raw basalt interlocked tiling, and light stone cladding for pavements. There are a few seats in front of the monuments in the wider shop-free sectors of the street. There are direct and indirect lighting units are well distributed. [6]</p>	<p>Although Al-Mu’izz Street is a very good example for a pedestrian street with its entire commercial, Social and touristic attraction, and its accessibility (near location) to many of public transportation (Underground Metro, Buses, Taxis...etc). And although it had been prepared to be shared road/space and provided with many facilities (Fixed and movable) such as Cars barriers, Signs and even gates on the main entrances and exits. It is unfortunately suffer from neglection, not only to the regulations and roles that organize the street using (pedestrian – vehicle)-(as Loading and emptying goods became problematic; many customers suffer have to make an effort in reaching some destinations; moreover ambulances and fire brigades cannot reach some off-streets easily and number of passing bikes are considered to be dangerous) but also from the insufficient paving material (rough basalt) which causing walking difficulties. Also the lack of regular street cleaning and litter clearance make unweelcome message to the passerby and users and even to make any social activities.</p>



Figures 8: the Egyptian government carried out extensive renovations to the historical buildings, modern buildings, paving, and sewerage to turn the street into an "open air museum". On April 24, 2008, Al-Mu'izz Street was rededicated as a pedestrian only zone between 8:00 am and 11:00 pm; and cargo traffic is allowed outside of these hours. Different shots to Al-Mu'izz street, Historical medieval Cairo, Cairo.

### The main Lessons that we can conclude from these experiments, to promote efficiency to the Shared roads/ spaces:

1. Small design changes can make a big difference to the attractiveness of a space and the way it is approached and used, and can help reinforce the local vision for the kind of place that want to be created.
2. The main Target of designing Shared/ Public spaces/roads is to create a space where people of all ages and abilities can work, rest, relax and play. Not for limited categories or ages otherwise it is not achieve its goal of Social interaction.
3. The quality of the walking environment is a main factor in people's shopping choices, and encourages them to spend more time with wider range of shops, than visitors arriving by cars, buses or bikes.
4. One of things that can limit creative and exciting use of public spaces is the challenge of managing and maintaining them. Hence active management of public spaces is vital to their usability and people's enjoyment of them, and can deter anti-social behavior. Regular maintenance will be required, including regular street cleaning and litter clearance, emptying litter bins, removing graffiti, fly-posting and clearing trade waste and any fly-tipping. All public space users

have a role in maintaining it. For example community and business engagement and creative design, choice of materials and pre-emptive surface treatment of these, can minimize such problems and ease remedial action, and it can also help to get everyone involved in reporting and problems and get agreement on whose job it will be to take remedial action when needed.

5. The space must be measured in relation to flows, so it can contain all the users and passerby social activities.

## 7. CONCLUSION

1. The study found that Shared Spaces does not offer a ready recipe for the organization, design and equipment of public space. Individual problem situations demand tailored solutions. Nevertheless, there are a number of general basic principles for the design of Public space and shared roads. To promote socially conscious behavior, the design should be based on local characteristics and one should use as few as possible traffic engineering and regulation elements. Priority signals should be replaced by human interaction.
2. Possible causal explanations could offer simple solution for the conflicts that may happen when we make a preliminary resilience strategy. Design participation is essential for this kind of project that required many public auditing be made before preceding the specialists meeting to finalize the conceptual strategy and the detailed action plan.
3. Applying the resilience strategy to the Cairo city center depending on the concept of shared roads helped in:
  - Conserving city center's land value with expanding and Increasing of the public spaces with providing a high quality civic space that is suitable for flexible uses.
  - Improving the Air quality according to the traffic congestion Reducing. That provided also safe social and commercial environment.
  - Cairo has the highest concentration of historical sites in the entire world with supporting the shared road concept and many and certain zones Cairo can be open walk able museum. That will encourage the Tourism and will affect positively on the Economic Sector.
  - With encouraging the public transportation and enhancing/ upgrading its facilities inside city center that will reduce the using of the private cars and that lead to reduce the traffic congestion.

## REFERENCES

- [1] Clarke, E: *Shared Space - the alternative approach to calming traffic*. In: Traffic Engineering Control, vol. 47, no.8, pp. 290–292, 2006.
- [2] Kaparias, I , Bell, M , Chan, C , Biagioli, T , Kennedy, J: *Investigating The Willingness of Drivers to Share Space With Pedestrians*. In: .Washington DC, 2011.
- [3] Schonauer, Robert ,Stubenschrott, Martin , Huang, Weinan , Rudloff, Christian , Fellendorf, Martin: *Modeling concepts for mixed traffic: Steps towards a microscopic simulation tool for shared space zones*. In: .Washington, 2012b.
- [4] Ismail, Karim ,Sayed, Tarek , Saunier, Nicolas: *Automated Analysis of Pedestrian-Vehicle*. In: Transportation Research Record: Journal of the Transportation Research Board, vol. 2198, no. -1, pp. 52–64, 2010.
- [5] Karndacharuk, A. , Wilson, D J , Tse, M.: *Shared space performance evaluation: quantitative analysis of preimplementation data*. In: .Auckland, 2011.
- [6] Abdel-Hadi, Aleya. , El-Nashar, Eman. , Safiaddin, Heba :*Pedestrian Street Life in Historic Cairo- Authenticity and Counterfeit*. In: international IAPS-CSBE& HOUSING Networks, 2009.
- [7] Ghoneem, Mahmoud Y. ,Elewa, Ahmed : *The Changes in the urban roles of the public spaces and its impact on the future plans of Great cities centers*. In: 1<sup>st</sup> International Conference on Architecture & Urban Design, 2012.

# ‘Urban Legend’ of *Wakaf* Cemeteries at Jalan Pangeran Antasari and Kemang

Feby Hendola Kaluara

Faculty of Engineering  
University of Indonesia, Depok 16424  
Tel : (021) 7270011 ext 51. Fax : (021) 7270077  
E-mail : febyhk@gmail.com

## ABSTRACT

This writing is a result of my analysis on seven *wakaf* cemeteries at Jalan Pangeran Antasari and Kemang. These cemeteries are facing some new developments: flyover and grandeur commercial place. Knowing there must be conflicts between people who retain them and developer who is tempted by the land, I try to look beyond functional matter of the *wakaf* cemeteries by questioning their existence for the people around them. I try to look what the cemeteries stood up for by searching the ‘urban legend’ that spreads around them and observing the spatial relation between them and the people. Eventually, this paper tries to explain that the *wakaf* cemeteries have special meaning to be looked for before massive developments annihilating them.

## Keywords

*Urban legend, wakaf cemetery, development, local culture*

## INTRODUCTION

Naming the street with one figure’s name is very common in a city, including Jakarta. However, some name is not known as important as figures in short of heroes or stakeholders. Some name, such as Haji Muhi or Haji Thalib, is a name without any big historical background. At the same time, near those streets, there are also *wakaf* cemeteries—a benefaction land for burial—which were mostly given by the important people: *Haji(s)*. “*Haji*” and “*wakaf*” are actually Islamic terms. In Islam tradition, there is a certain rule for wealthy people to give charity for poor people. One of the ways is to “*wakaf*”—to endow something “...which is dedicated in perpetuity to some pious or charitable cause” [1]. Usually the *wakaf* land’s status cannot be changed. It shall be maintained as what and how the giver wanted. Despite the fact about the land is potentially contested, some cemetery has even its own legend and sacred place no matter how modern Jakarta develops itself. This phenomenon also happens near Jalan Pangeran Antasari, South Jakarta. Facing the big development of Blok M- Jalan Pangeran Antasari flyover and the rise of commercial places, some *wakaf* cemeteries exist with their own entity. Some developer might see the cemeteries as potential property while the people keep maintaining it. Their status are in between—whether they can be functionally useful for the development if it was demolished or they can be something that makes the development restrained.

This writing is not trying to answer which one of the cemeteries’ status is the best. The fact that the *wakaf* cemeteries striving by the people living near it leads me to some questions: “what is actually the *wakaf* cemetery stood up for? Why is it so defended by the people?” By answering the question, it will lead us, especially urban experts, to know beyond functional matter of the cemetery.

Basically what I did to answer the question is observing seven *wakaf* cemeteries near Jalan Pangeran Antasari to Kemang. These seven cemeteries are currently facing the development of one of the biggest superblocs in south Jakarta: Kemang Village. At the same time there are also flyover project hovering Jalan Pangeran Antasari and the fact that Kemang itself was already gentrified by expats since long ago.

For this paper, I came to the cemeteries and tried to know how the people treat them (physically and non-physically) and if there was any ‘urban legend’ that had spread around them. What I mean ‘urban legend’ in here is a story, which is always told and preserved by the people about the cemetery without knowing whether it is authentically right or not, including the story of *haji* that gave them the land. Knowing the ‘urban legend’ of the cemetery would inform me what the cemetery represents for the people.

However, I would not report how the society reacts to the cemeteries in details. Instead of telling what they do when one of them passed away or how and why they pilgrimage, I aligned this writing by focusing on the spatial relations between the cemeteries and the people, the exclusivity of the cemeteries, and the story of *hajis*.

## ‘URBAN LEGEND’?

Before narrating the trip, I would like to explain about ‘urban legend’ first and why I use this term for the case. This term was probably first used (or at least famously used) by an American folklorist named Jan Harold Brunvand. In the introduction of *Big Book of Urban Legends*, Brunvand wrote, “Urban legends...are true stories that are too good to be true, and they are always said to have happened to a Friend of a Friend (or FOAF) [2].” In other words, ‘urban legend’, in Brunvand’s conception, is a kind of story whose main point is not the truth of it but how it is used by people to thrill another people.

Of course, Brunvand’s ‘urban legend’ represents urban life, especially in America, since many of his stories use modern phenomenon, such as automobiles, pets, sex scandals, etc., as the background or the topic. However, some ‘urban legend’ is actually ‘old’ legend which is told from one generation to another generation [3]. In other words, what changes in ‘urban legend’ from the old one to the new one is the context of time. Although the message of the story is still the same but the sense of ‘present’ is needed so it can be felt as something that happens presently near the people.

At the other hand, Koven in *Film, Folklore, and Urban Legends* also emphasized that ‘urban legend’ showed in films and other popular culture had some “motif spotting”—motifs or types of traditional narration which appears in popular films and television [4]. This also means that popular culture is important to look at to know what (urban) people believe or how they maintain their tradition in urban lifestyle. This also happens in Indonesia where many cinemas keep on showing horror movies. One of the most famous horror Indonesian movies is *Hantu Jeruk Purut*—“The Ghost of Jeruk Purut” (2006). Using Jeruk Purut Cemetery located at South of Jakarta as the background, *Hantu Jeruk Purut* is famously known with the character of headless priest. At the beginning of the movie some teenagers challenged themselves to explore the cemetery. Feeling disturbed, the headless priest sadistically killed them. At the end, the movie tried to show its message: do not disturb the ghost in the cemetery. I guess this is not the only movie which shows that kind of message, naming *Sundel Bolong* (1981), *Perjanjian di Malam Keramat* (1991), *Tusuk Jelangkung* (2003), *Kereta Hantu Manggarai* (2008), and many more which approximately show the same message no matter how old the story is—that the dead may not be disturbed and people should respect them or the dead may not rest in peace before they take revenge.

From the explanation above I can conclude that ‘urban legend’ is an unverifiable story that probably came from the past whose message is maintained by using contemporary media, including popular culture. Although popular culture maybe interesting to be seen deeper but in this writing I have to explore ‘urban legend’ in realm of urban space. Thus, the ‘media’ to maintain the story is represented in space where people usually refer to when they talk about it. Cemetery is, of course, the most popular place as the setting of the story. Since ‘urban legend’ is also presented in contemporary stuff, to observe it, then, is to see what presently has happened in the cemeteries and how they maintain what has become history. So, ‘urban legend’ in this paper is not about seeing what exactly the truth of the story is. Here, ‘urban legend’ is used to know beyond the place where the story emerged. This is a tool to gather information about what and how people believe in their urban life. It is important to be observed in urban design and planning realm because it also impacts on the urban space, including cemetery.

To know ‘urban legend’ of a place is also to know how the people make relation to the place itself from time to time. By walking through the seven cemeteries, I could get ‘urban legend’ which was told by people nearby. In other words I asked people what they think about the cemeteries and how the images of the cemeteries affect their everyday life. Some of them used and hid the cemeteries at the same time; some of them considered the cemeteries as what they belong; some of them thought the cemeteries was important because their ancestors buried there. I assume that ‘urban legend’ in this case is not only about the maintenance of some stories about cemetery but also the continuity of traditions and history of ancestors. Past, in here, is consequential.

## THE ‘UNSEEN’ CEMETERY

After knowing what ‘urban legend’ was, I was interested to observe some cemetery in Jakarta. It was because the frightening image appearing on the cemetery made me want to know the story about it –whether if it had impacted the cemetery as the space of the dead or not. I also wanted to know what the role of the cemetery in the middle of the rush of Jakarta modern living was. The seven cemeteries at Jalan Pangeran Antasari and Kemang became my choice because they were facing the hustle of new development.



Figure 1: The Seven *Wakaf* Cemeteries at Jalan Pangeran Antasari and Kemang

So I started my trip from Blok M terminal to Jalan Pangeran Antasari. It was a very bright day to take my steps on. Sadly, the sun could not shine fully on that long road because of hovering flyover. It was not yet ready but its shadow already darkened the space below it. I took a left-turn after seeing the district office. After walking for a couple of meters I found a junction. I was counting on my maps on the phone since I had not been at the destination. “Makam Bank” was written on the map and according to it I had to turn right to get to the cemetery.

Makam Bank was located next to an elementary school and surrounded by houses. Like other six cemeteries, Makam Bank had physical boundary: brick wall about 150 meters surrounding the area. From the outside we may not realize there is a cemetery behind that wall. All we could see were just top of trees. But this isolation did not mean that the people living there did not take care of it. There was a *gubuk*—a very simple small shelter from wood—for cemetery guardians to take a sit or a break so they could get comfort while doing their job. At the other part there was also a box with words written on it: “SUMBANGAN UNTUK MAKAM WAKAF” – “CHARITY FOR THE CEMETERY”. So I warded my hypothesis that the cemetery was not considered as something important by the people. The wall was not a mere solitary cover to separate the living with the dead.

I continued my journey to another cemetery nearest Makam Bank: Makam Kemang Raya. It would take a long walk that I decided to stop a bus. About five minutes had been spent to reach the cemetery with bus but punctiliousness was needed because there was no specific sign that marked it, except a black small gate. There were two men with their vendors in front of the gate. According to them the gate could not be opened and the only way to reach the cemetery was to get in from another gate. So I brought myself to another way to find the gate.

The other gate was behind one of the most famous restaurants at Kemang. The smell of food from the kitchen was lingering when I brought my step into the cemetery. It was still look alike Makam Kemang which had only trees and burials. But at one part of it there was a small building which was clean and with proper rooftop. Apparently it was the sacred burial. I asked a man nearby whose burial was that. He did not know that but was pretty sure it was considered very important by people around there and suggested me to not ‘disturb’ it.

After wandering for a while at Makam Kemang Raya, I ran on my trip chronologically to Makam Kemang Selatan, Makam Haji Thalib, Makam Bunga Cempaka 3, Makam Bunga Cempaka 1, and Makam Bunga Cempaka 2. Although Makam kemang Selatan and Makam Bunga Cempaka 1 were located near busy street, both of them were not differently treated like the other cemeteries: they were surrounded by wall.

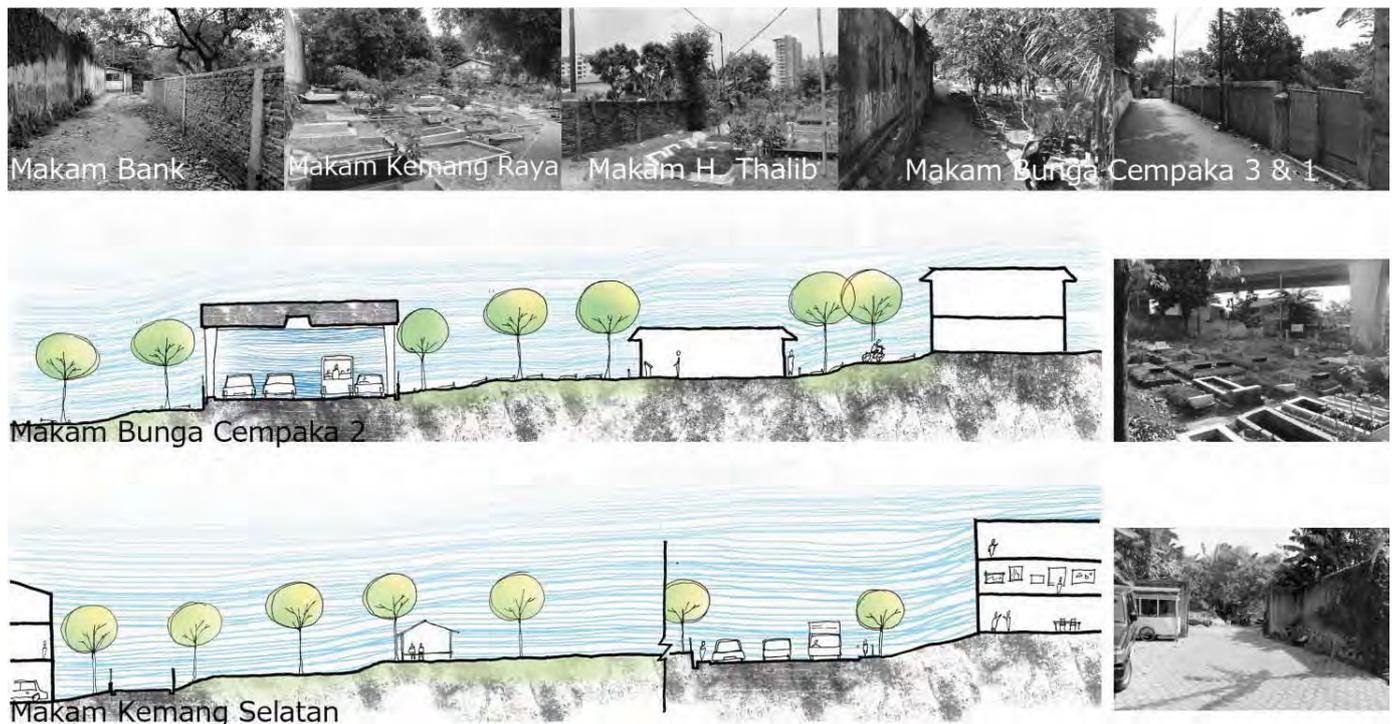


Figure 2: Surrounding by the Wall

The tendency to make a clear separation between space of the dead and space of the alive was always be there. However, people could not actually be apart with death itself. They still had an obligation to come to the cemeteries to pilgrimage or pray at the sacred burial. Thus, people surrounding the cemeteries tended to consider them as meaningful places.

At the same time, looking at how the burials set up, the cemeteries were not designed as something significant or monumental. They mainly emplaced spontaneously so that the orientation was not the same. There was no landmark or sculpture marking the place either. Makam Kemang Raya was the only *wakaf* cemetery I observed that had a specially threaten building for the ancestors. Still, a small simple building that looked like a house did not make any significant physical statement for its surrounding.

The seven cemeteries were also surrounded by settlements and commercials. It pointed out a sense of closeness between the dead and the alive. Paradoxically, the people seemed did not interest to make the cemeteries grandeur or physically standing out, yet they knew the cemeteries were important on behalf of their past time and cannot be separated with their everyday life.

## THE EXCLUSION

The absence of landmark could not obviate the distinction between space of the dead and space of the alive. Regarding to what I have explained before, Michelle Foucault once wrote about his conception of 'other space' that he called 'heterotopia', "Everyone can enter into these heterotopic sites, but in fact that is only an illusion—we think we enter where we are, by the very fact that we enter, excluded [5]". Any cemetery always pushes us to do certain gesture which makes us feeling excluded—instead of feeling like entering public space, coming into a cemetery is more like going into a private space. However, at the seven cemeteries, the sense of exclusion did not only make the visitor, especially an outsider, do certain gestures. It was not only about coming into space that had different nuance from its surrounding. It was more like entering a place that guarded by its surrounding. Unless we really familiar with its surrounding or people that lived around it, we would feel the exclusion.

The sense of exclusion assumedly came up because of the activity around the cemeteries. Some of the cemeteries were used for informal gathering and social interactions, such as Makam Bunga Cempaka 2 and 3. The others were not used like that but not far from it there were people gathering around. The cemeteries were indirectly guarded by them. Even though we knew the cemeteries could be entered easily but an urge to ask permission would usually come up.

The seven *wakaf* cemeteries, not like formal cemetery, were more private. They were only used for certain (dead) people. Makam Bunga Cempaka 1, Makam Bunga Cempaka 2 and Makam Bunga Cempaka 3 were managed by one foundation named "Yayasan Bunga Cempaka". So were Makam Haji Thalib (managed by Yayasan Fatahillah) and Makam Kemang Selatan (managed by Yayasan Al-Ihsan). Those five cemeteries could only be used by the foundation members. Makam Bunga Cempaka 1 even had more specific rule: only inheritors allow to be buried in there. That was the same rule with Makam Kemang Raya's. Meanwhile, Makam Bank was also used only for certain people although it was not managed in one foundation. Basically the people nearby who managed it. They also paid some charity for it. In other words the connection between the cemetery and the people could be long lasting because of the sense of belonging. Hence the seven cemeteries did not only exclude other 'community' or outsiders but were also maintained to keep what belonged to the community.

In an interview, the headmaster of Madrasah Ibtidaiyah Al-Ihsan gave his opinion about the excluding rule of the *wakaf* cemeteries, "if I give you something, will you share it freely to other people?" After explaining that *wakaf* land was usually given by *haji* as the important figure for people around him, he mentioned that the cemetery could only be used by people nearby as what the *haji* had wanted. Of course, there was an exception for indigents who had no relatives.

The exclusivity that people originally from near the cemeteries had would restrict their 'movement'. Because of the land that was given for their future sake, the people tend to live long time nearby or go back to where they come from after wandering outside their homeland. Moreover, most foundations facilitated their 'native' members with education and house for orphans. The price for the burials was also cheaper than public cemetery's so that the people felt helped by the foundations. This also affects the hierarchy of the society, which was mostly lead by the inheritors of land giver—the *hajis*.



## HAJI(S): LEGENDS ON THEIR OWN WAYS

So who are these *hajis*? “*Haji*” is the Indonesian word of “*Hajj*” which means “one who has made the pilgrimage to the holy city (Mecca)” as accomplishment of the fifth pillars of Islam [6]. In this case, *haji* is not a mere title but also a person that had taken important roles at the past and had specially been known for his abroad knowledge. Mostly they had been rich so that they easily gave their land for public facility, including cemetery. There were several *haji*'s names which were mentioned in my interview with some ‘caretaker’ of Makam Haji Thalib. One of them said that in 1970s Haji Abdul Majid gave his land, including the land for the cemetery and the street near it. At the other part, the head of Yayasan Al-Ihsan said that Makam Haji Thalib was given by Haji Kholid who was very knowledgeable. So many names of *hajis*, people nearby did not really know who they were and which one gave the land. But the head of the foundation was actually keeping the picture of Haji Kholid itself since the *haji* himself was his father. He also said that the students who had been taught by Haji Kholid often did pilgrimage to the cemetery and he also encouraged his followers to do the same. Which cemetery to be came in exactly –makam Haji Thalib or Makam Kemang Selatan that was near it too? I don't know for sure due my lack of time for this observation.

Meanwhile, at Makam Kemang Raya head of the neighborhood nearby said the sacred burial belonged to a Syekh—an Arabic term meaning “leader”[7]. The Syekh was his ancestor. He believed the Syekh's spirit would protect the neighborhood. Thus, people kept on coming and praying at the sacred burial before celebrating some events, such as wedding. But Syekh himself was not really famous. Even head of the neighborhood's son did not know his exact name. Though, he warned me to be respect to his burial.



Figure 4: The Sacred Burial at Makam Kemang Raya (left) and Activities around the Cemeteries (middle and right)

Presently, new generation did not know for sure who Haji Kholid or Syekh were. They knew there was someone who once owned the land and generously gave it for people's good. But some of them still do the tradition of pilgrimage, not in memorizing what the *hajis* had done, but more like to respect the spirit whom they believed could protect them. Indirectly they saw the burials as entities that connect them to God yet it became their precious to be kept on. They also became the reason to restrain the land from developers. By showing the legal letter, which told that the land was given by the hajis, people knew the developers could not do anything to grab it.

It seemed *hajis* (and syekhs) were indeed infamous legends that had their own ways to be known. One of them was giving some space that can be used and maintained by people to pray for them. As there were plenty of foundations establishing public and education facility, endowing some land became a way that should be emulated. And this way, I believe, would be done from one generation to generation.

## NO CESSATION FOR WAKAF CEMETERY

Seeing through the ‘urban legend’ of the seven cemeteries made us now that even a simple search like that can collect much information about the existence of *wakaf* cemetery:

1. The ‘unseen’ part of the cemeteries telling us how people tried to make a clear distinction yet they cannot live apart of it. The cemetery is still connected with their everyday life. They know it, walk through it, maintain it, and even use it for gathering. The wall then is just an announcement to separate which space is for the dead. But it only happens to people who live around it. For outsider, the wall is clearly a statement to make exclusion.

2. Generally, *wakaf* cemetery is usually maintained because of the rule in Islam restrict them to do so. Looking back on the observation, this rule eventually made the people consider it as something that belong to them. The *wakaf* cemeteries are stood up by the people in a sense to maintain their identity. Its entity became a statement to exclude whomever that did not belong there. At the same time, some burial is believed as the elongation from God so that it can be the center of blessings. That is also why the people defend it. Community needs it to maintain what they think that belongs to them. But this conclusion also has weakness because ironically not all of the people surrounding the *wakaf* cemetery intentionally pray or pilgrimage. I might say it is an indication of minority struggling which only some community still tries to retain what they have. Kemang itself is used to be (or still be) lived by many Betawis [7] who mostly believe in Islam. This fact probably impacts the way of the people to treat death since Betawi culture is more concerned in taking care of the dead than of a new born baby [8].
3. The foundations take important role in maintaining and keeping the *wakaf* cemeteries. This is not only by taking care of the cemeteries but also by giving the people education about their religion which can give them knowledge about *wakaf*. At the same time, the people may not know every personal of the *hajis* but they know that being a *haji* is good. The foundations can give a kind of opportunity for the people to know more about *haji*. Hence, the 'urban legend' of *haji* can be well spread.

The *wakaf* cemetery cannot be said as a civic space—in term of public space where people can come together to discuss their idea, like Agora in Ancient Greek. Nevertheless, it actually accommodates public activities. It is the extension of the community to preserve their past and to develop its tradition. If it works well then it can be the characteristic of the community. Therefore the big development, such as Jalan Pangeran Antasari Flyover and Kemang Village, cannot abruptly cease them to exist.

What I have done is just first step to take notice about one of urban phenomenon in Jakarta. There are still many more things on *wakaf* cemetery to be observed to enrich the study of urban planning and design; such as how *wakaf* cemetery can be valued as a property of the people or how *wakaf* cemetery impact the city. In other words, further study is highly recommended to do.

## ACKNOWLEDGMENT

Work on this paper was supported by Department of Architecture, University of Indonesia. The author thank Evawani Ellisa and Herlily for comments on earlier draft of this writing; and Amri Mahbub Al Fathon for discussions that encouraged the idea of it.

## REFERENCES

- [1] S. A. Nigosian, *Islam: Its History, Teaching, and Practices* (Book Style). Bloomington: Indiana University Press, 2004, pp. 89.
- [2] R. L. Fleming, R. F. Boyd, Jr, *The Big Book of Urban Legends* (Book Style). New York: Paradox Press, 1995, pp. 7.
- [3] *Ibid.*
- [4] M. J. Koven, *Film, Folklore, and Urban Legends* (Book Style). Lanham: Scarecrow Press, Inc., 2008, pp. 3.
- [5] M. Foucault, "Of Other Spaces" (in French), *Mouvement Continuité*, 1984.
- [6] S. A. Nigosian, *Op. Cit.*, pp. 112.
- [7] G. Tjahjono, "Reviving the Betawi Tradition: The Case of Setu Babakan, Indonesia" in *Traditional Dwellings and Settlements Revive*, vol. 15, no. 1, pp. 59 – 71, 2003.
- [8] <http://staff.blog.ui.ac.id/syam-mb/2009/05/18/siapa-dan-darimanakah-orang-betawi/>, accessed on February 10, 2013.

## Women's Space of Activities in Slum Areas: Territories and Negotiation

Nur Fatina Risinda<sup>a</sup>

Department Architecture, Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail : indarisinda@gmail.com

### ABSTRACT

As part of society, women who lives in city's slum areas, usually didn't get much attention about their existence. When we talk about their roles in slum areas, actually these women have three roles. The triple roles is reproductive role (domestic role), as they should do the housekeeping and take care of family; productive role, as primary or secondary income-earners to help her husband; and social role in community management (Moser, 1988; 1993, cited in Miraftab, 1995). Women in slum areas are special because she must live under limited resources and bad condition of settlement. They must face the family structure too, as in system patriarchy in family, man is the dominant one. This affected their own space to do all their activity. But this women still can use their space effectively and efficiently. They even can merge the boundary of their space very naturally. So with qualitative approach, ethnographic and mental map method, this research want to figure out their process of making this space, and how this women make interaction.

### Keywords

*Women, slums, space of activities, territory, negotiation*

### 1. BACKGROUND

Slum areas is one type of settlement that usually exist in big cities or even in suburban areas that had been caused by city's unpreparedness to accommodate the need of settlements since the population is getting bigger because of urbanization [1]. Slum areas has definition as overcrowding, poor or informal housing, inadequate access to safe water and sanitation, and insecurity of tenure [2]. But from this definition, there is a tendency to see the slum areas based only on its physical condition, whereas actually there is a lot of events and actors that involve, such as residents, merchants, children, local authorities, men, and of course women. Women become an important topic as one point of view to see and understand the slum areas, especially from gender view. This is not only because women are part of the society, but also because there is many artifacts of women's activities, starts from inside their houses to the outside, the public areas.

One evidence that can prove us that women has important roles in slum areas is an article that tell us the story about women that trying to protect their house from eviction and she's got beaten because of that [3]. But Miraftab (1995) said that sometimes women's condition in slum areas and the importance of their house as their survival place usually being forgotten [4]. That is why sometimes there is misconception of the government, usually in developing countries, to make rules or development that actually did not match with what women really need [5].

This happen too with the space that women use. Spain (1992) said that there is gender dimension in space that society made, especially in patriarchy culture which said that women already had their own roles and it is a domestic roles, childbearing and do the house keeping [6]. This make women be gendered as someone that usually at home, whereas outside the house or public space is men's space (masculine), because men is the one who work and find the resources [7]. This will be different with women who lives in slum areas and lives under bad economy condition.

Suparlan (1996) said that slum areas reflect the people who live there [8]. In this case that is the poor people. Poverty made women that live in slum areas should face the truth that their roles not only inside their house. Moser (1987) said that actually women in slum areas have three roles, not only do the activities relate to domestic or household tasks associated with children and family (reproductive), but because their husband's wages can afford their daily needs, these women should work to help her husband (productive), at the same time, this women have responsibility to take care the society too (community management) [9].

Here comes the conflict between the roles that women have, that makes women only can stay inside the slum areas, whereas they should face the limited resources and space there [10][11]. These women have their roles and activities, and this needs spaces. Where slum areas have only a limited space, it shows us that there must be another person who needs the space too, in this case that is the men or their husbands. So when there is some kind of room division by gender, it considered as a constraint

for women to easily do their roles. But Ostergaard (1992) said that women will make adaptation so the limited space in slum areas can still become their space of activities. This space is an adjustment of their activities and their family, so they still can focus on their family too, and they can do it under pressure or bad condition [12].

If it said from gender view that space inside the house is feminine space and outside the house is masculine space, then when there is a liminal zone like the front door, or there is fusion of boundary of space, it must something happen between people who lives inside the house. This fusion can show the position in the family and members' own space requirement. This space requirement leads to a territory, or as Storey (2001) said as the area that claimed by one person, or group, or even big institution like country [13]. Territory is bounded space, so when there is a boundary fusion, it means one person meet the other and then have their on way to make that fusion, and so about these women's space of activity.

## 2. STATEMENT

The boundaries of women's space of activity related to the concept of gender between man and woman in the family, and about their position especially in patriarchy system [14]. But before that, there is difference about concept of sex, gender, and feminism. Sex is how to differentiate man and woman based on their vital organ, by their biological form. Gender is a stereotype that made by social and culture norms about personality, behavior, characteristic between man and women that usually determine society opinion about man and woman, and it then become a social control [15]. Feminism is a concept more like a politic view, because feminism involved 'taking sides', especially from women side, that there should be equality between women and men [16]. Gender view is more about rights and responsibilities of women than judging what women should be.

As women should live with men, in this context as wife and husband, there must be space requirement as what they need. When this condition met the limited resources and bad condition in slum areas, it then results a negotiation and agreement than finally forming their space territories. For women who live in slum areas, this negotiation can make them didn't look like as an exploitation here, that they are not passive [17] because negotiation process concerned of agreement decision or the position of the decision making in the process of forming the boundary and territory of space [18].

So, if these women in slum areas have needs of space for their activities and they can make it as what they need, either inside their house or even it can be expand from their house (feminine spaces) to their alley, street, or another public spaces (masculine spaces), then it means this women can blend their need of space with their husband's need of space. In this case is with negotiation. So from that, we can say that the slum areas maybe reflects these women's roles and activities so clearly.

To prove this statement, the main question is about the process of how these spaces are made. Then research start from questions like how is the relation of these women and their husband in their daily life, what is the need of space for these women and their husband, then relate it with space that already exist in slum areas. Then what kind of negotiation that happened there, how can it give influence to their need of space and existing. Of course researcher will observe who is the actor and the hierarchy of them (family structure), and when and where this negotiation usually takes place. What kind of territories were made as a result of this negotiation, how about the boundaries, is there any transformation or not, what kind of transformation that happened.

## 3. METHODE

For this research, researcher will use ethnographic methode, especially about space ethnography. Ethnography is one of methode to do qualitative research. The goal is to capture poeple's point of view about how they interact each other, and the point of view with their world and surrounding (like vision, hearing) [19]. Ethnography also capture people's social interaction, behaviour, and perception that happen within a group, organitation, or communities [20]. Ethnography is about learn from people, not to studying people [21]. There are nine points that should be learned from people : space, actor, activity, object, action events, time, goal, and feeling [22]. From this nine points, researcher try to look how informant, in this case is women, use and form their own space of activities.

The research start with finding the location, and then finding the informants, and then do the participant-observation with the informant to capture how they make and use their space, by follow the informant a whole day to watch their daily life. Informants are women who live in slum areas that will become the case studies. Approaching include the pre-observation with the informant, participant observation, and writing ethnographic field notes. In pre-observation.the reasercher will make a permission to the leader of neighborhood and then find the informant. With the informant, which is women who already married and their age around 25-60 years old, the researcher will introduced herself and this aim of research. The main point of

this pre-observation is asking permission to the informant that she will become researcher’s informant for at least 1 month and then the researcher will enter their activities to learn what really happen with their space while they do their activities.

After that, the researcher will do the participant observation. It means the researcher will take participation in informant’s daily life, build good relationship with the people in the setting, and observe everything that happen while do the observation [23]. With this methode, researcher hope to find how every palce in slum areas is really important for women, as slum areas is the place that this women already made for their activities.

#### 4. CASE STUDIES

Case studies location is in RT 11 and 15, RW 10, Kelurahan Bukit Duri, Kecamatan Tebet, Jakarta Selatan. From geographical context, this location have been chosen because it is the poorest area in the area RW 10, and it is located exactly in the Ciliwung riverbank, so when rain season come, this location get easily drown by flood (up to 2 meter or more). Because of it, the condition of this area is so bad, especially about sanitation and drainage. Most of the building here is not really have formal land tenure, because it is located in riverbank which is owned by government, so they just pay tax for the building, not for the land. RT 15 has 450 people, whereas RT 11 populated by 500 people, with the ratio of women and men is 50:50.

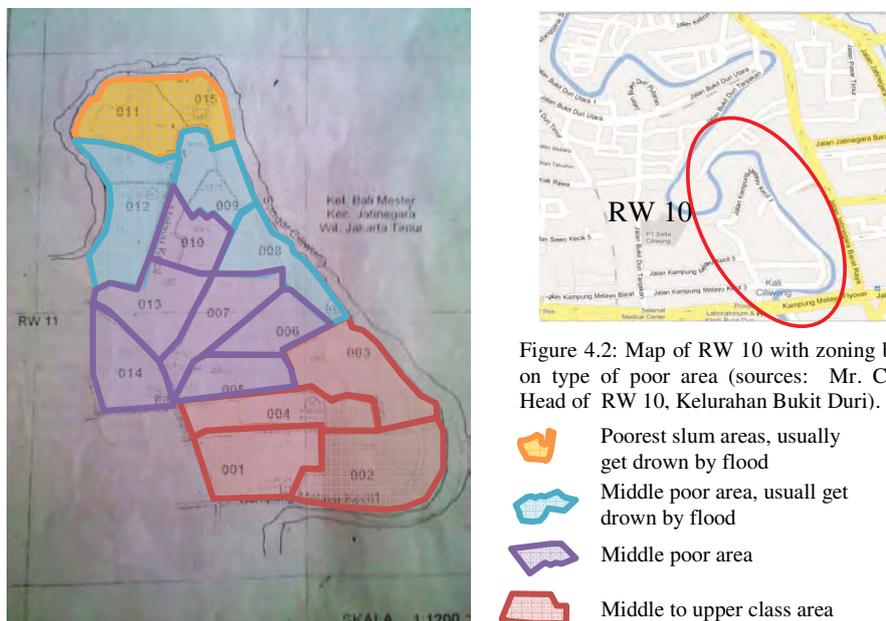


Figure 4.1: Map of RW 10 from ‘google maps’

Figure 4.2: Map of RW 10 with zoning based on type of poor area (sources: Mr. Cecep, Head of RW 10, Kelurahan Bukit Duri).

- Poorest slum areas, usually get down by flood
- Middle poor area, usuall get down by flood
- Middle poor area
- Middle to upper class area

For the specific site, RT 11 and 15 are shown by the orange color in picture 4.2. This area is the poorest area based on Bappeda DKI Jakarta Government standard (1997). This areas located in the lowest land of RW 10, while in upper land is middle to upper class settlement (red color in picture 3.2). This is related to women who live is RT 11 and 15, that as an adjustment of distance of their three roles, they work not far from their house, as in both RTs, there’s some women who work as a part time housemaid in another RT which is middle and upper class settlements in RW 10 (red area in picture 3.2). The other women work in home-based work, like small *warung* or small home industry that they own themselves. Only small number of women works as employer or work in office or department store, but some of these women work as seller in Jatinegara market. This is show us how these women, at the same time should help her husband to find the secondary resources or maybe the first one, but they still meet conflict with their roles and their space of activities. This is the main reason why the researcher chooses the location as case studies.



Figure 4.3: condition in RT 11 and

For this research, researcher will choose informant that is work and married. They must be still live until now in the location of case studies and already familiar with the culture in that location. One more important point is because my approach is participant observation, so researcher should make sure that informant agree to become this research informant and have time to be involved in this research.

## 5. FINDING

Actually as a pre-observation, researcher had already made some observation for under graduated thesis in location of study case with 10 women from RT 11 and 10 women from RT 15. As a pre-observation, researcher tried to learn about the daily life of informant and their house especially their typological functional spaces. Researcher try to learn how is the condition of space that already existed in slum areas especially in these women house. But for the explanation in this paper, researcher as the writer will explain two informants that has job and is married.

Theses example of women life in RT 11 and 15 relates with Moser's theory [26] about women's triple role: reproductive, productive, and social management as Miraftab said [27] that women in low-income family who lives in slum areas not only have a big responsibility to take care their children and family, but also as someone who find money for family daily needs. But what makes the pre-observation unique is women that usually work, do not really like to go outside their house after they come back from working. They prefer stay inside their house to rest than go out and meet the other women. But it doesn't mean that they are introvert, because they still connected with the other women by open their house door.

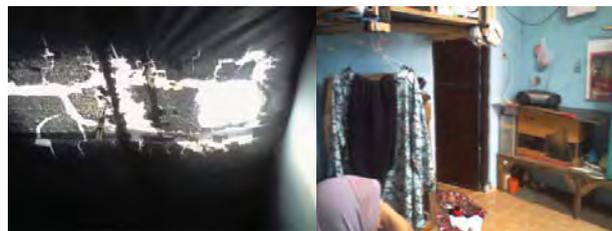
Because building condition in slum areas is usually crowded, just open the door still can make the women inside the house see their surrounding easily, and still keep her eye to watch their children while their children are playing outside the house. And because the door is open too, women who love to go around the neighborhood can come and share the story there. Like what happen to one of informant, named Mrs. Jml. She always open her front door to make people come and watch television together, while she still can rest inside her house.

The fact about inside and outside the house can be connected just by open the door and so the women inside can chose to stay inside but they still can socialize themselves is connected with what Arendt [28] said that balanced laboring body and laboring head will determine the quality of human's life. That is why women who work do not really like to go outside their house, because they use their house really well to re-product their labor so they can do the work. It makes women's roles so important because they must do the reproductive activity and do the productive activity, but at the same time, while they do the reproductive activity is for preparing themselves for doing the productive activity.

From observation in Mrs. Jml's house, it is known that the most of the room in her house is under her control. Like the living room, where a television is there, this is a place where she prepare her snacks and cakes too. After moving around her neighborhood (RW 10) to sell her cakes, she will stay in this room to watch television while resting. Because she opens her front door that directly connect to living room, her neighborhood or another women can come and watch television together. Her position in house reflects in her 2<sup>nd</sup> floor too, as she is the one who design the 2<sup>nd</sup> floor's roof to be changed by some kind of transparent materials so her 2nd floor can still bright without electricity (to reduce electricity cost)



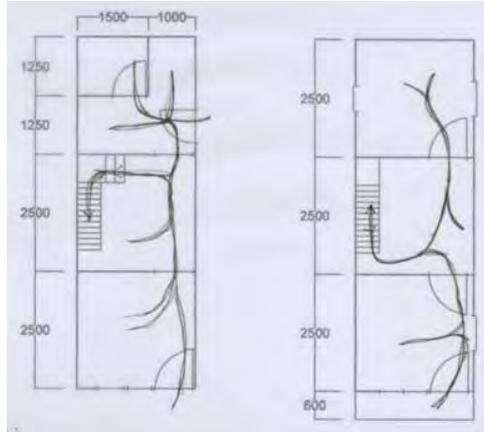
Picture 5.1 Mrs. Jml's living room



Picture 5.2 Mrs. Jml's 2<sup>nd</sup> floor's roof (left) and the effect of material in the room

As women who works in her own home-based work, it shows clearly how the house shows her position in the house and family. If we relate it to her husband, it relates how her husband is very seldom come home, because husband works as truck driver in expedition to another island that usually travel a lot. When her husband come home, he will spend most of his time resting in bed room, and the next day, he will go to work again. So that is why her control of her house is big because her husband did not really pay attention of what happen inside the house, and because Mrs. Jml is work too and use her house as the place where she can do half of her work, she has most authority to make her own territory.

Her son is one of her family member who already can earn money, so inside the house, he has his own territory too, that is his bedroom. But when he goes to work, his room is part of his mother space too, to do the house cleaning. That is why, Mrs. Jml movements is not so intense as in 1<sup>st</sup> floor (picture 5.3).



Picture 5.3 Mrs. Jml's movement inside her house in 1<sup>st</sup> floor (left) and in 2<sup>nd</sup> floor

Another interesting story is about the slope stair and the small space under it. Women in the site usually use a small space under or near the stair to become their space of activity. It shows us that even though they only have limited space available in their house, every small space inside the house can be used as space of activity.

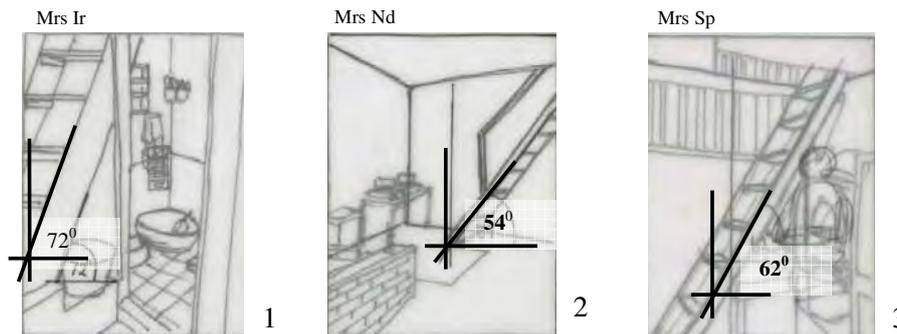


Figure 5.3: Some sloppy stairs inside informants' house: bathroom under the stair (left), bath room near the stair (middle), kitchen under the stair (right)

Most of informant uses the space under the stair as they kitchen or bath room, so even though the space for them to cooking only small space, but still they can do their roles as someone who prepared the food for family and even though there is only small space left inside the house but they still can use it as useful space.

Same as kitchen, some informant prefer bath room inside the house for bathing than they should do it in public toilet. One of informant, Mrs. Nd said that when she married with her husband, she got part of her parents-in-law's house that had been divided for her husband and her. Because it's only part of a whole house, there is no bathroom inside it. But because Mrs. Nd works as one of employer in handicraft industry that usually make the craft in their house (not in some kind of factory), she usually stay inside the house, she asking her husband to make a small bath room inside the house, so her husband make her small bath room inside the house. This is showing us how negotiation can take a role in decision making about space inside the house.

In this case, patriarchy that means man domination happen as Mrs. Nd's husband then make her bathroom, it is his responsibilities as man has a power more than women to do hard work. But when Mrs. Nd asking about the bath room, is a moment where women too can show her existence to openly show her opinion, that she needs private room to do the laundry, clean the dishes, and of course clean herself, and so she ask her husband about it, and her husband agree to make it inside the house.

## 6. CONCLUSION

From these two stories of the informants, we can see that women in slum areas, especially who is work and married, has a high position in spaces in slum areas, especially in their house. For example Mrs. Jml, can get this authority to merge the boundary because her husband rarely in their house, so Mrs. Jml exist with good position in house, so she can expand space inside the house to outside the house. Different story from that is about Mrs. Nd that needs bathroom inside the house, so she made a negotiation with her husband as the one who really own their house to make a small renovation, so they can have bathroom inside the house, and so Mrs. Nd can do reproductive role (washing and cleaning) and do her productive role (work) easier than she should go to the public toilet. This negotiation leads an agreement that her husband agree to build small bath room inside the house. This process show us that as head of family, husband in patriarchy system, have a big authority of what should have been in family, including space divided inside the house, but this case show that woman also has big position as the one who has activity inside the house and neighborhood more that the man, so when Mrs. Nd as a wife told something to her husband her need of space, she can negotiate it to get what she needs.

Beside these two main cases, actually there is a lot of story from other informants, but these two cases can be the first example before the next research that can show us how space inside the slum areas made by a big participation from women activities, as they are the one who spend most of time in this settlement. As sometime we realize in crowded settlements, there is a place such as security's post or head of neighborhood's house as the place where men usually meet each other and make interaction, there must be a big space and place inside the settlements that show how women also have big position in this community. And for the conclusion, it makes women is an important part of slum areas that of course should not be forgotten.

## ACKNOWLEDGMENT

This paper presented for all women that already become very good informants, very good teacher for this research. Thank you for my professors, especially Ms. Ir. Herlily, M.Urb.Des and Mr. Dr. Ing. Dalhar Susanto for helping me and always assist me from the start. Thank you for Mr. Cecep, head of RW 10; Mr. Husein, head of RT 15; and Mrs. Rahmawati, head of RT 11, for all the permission to do this research. Thank you for my parents, my sisters, and my brother that always support me. Last but not least, thank you for all of my friends that always stand beside me and always give me support.

## REFERENCES

- [1] Davis, Mike. 2004. *Planet of Slums*. Article from New Lift Review 26, March-April 2004.
- [2] *idem*
- [3] Wahyuni, Dewi Nova. 2006. *Pengukuran Paksa dan Dampaknya Terhadap Perempuan: Catatan dari Lapangan*. Jakarta: Publikasi Komnas Perempuan.
- [4] Miraftab, Faranak. 1995. *A Misfit between Policy and People: The Search for housing by Female Headed House in Guadalajara, Mexico*. Dissertation in University of California at Berkeley.
- [5] Efrini, Elvi. 2005. *Keterbatasan Ruang dan Dampaknya Terhadap Kualitas Hidup Perempuan di Permukiman Padat*. Thesis Program Pascasarjana: Kajian Pengembangan Perkotaan Universitas Indonesia.
- [6] Spain 1992, dalam Cowan, Susanne. 2001. *The Gendered Architecture of the Home in the Cinematic Space*. Dalam Built Environment vol 26, no 4.
- [7] Mc Dowell, 1983 dalam Spain, 1992, cited from Efrini, Elvi. 2005. *Keterbatasan Ruang dan Dampaknya Terhadap Kualitas Hidup Perempuan di Permukiman Padat*. Thesis Program Pascasarjana: Kajian Pengembangan Perkotaan Universitas Indonesia
- [8] Suparlan, 1996 cited from Efrini, Elvi. 2005. *Keterbatasan Ruang dan Dampaknya Terhadap Kualitas Hidup Perempuan di Permukiman Padat*. Thesis Program Pascasarjana: Kajian Pengembangan Perkotaan Universitas Indonesia.
- [9] Moser, Caroline. 1987. *Woman, Human Settlements, and Housing*. London: Tavistock.
- [10] Fineman, Martha L. 1991. *Images of Mothers in Poverty Discourses*. Duke Law Journal, Vol. 1991, No.2 (April 1991), pp. 274-295. Duke University School of Law.
- [11] Reardon, Sean F. 2011. *The Widening Academic Achievement Gap between the Rich and the Poor: New Evidence and Possible Explanations*. Stanford University.
- [12] Ostergaard, Lise. 1992. *Gender and Development: A Practical Guide*. New York: Routledge.
- [13] Storey, David. 2001. *Territory: The Claiming of Space*. London: Harlow Pearson Prentice Hall.
- [14] Gerson, J.M. & Peiss, Kathy. *Boundaries, Negotiation, Consciousness: Reconceptualizing Gender Relations*. Social Problems, Vol. 32, No. 4 (Apr., 1985), pp. 317-331. University of California Press on behalf of the Society for the Study of Social Problems
- [15] Crawford, Mary & Unger, Rhoda. 2004. *Women and Gender: A Feminist Psychology, 4th Edition*. London: Temple University Press.
- [16] *idem*
- [17] Gerson, J.M. & Peiss, Kathy. *Boundaries, Negotiation, Consciousness: Reconceptualizing Gender Relations*. Social Problems, Vol. 32, No. 4 (Apr., 1985), pp. 317-331. University of California Press on behalf of the Society for the Study of Social Problems
- [18] *idem*
- [19] Reeves, Scoot; Kuper, Ayelet; dan Hodges, Brian David. 2008. *Qualitative Research Methodologies: Ethnography*. Article in BMJ, August 30th. 2008, vol. 337.
- [20] *idem*
- [21] Spradley, James P. 1979. *The Ethnographic Interview*. New York: Holt, Reinhart and Winston.

- [22] *idem*
- [23] Emerson, Robert M., *et al.* 1995. *Writing Ethnographic Fieldnotes*. London: The Chicago Press.
- [24] Alexander, Christopher. 1979. *The Timeless Way of Building*. London: Oxford University Press.
- [25] Rutgers, Reinder. 2010. *Urban Analysis: Mental Map*. Technische Universiteit Eindhoven
- [26] Moser, Caroline. 1987. *Woman, Human Settlements, and Housing*. London: Tavistock
- [27] MirafTAB, Faranak. 1995. *A Misfit between Policy and People: The Search for housing by Female Headed House in Guadalajara, Mexico*. Disertasi University of California at Berkeley
- [28] Arendt, Hannah. 1958. *The Human Condition*. Chicago: University Of Chicago Press.

## Developing Squatter Kampung, a Political Resolution Case Study Kampung Lio, Depok, Indonesia

Antony Sihombing<sup>a</sup>

<sup>a</sup>Department of Architecture, Faculty of Engineering, Universitas Indonesia  
 a.sihombing@eng.ui.ac.id

### ABSTRACT

Urbanization is the main trigger to the emergence of squatter kampongs on spatially and environmentally fragile area. Characterized by filthy, dense, and unhealthy, the illegal kampongs can pose as anaesthetic problem and a treat for environmental damage for the entire urban area. Without adequate financial ability and knowledge, the low-income communities that live there really need some helps from other such as the government in improving their environment. In other hand, the government shows a big concern in helping environment improvement in squatter. One example is the government of Depok City, Indonesia, that forms a partnership with the community of Kampung Lio to improve the infrastructure and environmental condition of the illegal kampung. It based this paper to question of 'why the government has the willingness to help the arrangement and improvement of squatter kampongs?' To answer the question, this research is done by interpreting the results of literature review and precedents study on investigating the conditions of Kampung Lio. People of Kampung Lio have citizen identity card and have the right to vote on governmental elections, which make them feel important politically and give the chance to ask for helps from the government. The helps come in the form of partnership, where the community can be actively participated. The Depok City government gives fund assistance, while the community of physically involved in the environment improvement activities. In helping the community of illegal kampung, apart from the social motive to help the poor, political motives are the main reasons that the government has a willingness to help the people of squatter kampongs. The government has the responsibility to provide the proper kampung environment for all its citizens. Also because a good quality of kampung environment, especially for the poor on squatter is a political subject that can be used to measure the success of a government.

### Keywords

*Squatter kampung, partnership, low income community and government*

### 1. INTRODUCTION

High rate of urbanization that cannot be accommodated by urban capacity is the main trigger to the emergence of squatter kampongs in Indonesian urban area (Robie, 1986) [1]. Based of legality aspect, Sihombing (2007) explains that *kampung* consists of two settlement, which are legal and illegal (squatter) settlement. Legal *kampung* is spontaneous settlement that built on the legal land has certificate of formal land published by government. Meanwhile, according to Sihombing (2010) [2] squatter *kampongs* (illegal *kampongs*) are usually built up on spatially and environmentally fragile area, without legal ownership on the land. Squatter settlement is settlement occupying the prohibited land, e.a.: the coastal zone, water catchment area, lakeside, riverbank, marshland, and undeveloped green belt area. This research is done in squatter *kampung*.

A squatter is characterized by filthy, dense, and unhealthy *kampung* and these conditions can pose as an aesthetic problem and a treat to health of urban environment, and also becomes vulnerable area for many crimes to take place (Gouri & Abdullah, 2005) [3]. The communities that live in squatters are usually low-income communities with unorganized and undisciplined lifestyle, with low awareness on environmental hygiene and health (Gouri & Abdullah, 2005) [4]. These lifestyles make the squatter to be disaster prone, such as flooding, fire and environmental damage. With the limited knowledge and low income, the squatter communities really need some helps from other parties such as industries and government in improving the quality of their kampongs.

In other hand, the government with consciousness of its limitation in providing legal and proper dwelling for all citizens, especially for the communities of squatter kampongs, shows a big concern in helping to improve the quality of environment in squatter *kampung* (Brueckner & Harris, 2009) [5]. One example is what the government of Depok City does in Kampung Lio, by forming a partnership with the community there to improve the infrastructure and environmental condition of the *kampung*.

Kampung Lio is a squatter that locates on the edge area of 'Situ Rawa Besar' lake, Depok City. Although it is an illegal *kampung*, but the Kampung Lio community still get the help from the government of Depok City to improve the condition of their settlement environment, in the form of partnership between the government and the community. The government gives fund and planning concept, while the community actively involved in supervising, and physically involved in environmental improvement activities. Based on the government and community partnership that happened in Kampung Lio, this paper aims

to answer a question of 'why the government has the willingness to help the arrangement and improvement of squatter *kampungs*?'

## 2. RESEARCH FRAMEWORK

### 2.1 Research Methods

This study begins with a literature and precedent reviews related to partnership between the government and squatter community, including the roles of each party in environment improvement of squatter *kampung*. Then, the study focused on the government's role in the partnership, to figure out the reasons why the government, as a legal institution can have the willingness to help improving the environment quality of an illegal *kampung*.

Based on the research background and objective, this research was carried out by investigating the physical, environmental and social conditions in KampungLio, related to the partnership between the government and the community in environment improvement. Information collected with a qualitative approach, which was selected based on an understanding of the qualitative approach that can be applied to examine the meaning and process of human activities. In this case, to study the meaning and the process related to the efforts of the government in improving the quality of squatter *kampung*, with active involvement of the community. A qualitative approach, according to Wang (1954) [6] can be distinguished on three ways of research, consists of grounded approach, ethnography and interpretation (*interpretivism*), and this research specifically was done with interpretivism approach.

Geertz in Wang (1954: 186) [7] reveals that the interpretation approach is done by reading and interpreting the processes of human activities, assuming that social facts are real objects. The result of literature and precedent studies about partnership between the government and the community of squatter *kampungs*, as well as the motives behind the helps that government give to an illegal settlement, will be interpreted on the condition in KampungLio. This will be the basis in answering the research question 'why the government has the willingness to help the arrangement and improvement of squatter *kampungs*?'

### 2.2 Learning From Literatures

In practice, a partnership involves the relationships among authorized parties (stakeholders), with their own distinct interests, which led to the need for an arrangement or 'managerialism' in partnership activities (Turner, 1976) [8]. 'Managerialism tripartite' theory proposed by Turner who see a simple way to divide the parties involved based on their role in three groups of activities in the implementation of the partnership, those are planning, construction and management. While based on the actors, Turner categorized participating in the partnership, into three sectors (tripartite), those are popular sector (community) as user, the commercial sector (private) as a supplier, and the public sector or the government as a regulator. Community is the most important sector, because it is the party that will directly feel the results of the partnership. The active participation of the community will determine the quality of the partnership in order to fit their own needs, which in this study focused on partnership in improving the quality of a squatter settlement.

According to Arnstein (1969) [9], 'community or citizen participation' refers to 'citizen power', it means that in an order of a social life and governmental institution, every citizen has an important role politically. The 'citizen power' is formed, because every citizen has a role as supervisor and controller, beside as the consumer of governmental policies. The citizen will make sure that the government makes the right decision in creating public policies and fund expenditure in the sake of social justice for the community. In democracy countries, where the leaders are directly elected by the community, every citizen means a lot to give one vote. Because the political role, the government cannot ignore its responsibility to the community, including the responsibility to provide proper settlement environment for every member of the community that occupies both legal and illegal settlements.

Habraken proposed the concept of 'support' and 'infill' to describe the partnership relationship between the government and the community in providing proper settlement (Habraken, 1976) [10]. 'Support' is provided by the government, such as roads and utility networks infrastructures, from regional to neighborhood level. While the community "infill" the public infrastructure, by building their own dwelling with or without the help of others. The community also has the role to maintain the infrastructure provided for their own sake. An active involvement of community in this 'support' and 'infill' concept is to make the result of the development, especially in settlement improvement process, will be suitable with the final user, which is the community itself.

### 2.3 Learning from Other Countries

The debate about the relationship between the formal and the informal sectors in developing countries like Brazil, still focused on how creating an appropriate legal framework, considering the problems encountered is the growing of illegal settlements in urban areas, such as Pavao-Pavaozinho, Rio de Janeiro, Brazil (Elisabeth, 2012) [11]. Government with its limitations cannot legalize the status of the settlement, caused residents of the settlement automatically becomes the second grade community in acquiring public services and facilities. With its rundown condition, the illegal settlement also becomes a hotbed for distributing narcotics and other criminal activities such as fighting and killing. This shows that without adequate and legitimate

dwelling, residents of informal settlements are limited to obtain justice in access to facilities, services, public safety and comfort, as they should be.

Meanwhile, in the African countries, the government plays an active role for the provision of formal housing for low-income community through monetary policy and administration of licensing in the housing market (Boudreaux, 2008) [12]. But, in fact, employers in the housing sector think government complicates them with the complexity and high cost of bureaucracy. This difficulty is also felt by the community in obtaining adequate and legal housing. By so, there are informal housing and settlements in Africa that can be classified in two categories, namely settlements built by the community independently, and mass housing built by developers without any role or permission from the government. It appears that in providing decent housing in African countries, the two informal parties play the role illegally.

Many efforts have been made by governments throughout the developing world to improve living standard and secure land tenure in squatter settlements. While legalization of land ownership still becomes difficult to realize, social and political motives are the main reasons why governments of the countries help the squatter communities to improve their settlement environment (Gouri & Abdullah 2005). Participatory approach is considered the most effective way in facing the squatter, compared to direct apply of authoritative decisions. Information on community's views, ideas and choices will show the government how to make regulation and give the helps that most suitable with the community (Herbert, 1999).<sup>1</sup>

#### 2.4 Learning From KIP (*Kampung Improvement Program*) in Indonesia

Cities condition in Indonesia that grows and serves as the center of activities, inviting residents of other towns and smaller cities or villages to come to find a job and a better living. They come from various backgrounds of social, economic and living conditions, and mostly without a clear plan about their life in the big cities. Instead, these cities are still not ready yet with a plan to develop urban systems in order to accommodate the increasing number of activities and people, with various aspects and implications, including the receiving, managing, and utilizing the 'newcomers' as part of the urban planning and development. It then causes the forming of activities pockets, including squatter *kampungs* that grow and expand beyond the expected plan.

Most of these activity pockets are in the form of housing and *kampung* neighborhood that develops either on an existing residential neighborhood or unmanaged lands that does not exist in the plan designation, while the built infrastructure and basic facilities has not been prepared adequately, it results the declination of the environment condition. Most of people in these illegal *kampungs* are on low and middle income societies, with limited ability to improve their environment. This condition emerge the idea to carry out environment improvements in urban housing and *kampungs*, especially in urban village (*kampung*) that still need to be assisted by the government.

'Indonesia Department of Public Works' has initiated and developed the '*Kampung* (village) improvement projects' that have been recognized by *Mohammad Husni Thamrin (MHT)* Project in Jakarta, *WR Supratman* Project in Surabaya, and *Sartika Goddess Project* in Bandung. Through these *kampungs* and environment improvement programs, combined with the development of the potential and activeness of the communities, supported by various funding sources from both government funds and foreign loans, these projects spread to other cities across Indonesia, which was then known as *Kampung Improvement Program (KIP)* or City Housing Environmental Improvement (*Perbaikan Lingkungan Perumahan Kota (PLPK)*).

The purpose of these program are to complement and enhance the neighborhood infrastructure and basic services for the villagers as well as encourage and promote public or community participation in order to improve the income and productivity of the community itself. In its implementation, it is also addressed to the effort to plan *kampung* environment, by curb ownership boundaries of each parcel and legal status of ownership on land. Basic infrastructure improvement activities implemented according to the priority needs such as increasing the quality of road, water supply, building and neighborhood safety, electricity and provision of information.

The communities of squatter *kampungs*, with fund and knowledge limitations need the help from other parties such as private sector and the government in improving the quality of their environment. The limitation also makes them difficult to acquire legal dwelling, while the government cannot make a regulation and decision that can legalize the squatter *kampungs*. In other hand, the government realizes that every citizen has an important meaning politically, and an improvement quality of urban area, especially the fragile area like a squatter *kampung*, can give a good rapport for the government.

### 3. CASE STUDY

*Kampung Lio* is a fairly dense settlement, located on land that was formerly a marshy swamp area on the edge of 'Situ Rawa Besar' lake (Figure 3.1). The lake is in less good condition, with murky colored and bad smells water, as well as a lot of rubbishes pooled on it. Besides its bad condition, the existence of the lake was easily ignored from the highway because the access to this area is not clear enough.

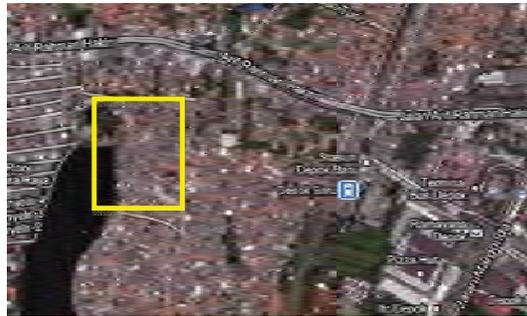


Figure 1: KampungLio and its surrounding

Access condition between KampungLio with other areas, such as public and social facilities like railway stations, bus terminals, places of worship, and traditional markets are close enough but without a clear and adequate road or access infrastructures. The entrance from the ArifRahman street is a main road, which can be passed by four-wheeled vehicles, but from the main road leading to the *kampung* and each dwelling in KampungLio area right on the edge of Situ, only in form of narrow footpath, which tend to be a dirt road, and have not hardened with asphalt or other materials and mostly can only be passed by foot.



Figure 2: People activities around Situ Rawa Besar

*KampungLio* also known as an area where the low-income community lives, as a settlement of beggars, scavengers, and other informal workers who have frequently gotten interventions from the NGOs, students, and other society at large. The economic conditions of the people can be seen from the settlement, environment, and housing condition. The environment circumstances tend to be dirty and wet (with dirt roads and open sewers). The majority of its citizens are as laborers, beggars and used plastics washers, with revenues under 2 million rupiahs per month.



Figure 3: Condition of the building (dwelling) on the edge of the lake (Situ)

Most inhabitants are migrants who have lived in this village more than 10 years. They live in a house that was built without a legal building permission by the government, and some of them lived in the dwelling by renting. The *kampung* condition reflects the poor and less fortunate condition of the people. Building structure is very irregular and generally not permanent, with an area per dwelling under 36 m<sup>2</sup>. Roofs are made of leaves or similar material, while the walls are made of woven bamboo that has not been processed yet. Drainage facility is also very inadequate make it very easily flooded in raining season.



Figure 4: Drainage and street/lane conditions in slum areas of *KampungLio*

Most people stay living here, because their economic limitation in acquiring legal and more proper dwelling. Apart of that, the proximity with their workplace is another reason, where most of them work on the near railway stations, bus terminals, traditional market, and around the lake. Most people always have willingness to improve the quality of their dwellings and environment, but limited by the lack of financial and knowledge ability.

From the 'Department of Spatial and Settlement Planning of Depok City also held a house improvement program that randomly selected some indecent houses from the entire houses in Depok city. With the limited quota only two houses per year from the entire city of Depok, the opportunity for *KampungLio* to get the help becomes very little. However, from the Depok City Government, the *kampung* gets financial assistance as part of the 'revenue and expenditure budget' annually for environment improvements, such as road, drainage facilities and water supply improvements, also in providing public and social facilities. In spite of the illegal status of the settlement of *KampungLio*, the community lives just like other citizens. They have citizen identity card (KTP) and have the right to vote in governmental election. They have access to public and social services just like other citizens.

#### 4. RESEARCH FINDINGS

Based on the government and community partnership in *KampungLio*, it shows that the government is conscious of its responsibility to give proper settlement environment for all citizens; both lived on legal and illegal land. While the illegal community, are still very concerned in improving the environmental condition of the settlement. Their knowledge and financial limitations make them need the assistance from other parties like the government.

The partnership is in the form of 'supports' by the government, and 'infill' by the community. The government provides funding and planning assistance at the regional level, for environment improvements. While the people of *KampungLio*, with mutual cooperation and their togetherness physically involved in activities for improving their neighborhoods and the dwelling units.

The illegal community economically, cannot afford more proper dwelling in a legal *kampung*. While the government cannot provide affordable settlement for the poor people in other location, and also cannot legalize the land ownership of the land, because *KampungLio* locates on a environmentally fragile area, on the swampy edge of a lake. These are the main motives that form the 'political partnership' between the Depok City government and the illegal community of *KampungLio*.

From the community point of view, there is no reason to refuse the help and partnership offered by the government. But, it is questionable why the legal institution like Depok City government has the willingness to help the community of an illegal *kampung* like *KampungLio*. Besides the help to improve the *kampung* environment, the people also gets recognition by the government by getting citizen identity card (KTP), and vote for election, as well as mutual access on public services and facilities just like people that live in legal *kampung*.

Every citizen that has the right to vote is important for governmental leaders, including votes from an illegal *kampung* community. *KampungLio* is popular as a settlement of the poor that need many helps and interventions from other parties to be improved. Both reasons make *KampungLio* important for the Depok City government politically.

#### 5. CONCLUSION

In helping the community of illegal *kampung*, apart from the social motive to help the poor, political motives seem to be the main reason why the government has a willingness to help the arrangement and improvement of squatter *kampung*s. Because 'citizen power' can be 'political power', where every citizen has a right to vote in election, which means the governmental leaders need to make the people believe on them.

Because a good quality *kampung* is the basic need of people in urban areas, the government has a big responsibility to provide it, especially for the low-income community. Politically, *kampung* environment for the poor, specifically illegal *kampung* is a main subject that can be used to measure the success of a government on its citizens. The illegal community itself realizes that they are a political object, and make it as a chance to ask for helps by the government. The helps come in the form of partnership, where the community can be actively participated in the environment improvement activities.

#### REFERENCES

- [1] Arnstein, Sherry R., *A Ladder of Citizen Participation*, JAIP, (1969), Vol. 35, No.4..

- [2] Boudreaux, Karol, *Urbanisation and Informality in Africa's Housing Markets*. Published in "Institute of Economic Affairs Journal compilation". Oxford: Blackwell Publishing, (2008).
  - [3] Brueckner, Jan K & Selod, Harris, *A Theory of Urban Squatting and Land-Tenure Formalization in Developing Countries*. Published in "American Economic Journal: Economic Policy, (2009), PP 28–51
  - [4] John F.C. Turner & Robert Fitcher, *Freedom To Build*, New York: The MacMillan Company, 1972.
  - [5] Habraken, NJ., *Variation; The Systematic Design of Support*. MIT: Cambridge, 1976.
  - [6] Riley, Elizabeth, *A Portrait of 'Illegality': the favela of Pavão Pavãozinho and the perceptions of its residents*. Paper was presented on ESF/N-AERUS International Workshop 'Coping with Informality and Illegality in Human Settlements in Developing Cities' Leuven and Brussels, Belgium, 23-26 May 2001.
  - [7] Roy, Gouri & Abdullah, A. Q. M., *Assessing Needs and Scopes of Upgrading Urban Squatters in Bangladesh*. BRAC University Journal, (2005), Vol. II, No. 1
  - [8] Siamwiza, Robie., *Consequences of Rural Poverty in Relation to the Urban Squatter Problem in Lusaka*. Published on Journal of Social Development in Africa, (1986). PP 35-52.
  - [9] Sihombing, A. (2007). Living in the Kampung: A Firsthand Account of Experiences in Jakarta's Kampung, *FORUM International Journal of Postgraduate Studies Architecture, Planning and Landscape University of Newcastle*. 7(1): 15-22
  - [10] Wang, D. & Groat, Linda. *Architectural Research Methods*. United States of America: John Wiley & Sons, Inc., 1954.
  - [11] Werlin, Herbert, *The Slum Upgrading Myth*. *Urban Studies*, (1999), Vol. 36, No.9, 1523±1534.
-

# Transformation from Conventional To Modern Urban Open Space In Semarang City

DR. Ir. Titien Woro Murtini, MSA <sup>a</sup>, Arnis Rochma Harani, ST, MT <sup>b</sup>, Yasmina Nurul Falah, ST <sup>c</sup>

<sup>a</sup> Faculty of Engineering, Diponegoro University, Semarang 50275  
 Email: titien\_wm@yahoo.com

<sup>b</sup> Faculty of Engineering, Diponegoro University, Semarang 50275  
 Email: arnis.rochma@gmail.com

<sup>b</sup> Faculty of Engineering, Diponegoro University, Semarang 50275  
 Email: yasminanf@yahoo.com

## ABSTRACT

*This paper discusses the changes from city open space in the city of Semarang in terms economic, social, cultural and physical. Population growth in the capital city Central Java is Semarang has increased every year. This increase will impact on the need for a place to stay, so the government will think of expanding residential areas and begin to ignore the open space area of the city. Open space set by the city government's policy is 20% from the city area, but in Semarang not complies. However, the changes public views about the town for some time is become the main focus, change the behavior of Semarang city started looking for open space this is due to the space they are confined within the house. Seeing this phenomenon, Government of Semarang City is keen to build open spaces of the city. But people tend to congregate in open space area which is in the center of town. So the difference in public open space and passive open space that serves is not visible. And this will bring a new impact to the city is the bottleneck. The results of this study can be used as input for urban planning and design of open space in the city of Semarang. The development policy of Semarang city government should be synchronized with sustainability issues in an effort to build a sustainable city. So the construction and arrangement of the town to be more controlled.*

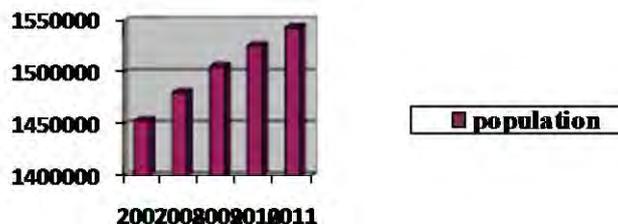
## Keywords

*Open Space, population growth, sustainability city*

## 1. THE DEVELOPMENT OF URBAN OPEN SPACE IN SEMARANG CITY

Semarang is the capital of Central Java, which has a population of 1,543,557 people or about 13.54% of the total population of Indonesia. Population growth in the city of Semarang has increased each year by the percentage of births increased 57.80% from the previous year. An increasing number of people can be seen in chart 1.1,

Chart 1.1 Semarang city population growth  
 Source: Center Statistic Center of Semarang City



This population growth resulted in a growing need for land; a land area of 373.70 km<sup>2</sup> Semarang must be able to accommodate the number increasing of people getting high. The problems that arise from the increase in population is the need for housing increases, changes in land use, traffic, and the structure of the chaotic city. The main problem of the city is a matter of the need for space.

According to Zahnd (1999) City is not something that is static because it has close connection with the life of the performer who carried out the fourth dimension: time. So the growth of the population formed the basis for the development of a city. In the development of the city through many changes, according trancik (1986) three basic problems of urban development are: (1) more urban buildings are treated as a separate object rather than as part of a larger pattern, (2) decision-making on the development of the region taken by urban plans that are two-dimensional without much attention to the relationship between buildings and spaces that form them, which actually is three-dimensional, (3) lack of understanding of human behavior. Development scale in town only aims to meet the needs of society regardless of city open space is actually very important to the life of the urban community.

Actual land use zoning is set so as to develop an area should be held on the written rules. Zoning regulations is basically a tool for control governing land use requirements and space utilization control provisions prepared for each block / zone designation (Law number 26 Year 2007 on Spatial Planning), which blocks / zone designation which is used to set through a detailed plan layout. Zoning regulations is more popular known as zoning regulation, which says zoning is meant to refer to the division city neighborhoods into utilization of space zones where in each of these zones defined control land use or apply the provisions in different laws (Barnet, 1982).

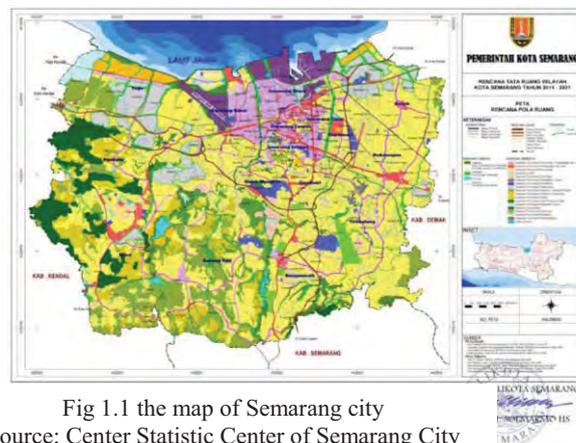


Fig 1.1 the map of Semarang city  
 Source: Center Statistic Center of Semarang City

Local Regulation Number 1 Year 1999 on Spatial Plan of Semarang, the basic concepts of urban development oriented to meet urban infrastructure services. Implementation of the above concept has many challenges, this is due to the wake of urban infrastructure has deteriorated sharply and functions.

## 2. THE RESEARCH METHODOLOGY

This study uses Post positivistic approach to research method that uses rationalism rationalistic in developing a theoretical framework and give interpretation of research results, and to use in examining empirical positivisms specific object (Muhadjir, 2000)

With this rationalistic and positivist approach to research methodology qualitative, generalization is constructed from the average individual or mean frequency diversity by monitoring errors are possible. This method requires a research design that specifies the object explicitly eliminated from other objects that are not investigated. Logical thought such as correlation, causality, and interactive while the objects were arranged in order and think the categorization and continuation with interval.

Exploratory study, as explained in the previous description, among others, addressed to:

1. satisfactory curiosity researchers to gain a better understanding,
2. examine the possibility of more in-depth studies, and
3. develop methods that will be applied in a more in-depth study

As an exploratory study, knowledge of the theory is still very small or vague, because it is through the observation then the problem can be formulated in more detail and be prepared hypothesis. The research was conducted by field exploration methods.

### 3. THE DEVELOPMENT OF PARK IN SEMARANG CITY

Semarang city there are many different open spaces of the city, one of the city parks. Garden City is a park located in the city that serves as the scale of the lungs of the city, and as aesthetic greening the city. State park consists of two kinds:

#### 3.1 Active State

Active Garden is a garden located in an area of town that is used as a community gathering area as community adhesive, and there are activities in it. Not only as a green area of the city.

#### 3.2 Passive Park

Passive Park is a park that was established as a town green area of the city region in which people are not allowed to indulge. Since the purpose of this park is just as green areas, infiltration areas.

The number of city parks in the city of Semarang in the next 5 years is only slightly increased, as can be seen in tabell.1:

Table 1.1 Added parks in the city of Semarang  
 Source: Center Statistic Center of Semarang City

No.	Tahun	Active Park	Passive Park	Total
1	2007	36	144	180
2	2008	37	149	186
3	2009	37	149	186
4	2010	27	149	186
5	2011	37	149	186

In the Semarang city, there are many different kinds of open space since the first was planned by the government to accommodate social interaction Semarang people. For example, KB Park, Simpang Lima square, Sri Gunting Garden, etc. However, some time ago in Semarang open space is not utilized well by the people of the city. Many city parks are not used unpunished. However, the situation turned around in 2 years, the city of Semarang looks hungry for open space. Active parks that was empty of visitors such as the park KB, Sri Gunting Park, and Gajah Mungkur Park invaded by Semarang people, even a passive park like Tugu Muda park, Diponegoro Park, Simpang Lima Square become a target of Semarang residents. Another thing is some road corridors being targeted as central Semarang residents gathered corridor of Pahlawan corridors, corridor of Pemuda.



Fig 1.2 the activity Semarang people in Tugu Muda Park, Simpang Lima squares and Pahlawan street corridor  
 Source: Survey data, 2012

This phenomenon is increasingly highlighted by the Semarang city government, a number of reasons such as changes in people's behavior began to run out of space for themselves in their environment, the lack of open space in their homes, the lack of open space environment in the city is the reason they look for places are considered able to meet the need for open space for them, this is a problem that occurs as a result of the increasing number of people in the city of Semarang.

Semarang city government who see the phenomenon and then give answer to the concerns of those people that looks hungry for public space of the city, the government began building city parks that had been active useless, ranging restructure plazas used a gathering place for the community, as well as rearrange the layout plan space and one urban area to improve the city park as shown in table 1.1.

#### 4. PASSIVE PARK CITY TUGU MUDA SEMARANG

Park serves as a symbol / identity or a landmark, will find a few sculpture in garden. According Spreiregen (1965) Landmark are forms a striking visual of a city. Tugu Muda Park is a park that became landmarks in Semarang because the park is designed as an integral part of the Tugu Muda monument which incidentally is the landmark of Semarang.

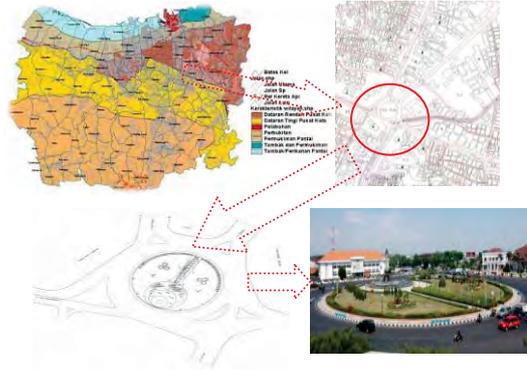


Fig 1.3 the location of Tugu Muda Park in Semarang city  
 Source: Survey data 2012

The park is located in the government buildings, and can't be separated from its essence as a memorial to fighters in Semarang who participated to gain independence from the colonizers. But what happens when this Tugu Muda Park is a magnet for the city of Semarang, every day the park is never empty of visitors. Passive Park is transformed instantly into an active park that is sure to impact the environment. The park is considered a puller as there is Tugu Muda monument as an icon city of Semarang.

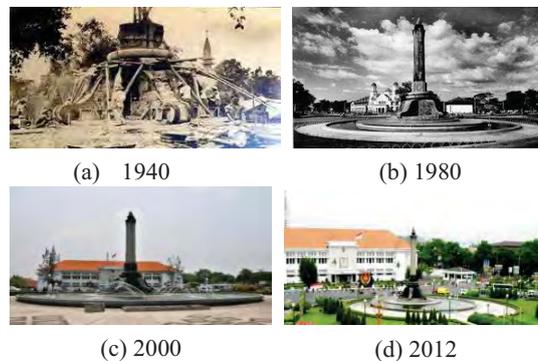


Fig 1.4 The transformation of Tugu Muda Park design from 1940 to 2012  
 Source: Survey data 2012

Tugu Muda Park design changes from 1940 to 2012 continued to improve, as a passive city park this park is considered to be quite good in terms of the elements of garden design and garden accessories. Changes are most apparent are the increasing number of green plants and the use of hard materials ranging reduced. This is used as a puller for the citizens of the city of Semarang so many who visit this park although not as Active Park. The existence of people to the park also bring adverse effects such as congestion caused by the lack of parking for visitors, the park being dirty, and many traders come into the park area.

## 5. SIMPANG LIMA SQUARE IN SEMARANG CITY

Semarang Simpang Lima Squares is the field that is in the middle of downtown or can be referred to the town square. Semarang city government planned Simpang Lima intersection that contains a big green area as city lungs.

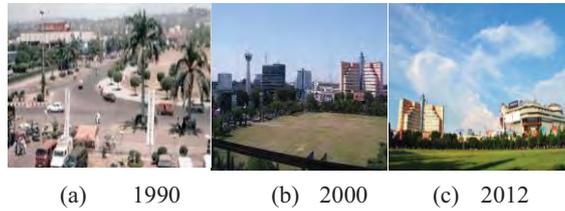


Fig 1.5 Transformation Simpang Lima Squares from 1990 to 2012  
 Source: Survey data, 2012

Currently, the Simpang Lima square turned into the center of the intersection of community in Semarang. All the residents gathered there to perform various activities, such as sports (rollerblading, basketball, and volleyball), playing, and just chatting. These changes result from the government changing form of plaza Simpang Lima to a new form, more modern. Basketball, volleyball until the jogging track is on actual field designed as the lungs of the city. Besides that, the green material is also reproduced in this Simpang Lima square. This phenomenon is considered as the cause of the Simpang Lima square use as public space of the city. Consequences arising within the Simpang Lima square are become jammed; traffic flow becomes blocked due to unavailability of parking space. The government's intention to improve the system of open space the city became one of the targets.

## 6. KB PARK IN SEMARANG CITY

KB Park has been built by the local government from 1973 until 1975. Park development objective is to utilize an empty area created by the meeting of traffic around the park. Parks became active in the middle of the town park as the lungs of the city as well as a recreational park. But in its development park KB is not very appealing to the city of Semarang, active park should be a place to play, a place of social interaction became a deserted park and unkempt. With the rise of open space needs for the city, the Semarang city government redesign active park, the park is surrounded by typical food Semarang is designed so that it becomes attractive gardens to visit.

Enthusiasm Semarang city residents come to the park increased than before, but the increase was not proportional to the number of people crammed into an open space other cities. Parks KB still not as busy intersection of five, young and memorial park road corridors hero. The park is expected have a high appeal to the citizens of the city of Semarang government just does not match expectations.

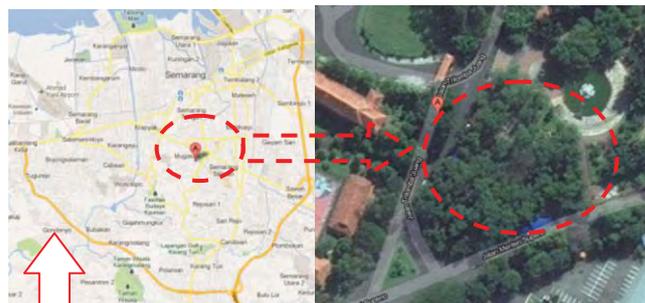


Fig 1.6 map of KB Park semarang  
 Source: Google map, 2012



Fig 1.7 KB Park semarang  
 Source: Survey data, 2012

## 7. ANALYSIS

Passive Park is a park that was established as a town green area of the city region in which people are not allowed to indulge. Since the purpose of this park is just as green areas, infiltration areas. But the gardens are located in the city of Semarang as Tugumuda Park, "Simpanglima" Field that it is intended as a passive park crowded. This is because its location is in the center of town, so visitors from various regions in Semarang can reach them. Unlike the Garden KB planned as an active park it was not too crowded visitors. As the results of interviews with visitors at the "Simpanglima" Field:

*"I went to "Simpanglima" Field when night of the week because here there are a lot of activities, from children to adults, I could bring my kid to skate and I can enjoy a night of Semarang city."*

According to Trancik (1986) the basic problems of urban development behavior not understand humans. Development scale in town only aims to meet the needs of society at the expense of open space the city is actually very important to the life of the urban community. This theory applies in this research problem, the people are wrong to apply the Government's goal to develop open space. The government intends to develop open space either park or plaza in the city of Semarang are taken too high by the city of Semarang, because the gardens are crowded even Passive Park. This is because the city of Semarang lacks space for their home environment, such as an interview with one of the visitors at the park Tugu Muda:

*"I am delighted to the Young Memorial Gardens because they can enjoy being with other visitors, and enjoy the city of Semarang. As well as boredom can be cured at home"*

With the development of open space in Semarang was not always bring positive effects but also negative effects, but what happens when it is an open space in the city of Semarang has undergone rapid change, becoming more modern, better, although considered Semarang people do not fully understand the concept of from the open spaces of the city. As the results of interviews with "TuguMuda" park visitors:

*"This park is made better than ever, and I think that people can come"*

This statement is precisely contrary to the purpose of government to change the appearance of the "Tugu Muda" park be more visually appealing with the aim of making the city a more beautiful Semarang. Not as a place to visit.

From the analysis above, it can be finding that the government's role to increase the open space the city is necessary to study on the wishes of the city of Semarang. As well as modern designs not always be in all the parks, there should be a significant difference between active and passive park design.

## 8. CONCLUSION

The increase of population in the city of Semarang making increasing need for land to grow, the need for housing increases, so that the narrowing of the land settlement. This resulted in reduced public space area private residences, housing up to an impact on the lack of land for public space of the city. So the government began to neglect the importance of public space to the city continue to improve land settlements. Unconsciously it will actually result in the saturated area of the narrow house; they then go out to find a place for social interaction, so their goal is the public space of the city.

Public space sought by the city actually been around a long time, but it was not touched by anyone. So when people experience boredom in the environment, they use existing open public space. The error that occurs is that people are not able to choose which city public space is really planned as a public space of the city; they just look factor "pleasure" only. What happens is wrong with the selection of the target public spaces of the city.

Governments who have an awareness of the importance of public space city began fix the city public space infrastructure which is available, ranging from golf, parks, and pedestrian ways. It is precisely this that makes people not being able to choose which public space that can be used and can't be used as a center of interaction. Precisely city public space which is the core region of Semarang city was invaded by the community. They do not know that what they use is passive city public space area.

Government regulations are made regarding the zoning application areas to be more enhanced, so that the spaces can urban areas as required, especially the open spaces of the city. City open spaces are enhanced not only the scale of the city, but also the scale of residential and community environment that is expected to satisfy the need for open space and not make people

converging at certain points they consider open space of the city. City open space should be designed according to function; in order to avoid the wrong target as of now this happens.

## 9. SUGGESTION

Government regulations are made regarding the zoning application areas to be more enhanced, so that the spaces can urban areas as required, especially the open spaces of the city. City open spaces are enhanced not only the scale of the city, but also the scale of residential and community environment that is expected to satisfy the need for open space and not make people converging at certain points they consider open space of the city. City open space should be designed according to function; in order to avoid the wrong target as of now this happens.

Another input is active and garden design standard passive park needs to be distinguished, so in accordance with the objectives and functions. Passive parks do not need to be complemented with attributes such as garden bins, seating, etc., so that people are not wrong perception park function. Modern design is not always on target so that the necessary studies before redesigning a garden.

## References

- [1]. Spreiregen, Paul D, Urban Desain: *The Architecture of Town and Cities*, Mc. Graw hill Book Company, New York, 1965
- [2]. Stephen Carr-Mark Francis-Leanne G. Rivlin-Andrew M Stone, 1992, *Public Space*, Cambridge University Press, USA
- [3]. Tracik, Roger, 1986. *Finding Lost Space Theories of Urban Design*, Van Nostrand Reinhold, New York
- [4]. Zahnd, Markus, 1999, *Perancangan kota Secara Terpadu: Teori Perancangan Kota dan Penerapannya*, Kanisius, Yogyakarta.
- [5]. Peraturan daerah kota Semarang no. 14 tahun 2011 tentang rencana tata ruang wilayah kota
- [6]. Peraturan Kementrian PU no. 8/2008
- [7]. UU No. 26 Tahun 2007 tentang Penataan Ruang
- [8]. Perda No. 1 Tahun 1999, tentang Rencana Tata Ruang Wilayah Kota Semarang
- [9]. [www.googlemap.com](http://www.googlemap.com)

## Void: A Mechanism of Delaying Space

Miktha Farid Alkadri<sup>a</sup>, Yandi Andri Yatmo<sup>b</sup>, Paramita Atmodiwirjo<sup>c</sup>

<sup>a</sup>Department of Architecture, Faculty of Engineering, University of Indonesia, Depok 16424  
 E-mail : mikthafarid@gmail.com

<sup>b</sup>Department of Architecture, Faculty of Engineering University of Indonesia, Depok 16424  
 E-mail : yandiay@eng.ui.ac.uid

<sup>c</sup>Department of Architecture, Faculty of Engineering University of Indonesia, Depok 16424  
 E-mail : mita@arsitektur.net

### ABSTRACT

This paper presents a work in progress on the exploration of the idea of void as a delaying space in architecture. The problem of presence and absence as a form of representation should be understood for the transformation of void mechanism concept. Spatial context approach is used to translate the mechanism of void space as development of design method. The element of absence-presence and tangible-intangible becomes an important way to read the trace of void. Based on the exploration of the void mechanism, this paper concludes that there is a system of spatial discontinuity which works in the delaying process. The process helps to define the traces of void that was formed which then offer opportunities to be developed for further design work.

### Keywords

*Void, delayingspace, spatialdiscontinuity, absence-presence, tangible-intangible*

## 1. BACKGROUND

Void : containing nothing; empty; vacant; not occupied; not filled ; Noun : the state of nonexistence; an empty area; a vacuum ; Verb : declare invalid; clear for occupants; to be emitted or evacuated, emptiness, nothing, zero, heaven, Ma, rem, chipper, sky.

The problem of representation of space is constantly emerged in the discussion of architectural space, either in the form of the presence or the absence of space. To understand this matter, it is important to see things that were shaped like an "absence" prior to determining the form from the presence of the space itself.

The artist Roslyn Piggott introduced the element of emptiness through her work by collecting various kinds of air sample in the tube [1]. This work demonstrated a mechanism in which the container forms the material it contains. The space is moved by the transformation of container, in various forms, such as long tubular, hollow, transparent, or solid tube. Indirectly, it represents a form of space inside the tube by the material and the surface of the container exterior. Therefore, the meaning of emptiness captured by our senses is the same as the external element that enclosed the space.

StraBmann suggested that space was present by means of occupying the emptiness of space itself and captured by our sense as observer through visible things [2]. In this way, we can feel the textures of space visuality. The presence of dark space is basically not caused by the absence of the light in the space but by being negative against the element of presence. The light actually is not the opposite of the darkness. In the darkness, we have no means of seeing, therefore we acted as the subject with the absence in our perception. In this way, our thinking, captures the presence of void, which is actually only a trace about the image structure that is present simultaneously with the traces of absence in the space.

The above ideas suggest that the presence of void, the state of absence is emerged as a temporary moment which has occurred. The essence of the visible things is located at the residue of the invisible things as in memory. This paper addresses the presence of space which is deformed as another story of void ideas. This idea becomes important to discuss the contexts of unoccupied, unexploited, dan unprogrammed space [3].

The discussion in this paper begins with the understanding of void as presence and absence, in order to explore various related elements. Then, these elements are used as the approach in studying the spatial order. The results suggest some parameters that become the basis for developing design method, which will be developed further.

## 2. LAYERING

Void : unidentified, invisible, unconscious connections, uncanny, effacing, empty set, the dash, experience, impossible, discontinue, transition, connector, unseen, closed off, veiled, invisible, hidden, secret, memory, sign, movement, scenario, stage layout.

One example of the empty space exploration through memory is Jewish Museum in Germany. The Architect, Daniel Libeskind [4], defined the quality of space in the museum building by displaying communication among mental, personality, and emotional level of the museum visitor and the dimension of the historical Berlin City.



Figure 1: Jewish Museum Libeskind

For example in Jewish Museum the quality of space was shown along the corridor or bridge which are connected to each other as a performance of the “absence”. One of the interesting things in the journey through building space is the void which appears not only as the physical void, but also as the presence of space in memory throughout the museum. The experience and the quality of space become the elements that contribute in producing the memory of void. As a result, the museum visitors were encouraged to imagine what they feel about the void inside the museum. The attachment of the furniture objects as the space filler does not lock the meaning of void in the space. Therefore, the idea of “the absence” of the space still appear simultaneously with the conveyed text of memory. The idea of absence in this case does not mean exposure of the absence at all, but rather the problem of “delaying” so that it is still present as a sign [5].

Sign in the structure of spatial representation contains lines and diagrams which create opening and closure around each other [6]. However, such mechanism of opening and closure depends on the dominant area, because the line area is not exactly the opposite of diagram and vice versa. This area could also be an affirmation or negation between them. This operation has the same mechanism with the void translation in the matter of presence and absence of space.

The idea of void as “presence” refers to the moment of absence, in which the absence becomes the displayed condition. There are two parameters as the main element in the “moment of absence”, the empty set [7] and the dash [8]. The empty set or regularly symbolized with { } refers to a set that has no members at all as a result of intersection of two unrelated elements. Furthermore, the results of intersection was present as an impossibility because it was blocked by the boundary connection of another universe. Meanwhile, the dash refers to a sign of separation or connection between the two unrelated sentence. This sign is the element of grammatical structure which gives a new meaning to the whole sentence. It functions almost like a colon, marking the limit boundary in a series of words so that it presents a meaning that gives orientation to the series. A whole sentence basically consists of a series of pattern languages separated by meaning. This separation becomes a cryptic space, in which the dash breaks into that structure. This break finally gets into the delay condition, which connects the assumption from the original statement to intention. In the end, the existence of void in this presence has resulted in the space as a medium between two substances or it can be termed as the in-between space. However, this “in-between space” might be identified or unidentified depending on the spatial context.

The idea of void as “absence”, relates to the problem of absence that can be inverted to presence in architecture. Eisenmann named it as a rhetorical figure [9], that is the situation of new form that disappears from the final form and loses the meaning. That process of losing is translated into the absence situation. This process involves an order as a representational figure which represent, something external. The difference between rhetorical figure and representational figure is the meaning of

absence within and not related to the outside. Arepresentational figure presents something in that absence, while a rhetorical figure contains that absence and therefore, opens possibilities.

The layer of absence consists of two parts, the unknown space and the image of absence. And both parts might affect the idea of void. First, the term of “the unknown space” refers to the unconscious connection [10], that was a cross connection about the different what is seen and what is imagines, whether it is materialized or not. However, what I want to reveal here is about how the unconscious connection is related to reality and the term of uncanny. Hegel [11]proposed the concept of uncanny through the visionary notions in which the absence was expressed through fragility in the emptiness. This suggests that the condition that was seen normal, homely or safe, basically kept something secret or unhomely thing inside. In other words, there is a crypt meaning which hides among the invisible.

Second, “the image of absence” [12]refers to the condition which consists of invisible form but still can be felt. In other words, it can be said that space is present in different materials. The way of reading “the image of absence” can be done with two methods, by remembering the tracks or by experiencing the space. The method of remembering the track is called “effacing”. It can be known by looking at the remains of memory or trace of sign. In this way, it is possible to separate the visible matters and the stated matters as the translation of void in architectural space. Goulthorpe [13] revealed that exploring of the absence trace also can be done by writing as image and then, the image will create spatial of repetition and temporary transformation. This method allows us to record the meaning of absence in image by tracing object in the most recent condition of reality. Related to this idea, Brook [14]defines the absence is not only as a literally empty space, but also by the movement of activity inside the space. For example the meeting point between spectators and actors in a boundary, creates interaction between object and subject in that space. Therefore, the absence involves the movement, scenario, and layout of stage which are present through the movementsduring the performance.

Based on the above discussion on void as absence an presence, we can conclude some elements that are involved in the idea of void in two kinds of translation.

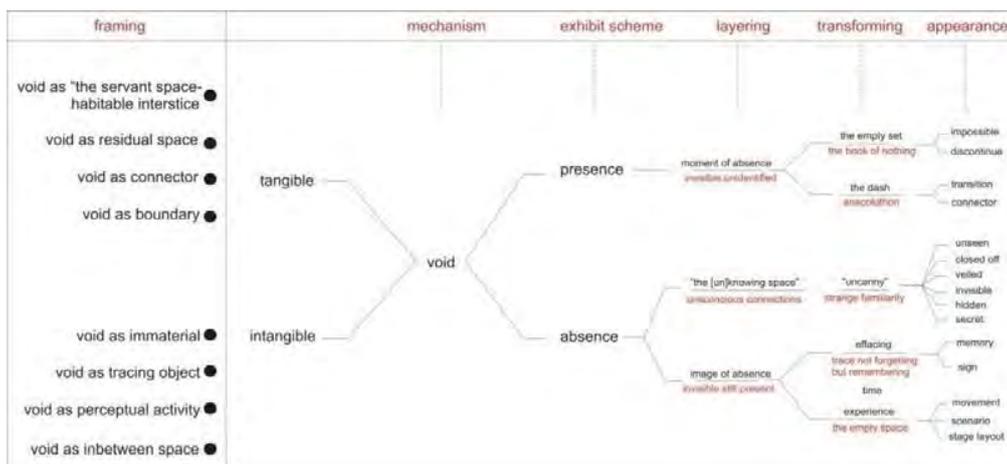


Figure 2: Framing of Void Mechanism

There are eight parameters that form the discontinuity mechanism based on void exploration which are void as boundary, void as residual space, void as connector, void as the servant space, void as immaterial object, void as tracing object, void as perceptual activity, and void as in-between space. These parameters become the basis in “reading the void”.

Both the absence and presence have a different mechanism of void. The idea of “moment of absence”, refers to passive observation. We just need one time slicing in object observation because the object is tend to be static condition. On the other hand, the idea of “image of absence”, needs the object observation that could capture thedynamic condition of space experience and activity. In addition, there are some characters present in “the moment of absence” such as the invisible and undefined transformation of absence in the space. Meanwhile “the image of absence”, we can still feel the object through its trace although both of them arephysically invisible. Therefore, the state of absence can be found through experiences in the space.

### 3. FRAMING

Void : tangible, intangible, the servant space, residual space, connector, boundary, immaterial, tracing object, perceptual activity, inbetween space.

To discover the absence and the presence in the ideas of void, we try to explore that the idea within spatial context through qualitative analysis. This exploration is to see how each element of void can work with the context-related elements. It also questions whether the ideas of void work with the keyword in the same way or changed into other mechanisms. One of the parameters that we use in studying the spatial context is explaining “singularity” [15] contained in the site context. The location of site context that we chose is Kampung Pulo, Jatinegara in East Jakarta. There are five spots that were analyzed in the study of the void, corridor area, gathering area, house yard area, space in between houses and the edge of main street. This qualitative reading of the void in the context will reveal different ways of understanding the void.



Figure 3: The Reading of Void as “boundary”

Figure 3 illustrates the reading of void as boundary in the corridor area. The shaded parts show void area, which is the building wall. In this case, the void refers to an “impossibility” as shown in “the empty set”. It is formed by the boundary which separated the universe in that area between the outside and the inner parts. The outside consists of the street and the courtyard, and the inner parts consist of elements in the house such as living room, kitchen, and bedroom. Therefore, the void space revealed in this area is an invisible and unidentified space.



Figure 4: The Reading of Void as “Intermediary”

Figure 4 illustrates the reading of void as intermediary in the corridor area. There are two functions of voids which work in this area, as connector and as separator [16]. These functions refer to the opening space like door, window, and ventilation. These openings become the connector and separator between architectural order and social order [17]. Concept of space as intermediary is also related to the concept of transparency. Rowe and Slutzky [18] described this transparency as simultaneous perception in different spatial locations. The simultaneous perception is present as overlapping images with slicing between them. Finally, the slicing represents intermediary space in the idea of void.

Following the similar methods, all the five spots in Kampung Pulo were analyzed to explore the idea of void. The analysis is presented in Figure 5.

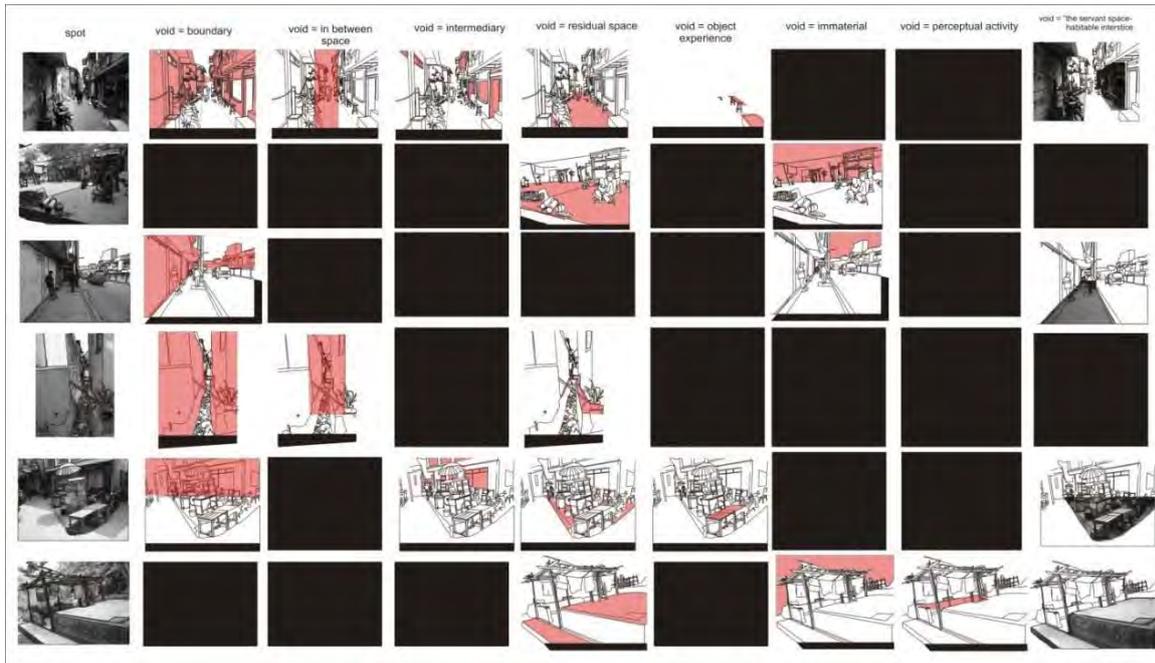


Figure 5: Exploration of Void Mechanism in Spatial Context

Based on the analysis, the ideas of void can be explored at spatial context in a comprehensive way. The ideas of void can be classified into two categories, the tangible area and the intangible area. In the tangible area, void is presented as a form that can be seen and felt directly. Meanwhile the intangible area, void merge with the abstract space that must be defined following the “presence” and “absence” mechanism in that space.

#### 4. CONCLUSION

From the exploration of void and the spatial context above, we conclude the idea of void as a delay or void as a delaying event. In this context, the event captures a moment as a discontinuity of time within an image. The discontinuity establishes the absence of space as a void. Tschumi [19] also explained that the idea of discontinuity is derived from dislocation phenomenon. The understanding of absence in discontinuity is important so that the delaying elements can be defined and transformed in architectural space. Libeskind defined an absence by referring to the silent space [20] which is a space that is intended for predator or terminator, and space that cannot be passed. This space is also not for architects because architects tend to do something like an actor in theatre. They always want to appear and act, so that the way for following the silent space for architect is divergence. Divergence is separation between symbol and experience from previous path. Therefore, the way of understanding the spatial absence from previous path is cutting the time that is running at that moment. So the spatial does not produce the history translation in one kind, but diverse to many stories. The steps of stories decide new meaning of the delaying, that is interspace.

This paper has illustrated a work in progress on development of design method based on the ideas of void. Although the analysis was limited to certain spatial context, the findings suggest opportunities for this approach to be applied in other various context. This paper concludes a possibility to explore further the delays space through discontinuity mechanism at the spatial context. There are eight parameters that making the discontinuity mechanism based on void exploration at spatial context, that are void as boundary, void as residual space, void as connector, void as the servant space, void as immaterial object, void as tracing object, void as perceptual activity, and void as inbetween space. The purpose of these parameters is for the reading of the spatial issue and the translating spatial program within the architectural design process. These findings open some possibilities to be applied in further design work.

#### REFERENCES

- [1] O'Brien. *Absolute Zero-Revealing the Void*, Journal of Monash University, Australia.
- [2] S. StraBmann, “The Void/Nothing But Space”, Retrieved 29 November 2012, From Web :<http://www.igloo.ro/en/habitat/126/sarah-stramann-the-void-nothing-but-space/>, 2012.

- [3] F. Sebregondi, "The Event of Void-Architecture and Politics in the Evacuated Heygate Estate", University of London. September, London, 2011.
- [4] D. Libeskind, "The Space of Encounter", Thames and Hudson, United Kingdom, 2001.
- [5] B. Tschumi, "Architecture and Disjunction", The MIT Press, London, 1999.
- [6] A. Benjamin, "In : Any Diagram 23", Architecture New York Ten Dollars, New York, 1998.
- [7] J. D Barrow, "The Book of Nothing", Vintage, Great Britain, 2000.
- [8] Z. Mennan, K. Mehmet, and Y. Keren, "In : Anytime, The MIT Press, London, 1999.
- [9] P. Eisenmann, "In : Theorizing A New Agenda for Architecture Theory", Princeton Architectural, New York, 1996.
- [10] I Borden, J. Kerr, J. Rendell, and A. Pivaro (Eds), "The Unknown City: Contesting Architecture and Social Space", MIT Press, Cambridge, London, 2001.
- [11] A. Vidler, "The Architectural Uncanny", The MIT Press, London, 1999.
- [12] C. Buci-Glucksmann, " In : Journal of Philosophy and the Visual Arts No.6 "Complexity", Academy Group Ltd, London, 1995.
- [13] M. Goulthorpe, "In : Anytime", The MIT Press, London, 1999.
- [14] P. Brook, "The Empty Space", Touchstone, Simon & Schuster, New York, 1968.
- [15] P. Eisenmann, "Diagram Diaries", United Kingdom: Thames & Hudson, 1996, p.36
- [16] G. Teyssot, "In : Log 18", Winter, USA, 2010.
- [17] A. Forty, "Words and Building", Thames & Hudson, United Kingdom, 2000.
- [18] Wordpress, "Transparency", Retrieved 10 December 2012, from Web : <http://architecturality.wordpress.com/2010/10/20/transparency-i-layering-of-planeslayering-of-spaces/>
- [19] B. Tschumi, "In : Anytime", The MIT Press, London, 1999.
- [20] D. Libeskind, "The Space of Encounter", Thames and Hudson, United Kingdom, 2001.

# Accelerating Village Development through Institutional Arrangement

Ni Gst.Ag.Gde Eka Martiningsih<sup>a</sup>, I Gusti Agung Sri Rwa Jayantini<sup>b</sup>

Faculty of Agriculture Mahasaraswati University, Denpasar  
E-mail : [ekamtb@yahoo.co.id](mailto:ekamtb@yahoo.co.id)

English Department STIBA Saraswati Denpasar  
E-mail: [srijay04@yahoo.com](mailto:srijay04@yahoo.com)

## ABSTRACT

*This paper tries to present several activities that are of use to help people in accelerating village development through institutional arrangement. Institution is one of the important elements for development process. In Bali as part of the Indonesian archipelago where culture ties people strongly and influences Balinese way of life, the informal institutions have stronger influence than that of formal institution. Through the so-called IbW that stands for Ipteks bagi Wilayah (Technology for Region), community engagement is hoped to be attainable. The community empowerment programs were carried out in two sites namely Angkah village and Bengkel Sari village. In Angkah village and Bengkel Sari village of Bali Province where some groups of community had already existed, many empowerment activities were conducted. For example, a half of cattle raiser group members took their cows in the communal barns and sixty percent (60 %) of micro enterprise products were sold to the other villages. In summary, what people in Angkah village and Bengkel Sari village do is, indeed, very useful for technology dissemination. It is this community empowerment programs that show the process of knowledge transfer among community members which can be utilized as a means of institutional arrangement.*

## Keywords

*institutional arrangement, village development, community engagement*

## 1. INTRODUCTION

It is irrefutable that development involves tangible and intangible aspects of human life. As they refer to infrastructure used as built capital, the tangible aspects are easily seen from the physical parts of development outcomes. To support the development, built capital includes various human-made objects and systems like sewers, water systems, electronic communication, equipment for processing plants, and even soccer fields (Flora, 2008). The intangible aspects seem equal to what it is defined as social capital. Social capital reflects the connections among people and organizations or the social glue to make things, positive or negative, happen (Coleman, 1988; Portes and Sessenbrenner, 1993 in Flora, 2008). Development that primarily aims at managing environment and gaining human welfare involves social capital for it plays a significant role to create a healthy ecosystem and a vital economy (Triglia, 2001; C. Flora, 1995, 1998a, 2000; J. Flora, 1998 in Flora, 2008).

This paper focuses on the utilization of institutional arrangement and community engagement as parts of social capital to accelerate village development. As the operators to gear the development in rural areas, universities should participate in rural areas development. Flora (2008) proposes the involvement of academics with their institutions in accelerating development through biosecurity. To interpret this involvement, university investments in both bridging and bonding social capital are often key entry points for participatory rural development. As a good start, it is suggested that universities should begin working for biosecurity to increase inclusion. In a wider sense, working for biosecurity means to involve people in preserving their environment in the support of invasive species eradication. Saving rural area environment should include community participation. Community members should show their engagement so that the planned development programs can touch the grass root in their implementation.

Furthermore, Flora (2008) emphasizes that universities can optimistically hope that investment in social capital, communities and regions results in improved initiative, responsibility, and adaptability. "The indicators showing a balanced increase in social capital are a shared vision (which takes time and trust to develop), building first on internal resources (which means the community has together determined their existing assets that can be turned into capitals for participatory rural development, looking for alternative ways to respond to constant changes (rather than the silver bullet solution that a certain investment will solve everything), the loss of the victim mentality (feeling overwhelmed by globalism or climate change), and loss of a cargo cult mentality (where the community waits for an outside investment to rescue them)." (Flora, 2008).

Inspired by the fact that universities can be involved to encourage village development through various community service programs, the IbW programs funded by the Indonesian Directorate General of Higher Education in collaboration with the government of Tabanan regency in Bali Province were conducted in two villages namely Angkah and Bengkel Sari. In the Indonesian language, *IbW* that stands for *Ipteks bagi Wilayah* which literally means technology for region. Therefore, the funding is used to conduct several community service activities to drive the community development through the transfer of technology. The programs began in the early of 2010 that lasted two years. All planned activities finished in 2012 covering the

activities to establish some farmer groups and manage their farming through collective works, to encourage the farmers' capacity building in technology transfer among the existing groups as well as to promote strong production power for the community welfare.

The IbW programs are primarily dedicated to community service. To empower community in rural areas, universities should utilize the existing capitals where the programs are implemented. The general aims of the IbW are to strengthen the social capital and to provide ongoing mentoring. How can universities strengthen the social capital and provide ongoing mentoring for the community living in rural areas and ensure that their investments support sustainable development? The answer for this question is reflected in the benefits that people gain through several designed and implemented IbW programs. Take for example, the groups of farmers in rural areas are able to access the wider prospective market to sell their crops by adopting the bigger enterprises' success. In this way, the IbW programs facilitate the groups of farmers to gain more profit as they are able to either map or reach all of the possible markets to sell the rural community's products. In addition, the farmers are also able manage the waste of their plantation and pet to produce organic fertilizer. For the women small enterprises, the IbW programs are proposed to explore women' skills and creativity. Generally, the proposed program aims at managing their home industry. Management knowledge that women adopt is expected to benefit them in transferring their ability for the sake of family's welfare.

Tabanan regency is one of the rich regencies in Bali Province. The government plans to drive new village development more actively. The important strategy for a new village development is implemented through local institution building. In the regency where seventy percent of the community members are farmers, capacity building must be performed through the institutional arrangement. However, Tabanan government has limited staffs to implement all programs in many villages and to develop all potentials as the assets of the villages. The university involvement and investment in accelerating village development is part of the efforts to improve the quality of education, research and services. Hence, the implementation of the IbW programs is the alternative to cope with rural community's problems which, at the final end, is expected not only to arrange the existing formal and informal institutions but also to make farmer wealthier through their land production.

In the third world or developing countries including Indonesia, institutional arrangement is one of the elements that is significantly needed. The role of institution is very important. In Bali as part of the Indonesian archipelago where culture ties people strongly and influences Balinese way of life, the existing institutions need to be seriously arranged. The informal institutions in Bali have stronger influence than that of formal institution. Hence, through the *IbW* that stands for *Ipteks bagi Wilayah* (Technology for Region), community engagement is hoped to be attainable. In addition, community is also facilitated to build several groups of team work in order to increase community capacity building. Among their existing groups, the farmers, women and cattle raisers in the villages where the IbW programs were implemented participate actively. Through the interaction and communication in many occasions, they can explore the opportunities to build their contribution to each other. Both knowledge transfer and capacity building may be expected to take place at the time the groups of farmers conduct their collective works, meetings to solve their problems in farming, raising their cattle and expanding their small enterprises. In this way, community engagement and institutional arrangement are the capitals to be utilized in accelerating village development.

## 2. LITERATURE REVIEW

Development is a process to gain the aims of a group of people, community or nation for better economy. This definition is often used to measure how development shares its benefit for people. It is a process that is believed to be an alternative to solve community problems including all aspects of people life such as poverty, socio-economic gap, crime, justice, art and culture, agriculture, etc. Arif (2000) states that nothing but development is the best way to solve the problems that exist in people life such as socio-economic problem and unemployment. As the outcomes are dedicated for human welfare, development takes place in all countries in the world. Developed countries had undergone lots of processes that make them be on the state of being 'developed'. The USA, UK, Japan and many other countries in Europe are the examples that come easily in people's mind to be called as developed countries. For sure, development does not only take place in the developed countries. In the third world countries like Indonesia, development is the key factor to cope with a group of people's, community's as well as nation's problems. However, development for the third world countries may sometimes become a nightmare because the development outcomes only take people to worse condition. For example, poverty alleviation cannot be perfectly done in development due to mismanagement. This often happens continuously since the policy makers in government fail to fulfill people's needs. In addition, some developed countries tend to expand their power for the sake of more economic profit. This motive will affect the poor countries that are still on their track to fix several national problems.

As known as the agricultural country, one of the specific meanings for development in the Indonesian context is the development for the agricultural production. In marketing their farming crops, the community members are often disappointed due to the low price when they sell their product. This makes them not produce the commodity anymore. On the other side, the gap of the poor and the rich in Indonesia is obviously seen. People who have money will buy the imported products. It becomes their lifestyle since it feels more prestigious to buy foreign products. As a result, the Indonesian products have no competitive power and lower selling price. The impact of this situation is that all community basic needs are hard to afford due to people's low income.

Crewe and Elizabeth (1998) state that the success of development is subjective. It depends on the values used to measure the success and the failure of development. They illustrate two projects used as the examples to strengthen their assumption. The first project is how technology innovation in Rome was used for the benefits of poor people. This small

fishery project was conducted to improve people's nutrition. As the project began, many people were involved in the technology adoption process. Even women showed their active participation in this project. At the end, without a good support from the government, this project was only a story for the history. The second example is the use of stoves with an easy technology. The project aimed at reducing the use of woods for cooking in the households so that the wood cutting is under control. However, on the due date, the funder is not satisfied because it is considered that the project gives nothing for national economy, wood preservation and the measured global pollution. On the other side, women were, in fact, helped by the project program. They could feel that the project make their burden lighter. This demonstrates that the development failure is partly caused by how the project is implemented. Many projects have the features of 'top down' that easily make people the ones who cause the failure.

Facing such phenomena, Ife (2002) states that the bottom up management is more useful than the top down management. The top down management disharmonizes community objectives with the government policy while through bottom up development, community can manage their resources in smart manner. People also know what they really need. The best way to implement the development programs is based on community engagement. When community is engaged to realize several planned programs for development, environment and social justice should always be on the top of priority list. The policy makers should be smart in designing the programs that are not only beneficial for a short period but also be of use for long period of time. Instead, it should be sustainable and convenient. Once the programs fail to fulfill the principles of social justice and equality, people may become skeptical. Or, to make it worse, there will always be victims in the long queue waiting for some cash that lasts only for several days.

Falk (2011) tries to see development from sociological perspective. He starts with a question, "what is 'development'?" He considers that this apparently a simple question is not really so simple. Development programs are regularly based on the assumption that people's behaviour can and should be changed. "There are two dimensions to change processes. If it is assumed people *can* change their behaviour, there is a clear strategic dimension of the research, whereby aspects of change at individual, community and policy levels are desired by someone or some group for some purpose. If, on the other hand it is assumed people *should* change, this implicates an ethical and methodological dimension." It is because the justification for assuming the right to intervene (Fox, 2009 in Falk, 2011) in people's lives involves both an ethical question, situated in time and culture (Simons & Usher, 2000 in Falk, 2011), as well as a methodological one. For the methodological question, Falk refers to Christie (2006) as the example.

Furthermore Falk (2011) discusses why ethics is at the basis of development. It is stated that the word 'participation' is just another word for 'intervention' is clear. After all, any process of knowledge sharing, participation, intervention, collaboration, change and many other terms, involve intervening in people's lives. "Essentially, *what* people do is always and irretrievably embedded in a process –*how* people do it. There is no *what* without *how*, and it is the *how* that determines the success or otherwise of development as well as the success of its outcomes. A process must involve interaction as the basis, and interaction may result in people changing. Change is what intervention relies on and is the basis of development." In support to the importance of community engagement in development, Falk (2011) adds that development then is concerned in some way with interventions. Interventions are a partnership between people with a common interest. Such partnerships are not necessarily easy to develop or support. These partnerships may have several characteristics like complexity, resource poor, lack staff stability and reflect the divisions or inequalities in any society. Development relies on building trust between the participants. Trust that the intervention is indeed in the best interests of the participants.

With regard to how development should be designed and the involvement of universities in accelerating development, Flora (2008) shares her perspectives on maintaining social capital which usually divides into bonding and bridging. It is found that investment in both bonding and bridging social capital including accepting the time it takes to build trust and reciprocity, is often an important entry point. A particularly effective way to build social capital is to work with diverse groups in the community to strengthen, for example the youth groups as human capital. The university as participatory rural development practitioner must have the patience to build trust and reciprocity through doing what they say they will do. The question of how universities with its academics can do in taking part to rural development is best answered through a constant and well-connected rural presence. The investment can also be done by giving local people a way to reciprocate in a way that maintains their dignity and meaning.

With regard to how institutional arrangement should be understood, according to UNDP's website, "institutional arrangements are the policies, systems, and processes that organizations use to legislate, plan and manage their activities efficiently and to effectively coordinate with others in order to fulfill their mandate." It is also explicitly stated that institutional arrangements should be managed by involving universities, public administration and the private sector. This reflects that the universities involved in community services should consider the typical institutions exist in community. As Moers (1999) states that institution plays a significant role to improve and accelerate community development especially in remote area. In Indonesia, institution arrangement includes formal and informal institution. Even though some experts state that the role of institution is still neglected, the importance of institution, in fact, strongly affects the economic system. In Bali, the concept of institutional arrangement in rural areas is closely related to the existence of local informal institution which ties people and their custom strongly. The informal institution is useful to drive remote community activities since this institution has stronger effect than that of formal institution. Thus, strong local informal institution often becomes the key factor to accelerate rural development.

### 3. METHODOLOGY

This research utilizes qualitative methodology which was performed by doing observation, interview with community members, and government staff in Regency and District level. The interview was conducted with groups of male and female farmers. Through in-depth interview, the representative data describing the quality of community life in Angkah village and Bengkel Sari village were gathered. In addition to the interview with the farmers, the observation was of use to clearly see the benefits that people gain from the IbW programs. The improvement of people's quality of life can be felt through some trainings provided for students of vocational school and village community.

The objectives of utilizing qualitative methodology in conducting this study were divided into two categories. Generally, the objective of this method was to investigate the improvement of community awareness on the importance of building local institution in community level to drive the capacity building. This will result in the establishment of community engagement and institutional arrangement. Specifically, the qualitative method applied in this study was to clarify to outcomes of several community service activities that have been performed. To make it clear, the aims of designing some programs invested in Angkah village and Bengkel Sari village were:

- (1) to encourage the fruit farmer groups to join the training about how to manage plantation and to avoid the pest and diseases attack
- (2) to assist farmer to eradicate and clean their plantation with organic fertilizer to improve the plant growth
- (3) to assist farmers in taking care of their cows
- (4) to provide an applicative technology to produce organic fertilizer from cow manure and organic waste
- (5) to share tips on how to produce the hygiene product to gain good market and price
- (6) to conduct a training to manage small enterprises.

### 4. DISCUSSION

#### 4.1 Accelerating Village Development

One of the sustainable development criteria is that the actions taken by the authority have to assist people to gain benefit from the development programs released for the good of community. Sustainable development should not only be profitable in economic aspect but also be beneficial for the community to manage the environment for the next generation. This is in line with Sastrapratedja (1986) who states that sustainable development orientations include action oriented, quality oriented, goals oriented and future oriented. The four orientations can assist the policy makers to determine the priority in performing the activities for the sake of gaining the expected development outcomes. In Bali, development is also conducted to give more benefits for Balinese people. The strong power of culture and religion in community assists people to live in harmony among the households. Each community member bases their action on the philosophy of *Tri Hita Karana* (THK) that is fully respected since the concept of creating the harmony between the creator and the people, the harmony between person to person and the harmony between community and environment.

Table 1: The Natural Resources, Human Resources and Infrastructure in Angkah and Bengkel Sari Villages

POTENCY	ASPECT	PRELIMINARY SURVEY RESULTS
NATURAL RESOURCES	Agriculture	<ul style="list-style-type: none"> <li>• The farmers are not yet satisfied with the harvest from about 780, 3 Ha rice field, even more, it is now raid by rats</li> <li>• The enthusiasm to carry out organic farming on rice fields is still low</li> </ul>
	Dry Field Farming	<ul style="list-style-type: none"> <li>• The farmers are not yet satisfied with the harvest from about 802,2 Ha plantation</li> <li>• The harvest of mangosteen and sawo is satisfying</li> <li>• Market networking has not been optimal</li> <li>• The farmers are still being hampered by product continuity which is not optimal yet</li> <li>• Land sanitation and fertilizing have not been carried out by the farmers effectively</li> <li>• Mangosteen and sawo waste has not been managed well</li> </ul>
	Livestock	<ul style="list-style-type: none"> <li>• The farmers are still letting their cows wandering outdoor (no cowshed yet)</li> <li>• Modern technology used in livestock feces and urine waste processing is still limited</li> </ul>
	Water Resources	<ul style="list-style-type: none"> <li>• River utilization has not been conducted</li> <li>• Waterfall potency has not been utilized</li> </ul>
	HUMAN RESOURCES	Education
	Law	<ul style="list-style-type: none"> <li>• Lack of knowledge on community law which includes:               <ul style="list-style-type: none"> <li>• Village boundary</li> <li>• Traditional law</li> <li>• Traditional law of inheritance</li> <li>• Land certification</li> </ul> </li> <li>• The life skill capability of the housewives &amp; PKK members of making plaited mats and traditional cakes for ceremonies is not yet satisfying</li> <li>• Low creativity in terms of home industry diversification</li> </ul>

	Creative Economy	<ul style="list-style-type: none"> <li>• Low capability of home industry product packaging</li> <li>• Low capability of marketing the products of home industry</li> </ul>
	Economic Institution	<ul style="list-style-type: none"> <li>• Farmers, breeders/cattlemen, and creative economic enterprises as well as women have not yet been institutionalized</li> <li>• Products marketing has not yet been done collectively so it still depends much on collectors</li> <li>• The access to financial aids is still limitedly opened because institutional effort is still weak</li> </ul>
	INFRASTRUCTURE	<ul style="list-style-type: none"> <li>• There is one improper type machine in the village office</li> <li>• There is one bad-condition computer in the village office</li> <li>• No internet access yet</li> </ul>
	Government	<ul style="list-style-type: none"> <li>• Incomplete kindergarten playing equipment</li> <li>• Insufficient facilities for primary and secondary school libraries</li> </ul>
	Health and Sanitation	<ul style="list-style-type: none"> <li>• Chikungunya attack is still a serious problem in the two villages.</li> </ul>

In the first year, the IbW programs in Angkah village and Bengkel Sari village had resulted in positive impacts for communities in the two villages i.e Angkah and Bengkel Sari. Prior to knowledge transfer process between the groups in these villages, building several groups and encourage the capacity building among the existing groups of community members are necessary. The close relationship and strong partnership give positive influences to accelerate community engagement in the two sites. The community in Angkah village and Bengkel Sari village also support each other. For example when community in Angkah village conducted training for the improvement of their farming activity, some of Bengkel Sari's farmer groups willingly joined the training. Similarly, the Angkah village groups of farmers would also join the activities performed by the groups of farmers in Bengkel Sari village. This demonstrates that communication between two communities may help the establishment of knowledge transfer processes.

Several activities had been undertaken in Angkah village and Bengkel Sari village to manage the villages' potentials and to utilize them as the capitals in accelerating the village development. The programs cover the improvement in building the small existing enterprises such as women home industry, farmer groups, and fruit farmer group to sell and promote their production. Through the IbW programs, the groups of farmers are expected to sell their product in a wider market by implementing by the bigger enterprises' tricks to access the prospective market. The IbW programs also include the efforts to facilitate groups of farmers to access all of the possible market for rural community's products so that the members of farmer groups and small enterprise groups gain more profit. Other activities had also conducted by the community in Angkah village and Bengkel Sari village through the IbW facilitation like building the village animal barns and giving some training for the farmers to manage the waste of their plantation and pet to produce organic fertilizer. For the women small enterprises, the IbW programs were designed to train women to explore their ability both for managing their small home enterprises and for transferring knowledge from one groups of women to the others. The result of this women group encouragement is that the groups of women had gained more profit. For the cattle raiser groups, the impact of waste management can be seen on the organic farming activities in the two villages. In addition, the cattle raisers took their cows in the village barns collectively and the farmer groups called *wana sabo* had used organic fertilizer. Table 2 demonstrates the activities that had been performed in the village of Angkah and Bengkel Sari.

Table 2: The activities and the outcomes of the IbW programs in Angkah and Bengkel Sari villages

No	Activities/Products	Produsen	The Sites
1	Making various cakes for offerings in performing Balinese Hindu	The Groups of Homemade Industry called Mekar Sari	Bengkel Sari Village
2	Nonrice cakes made for household needs and for the offering	The Groups of Independent Household Industry in Angkah Village	Angkah Village
3	Export quality mangosteens which are not produced in its harvest period and the use of organic fertilizer	The Groups of Samsaman Kaja Mangosteen Farmers	Angkah Village
4	Export quality sawo which are harvested after the use of organic fertilizer	The Groups Kelompok Sawo Wana Sabo	Bengkel Sari Village
5	Wine and crackers made from sawo	The Groups of Homemade Industry called Mekar Sari	Bengkel Sari Village
6	Juice made of mangosteen	The Groups of Independent Household Industry in Angkah Village	Angkah Village
7	Compos and Bio Urine Made of Cow Manure and Urine	The Groups of Cattle Raiser Called Dina Tirta	Bengkel Sari Village
8	The Offerings Waste	The Women Groups	Angkah Village and Bengkel Sari Village
9	The activities were conducted by giving some training to groups of rice paddy farmers, farmers who plant corn, groups of farmer during the harvest time, the mapping of water	The IbW team of Mahasaraswati University and the community involved in the programs	Angkah Village dan Bengkel Sari Village

	fall as tourist area, facilitating the determination of traditional village law called <i>awig-awig</i> and <i>awig-awig subak</i> .		
10	Empowering the establishment of groups of farmers to socialize and train farmers to implement the techniques of safe fishing for the environment and individual safety.	The Groups of Farmers in the hamlets, smaller part of the Angkah Village.	Angkah Village

#### 4.2 Institutional Arrangement and Community Engagement

The synergy between institutional arrangement and community engagement is necessarily needed to establish capacity building in order to gain the expected objectives. How important is institution for a country and its development? Institution is one of the important elements for development process. Institutional authorities are the decision makers who are expected to encourage people to involve themselves in development. Despite the statement of some experts who state that the role of institution is still neglected because institution is considered not important, the importance of institution, for instance, strongly affects the economic system. Nowadays in the economic area, institution plays a significant role (Moers, 1999). When the economic theory is widely expanded, institution is necessarily needed to be a guarantee for minimizing transaction cost and constructing conducive atmosphere at community level. For its role to be significantly needed to motor the development, particularly in rural areas, community engagement is no different. How can development outcomes be attainable if community does not want to participate either individually or collectively? As important as the existing institutions that should be arranged, community engagement in development is also a key point since the government programs need people participation to make them successful. Besides being the object of development programs in the sense that programs are designed to improve the people quality of life, people are the actors to perform the policies of authorities. Therefore, they have to be engaged in development through the activities conducted by their groups in community.

Capacity building of farmer groups in community village will drive community to raise the awareness to identify their problems and then to be able to cope with them. It can also be useful to encourage people to cope with their problems independently without government support. It is important to raise community confidence and try to make people have a critical thinking especially the young generation. Improving the capacity building of community will encourage the young generation as the innovators who are able to encourage their community to live a better life. If people have their innovators, there is a hope that the transfer of knowledge and technology among groups in the community village will succeed. Nowadays, as the matter of fact, the support from an agriculture field assistance staff that is sent by the government through the agriculture department is very rare. Sometimes the authorized staff sent to community depends strongly on the government policy. This condition may challenge the community to actively and independently find the answers for their own problems.

In regency level, there are policies designed for development programs that are included in the middle term strategy and long term strategy. To gain the expected outcomes for the sake of human welfare, these two strategies have to engage community since interaction among people is the capital that can be utilized as the glue in collective works. People believe that the important step to accelerate regional development is through community engagement. The main objective of community development has to be related to environment sustainability and social justice (Ife 2002). In developing countries the government policy sometimes tends to be not applicable. As a result, it is difficult for the community members in rural areas to raise their awareness and to manage their life. Say, for example, the program of direct cash services and rice for the poor. The phenomenon taking place when the programs were conducted demonstrates how poor people are really in hunger of services. They live in poverty continuously that those two programs are not the sustainable alternatives to improve the quality of their life. Hence, community management in remote area should be a government focus. It must become the priority of the regional development in the aims of alleviating the poverty. It is widely believed that until today the majority of people living in poverty is found in the village. For this reason, the central government has to drive the regional government to make a priority of village community management. The regional government may involve more people to participate in performing development programs. Through community based management, the government can measure to what extent the designed plans benefit people.

In the efforts of improving and accelerating development especially in remote area, two significant elements that can be continuously utilized in accelerating village development are institutional arrangement and community engagement. Institutional arrangement may take place if there are institutions established by the community on which they rely some activities. Then the existing institution in rural areas encourages community engagement. This will happen through the groups of community that people participate in. In their groups, people show their participation, create their partnership, interact to each other to maintain communication. Communication among their peers can help community to talk more about the issues they need to discuss like technology in farming and raising their cattle, the use of fertilizer and the eradication of pest and disease. As can be seen in figure 1, these two elements are the pillars in the 'house' of village development. The synergy between institutional arrangement and community engagement in accelerating village development plays a significant role to lead people in living a better life.

This paper tries to put forward the issue of accelerating village development through the implementation of IbW programs which involves universities as the scholars in collaboration with the local government to accelerate development by strengthening the existing social capital where the programs are implemented. This demonstrates a synergy between universities and government that needs the academics' support to provide ongoing mentoring to address the community problems. The specific focus of this study is to show the utilization of institutional arrangement and community engagement as

the two pillars to ensure the implementation of all development programs. For the institutional arrangement, the informal institutions that have strong power to involve community's participation in the planned development programs should be wisely utilized. In the sites where the IbW programs were implemented, the community was strongly tied by their religious activities ranging from performing ceremonies in their family shrines to reflect the level of households' activities to conducting collective works for the village temple ceremonies to demonstrate the need of communal participation.

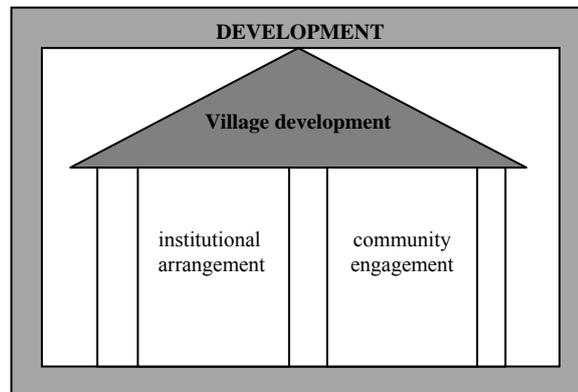


Figure 1: The synergy between institutional arrangement and community engagement

## 5. CONCLUSION

The community in two villages i.e. Angkah and Bengkel Sari villages where this community service was conducted agree that the IbW programs are beneficial for them to create many encouraging activities. One of the main sustainable development points gained through this program is that the university investment in the village has assisted people to increase their quality of life. The expected sharing benefits of the programs are not only profitable in the economic aspect but also sustainable to strengthen the social capital. The IbW programs are also intended to train the community to manage environment for the next generation. The strong impact of IbW programs in Angkah and Bengkel Sari villages is how the institution especially local institution can drive community to increase the awareness on the environment management and to independently face the challenges by themselves without government support. In the first year of the IbW programs that was in 2010, several works had been successfully conducted such as building farmer groups, managing small enterprises, and encouraging entrepreneurship habit in community to improve the family's and village's welfare. Here, the farmer groups were assisted to manage their plantation, to eradicate pest and disease attack as well as to give fertilizer in the farmers' plantation based on organic farming. The groups of farmers, women and cattle raisers in the two villages are the informal institutions that should be managed to help the establishment of community engagement to be used as the capitals in accelerating village development.

## 6. ACKNOWLEDGMENT

We would like to thank Directorate General of Higher Education in giving the funding for the programs we are willing to implement in two villages of Tabanan Regency, Bali Province, Rector of Mahasarawati University Denpasar, the Director of The Centre of Community Services, and the Government of Tabanan Regency that have already facilitated this program through the moral and financial support. We would also like to express our gratitude to Angkah and Bengkel Sari communities that have already focused on all of the IbW programs conducted in their village.

## REFERENCES

- [1] S. Arif, *Menolak Pembangunanisme*. Yogyakarta: Pustaka Pelajar, 2000, p.356
- [2] Bappeda. *Rencana Pembangunan Jangka Menengah (RPJM)*, Tabanan Regency. 2010
- [3] E. Crewe, H. Elizabeth. *Whose Development? An Ethnography of Aid*. London: Sage Publication. 2005, p.107 BLM ADA KOTA TERBIT
- [4] I. Falk, "Ethics of Development," unpublished.
- [5] C. Flora, "Social Capital and Community Problem Solving: Combining Local and Scientific Knowledge to Fight Invasive Species" (in Indonesia and Australia), *Kritis and Learning Communities*, special co-publication. pp. 41-54, 2008
- [6] J. Ife, *Community development. Community-based alternatives in an age of globalisation*. Pearson Education Australia. p. 309. 2002
- [7] E. Martiningsih, "The Role of Women In Comunity Management of Biosecurity." (in Indonesia and Australia) *Kritis Edisi Khusus Pengelolaan Ketahanan Hayati Berbasis Masyarakat*. pp. 110-30, 2008.
- [8] Moers, L., "How Important Are Institutions for Growth in Transition Countries?" unpublished
- [9] Sastrapratedja, M., J. Riberu., Frans M. Parera. *Menguak Mitos-Mitos Pembangunan (Ethic and Critical opinion)*. Jakarta: Gramedia Pustaka Utama. 402 p. 1986.
- [10] Soewandhi, S.N. *Sebuah Pemikiran Tentang Diseminasi Karya Pengabdian Kepada Masyarakat Perguruan Tinggi Indonesia*. Application Ipteks Magazine "Ngayah" vol.1. no.1 pp. 1-16, 2010.
- [11] Suwondo, K. "Etika Pembangunan Berkelanjutan." unpublished.

# Coping in Widows Who Have Children with Moderate Mental Retardation

Bania Maulina<sup>a</sup>

<sup>a</sup>Faculty of Medicine, Islamic University of North Sumatra

E-mail : maulinania@yahoo.co.id

## ABSTRACT

*Stress appraisals could include harm/loss, such as loss of a loved or valued person. The other one was to care for a handicapped child. This study is also a follow up that initially analyzed quantitatively. The researcher was interested in one of participant that was raising a disabled child, i.e moderate mental retardation and at the same time, she became a widow. But, she showed different reactions from the others generally. It was a unique case. A qualitative method was chosen to gain a detailed description about how the participant reacted to, how to deal with and how she could survive related to her current condition. Moreover, there are many problems arised. Data was obtained from depth interview and observation. Analyzing of data was also associated to the coping theories. The result found that belief in God as her coping and took on a major role. But, it was not only involved cognition and emotions, but also spiritual aspects. Maybe, there is other approaches that could explain the aspect, deeper than the coping theory.*

## Keywords

*Widow, coping, stress, belief in God, mental retardation*

## 1. INTRODUCTION

Certain environmental demands and life events produced stress in substantial numbers of people. Stress appraisals could include harm/loss, such as loss of a loved or valued person. The others one was caring for a handicapped child. Many researches related to stressful experiences impact to lost a spouse or raising a disabled child.

The stressful effects of the death of a spouse in a large sample of women and men. It found that women and men were more likely to exhibit serious depression during the first year after the death of their spouse than were a married women and men who had not lost their partners. The other studies also found that middle aged widows were involved in various forms of compensation, such as the consumption of drugs, alcohol and sometimes were diagnosed mental disorders. They tended to use drugs to cope with the loneliness problem. Many middle aged women could not adjust well related to their status as a widow. This feeling is reinforced by the frustration of sexual urges that could not be met and the family income will not meet again for fulfilling family life<sup>1,2</sup>.

Being a mother and father at the same time required additional responsibility that could ultimately led to the overload role<sup>1</sup>. Some conditions were related to widowhood, such as a sense of grief, economic problems, sense of deep loneliness, less leissure, e.g chance of being interested in activities outside the home or do activities with their neighbor together contributed to the level of stress experienced. Widows were also facing social problems, i.e reluctant to leave the house alone and seem strange when there was no partner. The length of their widowhood were also associated with the level of stress experienced. A woman who had been widowed less than 5 years tend to experience greater stress, included dissatisfaction of revenue and had more negative emotions than women who had been widowed for more than 5 years<sup>1,2</sup>.

But, it did not appear on a woman that now became a widow. This widow was 42 years old when her husband died and has been a widow approximately 1.5 years. The researcher did preliminary obeservation before and found that she did not exhibit negative behaviors like the previous researches. This widow was still doing her rountine activities, such as going to market, going drive her child to school and opened a business selling clothes.

Beside as a widow, she also has a handicapped child. Research on the widows' coping who was raising a handicapped child, had done. The presence of a disabled child in the family is the most disappointing. Negative feelings, such as angry, rejected, sadness, shame, guilt, self-pity, depression and even conceal or refuse to admit the child as hers. The stressors experienced by widows also included grief from the loss of a normal child, child's handicap severity, the chlid's lack of social skills,

dependence upon someone, fear regarding the safety and health of the child, prospect of children lifelong, social isolation, huge expenses, such as fee for therapy<sup>1,3</sup>.

One kind of handicapped children is mental retardation. The American Psychiatric Association (APA) describes mental retardation in the Diagnostic and Statistical Manual, 4<sup>th</sup> Edition, Text Revised (DSM). In the DSM, a diagnosis of mental retardation requires an IQ of approximately 70 or below as well as deficits in areas of adaptive functioning. The DSM definition further codes mental retardation by severity. Mild mental retardation has an IQ range of 50-55 to approximately 70, moderate mental retardation has an IQ range of 35-40 to 50-55 and severe mental retardation has an IQ range of 20-25 to 35-40. Persons with an IQ below 20 or 25 are diagnosed as profoundly mentally retarded<sup>4</sup>.

Further, research on widows who are raising handicapped children is also scarce. The previous studies found the widows experienced stress related to behavior problems of their children and stress would increased along with the bad behavior or difficult emotions<sup>1,5</sup>. The previous studies also found that stress in mothers of children with moderate mental retardation had higher than children with mild category<sup>6,7</sup>.

Coping in mothers of children with disabilities also tend to be less adaptive than mothers who did not have children with disabilities<sup>8</sup>. The previous research findings indicated that some mothers thought eventually would get better with the medication<sup>1</sup>. The other study found that middle-aged widows who caring for handicapped children may be at risk for stress, depression and less adaptive coping. Further, in-effective (in-adaptive) coping, included withdrawal, aggression, self medication and defense mechanisms<sup>9</sup>.

But, it also did not appear on a woman who was raising a moderate mental retardation child. Although at this time, she was in middle-aged widow and had been widowed for less than 5 years, but she did not show like behaviors in the previous findings. Based on preliminary observation found that this woman showed different reactions from the others generally. Actually, she always care for her disabled child, take her handicapped child wherever she goes and goes drive her child to school.

This study is also a follow up that initially analyzed quantitatively. The researcher was interested in one of participant that was carinf for a moderate mental retardation child and at the same time, she became a widow. The researcher often interacted with this women before and saw her routine activities. The researcher thought that it was a unique case because she showed different reactions from the others generally. In the most cases, the widows usually showed negative reactions, such as aggression, self medication and defense mechanisms, but this women did not. The researcher interested to get a detailed description of how this women could survive related to her current condition. Moreover, there are many problems arised. So, to provide a detailed description of how the widow deal with her problems and how she could survive with many problems until now, which could be approximated by coping theories. One of them is the coping theory of Lazarus and Folkman.

The coping theory of Lazarus and Folkman related to cognitive approach. Concept of cognitive appraisal refers to evaluate cognitive process, that is the person evaluates the significance of what is happening for his or her well being. Coping is an effort to change cognitive or behavior to manage internal or external demands, that are assessed as a burden or something that is beyond the limit of individual ability. There are two general types of coping. The first, termed problem focused coping, is aimed at problem solving or doing something to alter the source of the stress, such as seeking of instrumental social support, taking direct action. The second, emotion focused coping, is aimed at reducing or managing the emotional distress that is associated with the situation, such as avoidance, seeking of emotional social support, acceptance and turning to religion<sup>10,13</sup>.

Cognitive has a significant role in the stress response and can be drafted into the interaction of two processes, termed: appraisal and coping<sup>11</sup>. Appraisal is a fundamental component of the process of coping that determine whether a situation is considered stressful. Changing cognitive appraisal of individual can reduces stress. Coping begins with the individual's cognitive appraisal of the meaning or significance of the problem to his or her life. It means that if a person feels that something is a stressful situation, coping is needed and otherwise, if a person does not feel something as a stressful situation, coping is not necessary. Perceived stressful situations can be minimized through effective coping skills<sup>10,12</sup>.

A qualitative method was chosen for this study to help the researcher gain a detailed description about how the widow reacted to her condition, how she cope with some problems and how this widow could survive related to her current condition. Moreover, there are many problems arised.

## 2. METHOD

A qualitative method was chosen for this study to help the researcher gain a detailed description about how the participant reacted to her condition and how to deal with some problems. This study is a follow up that initially analyzed quantitatively. The researcher was interested in one of participant that was caring for a moderate mental retardation child and at the same time, she became a widow. The researcher often interacted with participant before and saw her routine activities. The

researcher thought that it was a unique case. Based on preliminary observation found that the participant showed different reactions from the others generally. In the most cases, the widows usually showed negative reactions, such as aggression, self medication and defense mechanisms, but this participant did not like that. The researcher interested to get a detailed description of how this participant could survive related to her current condition. Moreover, there are many problems arised.

Because of sample size limitations, that was so difficult to find participant according to the research criteria, so this study only involved one participant. After the rapport built up, the researcher asked her permission to participate in this study. Data was obtained from depth interview, observation and document. It was done to get credibility. It meant that data obtained from the participant actually a picture of the participant herself. The researcher prepared an interview guide. It started from the problems related to widowhood and her experience who caring for mentally retarded child. The participant was interviewed in her quite room. The interviews lasted between 60 till 90 minutes. The researcher required some meeting to discuss the problems related to her experience as a widow who was raising a moderate mental retardation child. The Observations conducted in two sessions, the time of the interview and and outside the interview schedule, include expression, body language and her current daily activity. But, the researcher did not find some document.

So, because of the research purpose is to provide a detailed description of how the participant deal with her problems and how the participant could survive with many problems until now, which could be approximated by coping theories. One of them is the coping theory of Lazarus and Folkman.

At last, the researcher also confirmed the time for data retrieval. The interviews were audiotaped and transcribed verbatim. The researcher got a narrative data. So did the observation data. The researcher analysed the transcribed verbatim that have been collected. The researcher changed it into transcript. The transcripts were re-read to identify the ideas and meaning being expressed. After that, analysis and interpretation of the participant as a single case was done. Finally, the researcher will obtain a complete picture of participant that has a unique characteristics. Analyzing of data was also associated to the coping theories.

### 3. RESULT

The death of her spouse was a social condition that could led to a change of her life and required her to adapt. The participant must adapt to go somewhere alone without her spouse. It was something unusual for her. Many of the feelings experienced after the death of her spouse, such as reluctant to leave her house alone, felt unsecure and finally this feeling made her to be withdrawn, that reffered to in-effective (in-adaptive) coping. It meant that actually, the participant also felt a grief, showed reactions impact to her death of her spouse or in other words, it could conclude that the participant used coping in-effectively (un-adaptively), like Gass Sternas's findings. But it was not happened for a long time like Gass Sternas's research. The participant did not require a long period to cope with her condition. She only took a shorter time to adapt than widows in the previous research. The adaptation process from having a husband to became a widow occured in a short time than the others.

The adaptation process, namely having a husband then did not have a spouse encouraged her to adapt and this process influenced to stressful experiences, but it was happened in a short time. The participant absolutely need more time to adapt this condition. It was happened for several period but she got social support, especially emotional social support from her family and encouraged her to adapt to her current condition.

The observation data showed that the family member, like her elder or youngest sisters looked to visit her in the house to tell stories and joke with her. They also asked her to leave the house (go outside) to go on holiday or stay at the other family member's house out of the town. Family members took on a role as assistance, providing advice and someone in whom to confide private feelings. At last, she began to open to social activities again.

‘Need a long time to adapt with widowhood..First, after death of my spouse, if there is a invitation, I never go. Because no partner. I feel blame.. If I go somewhere alone, I feel clumsy, awkward.. For forty days, I never go outside. For sweeping the yard, I feel blame..’

‘..Approximately five months later, after my sister persuades me to go somewhere and give me support. After that, I will attend invitation. Sometimes, I will sweep the yard...’

It was similar to Lahey's statement that having someone to talk to, receive advice from and be cheered and reassured by is an important factor determining individual's reactions to stress. Individuals with good social support are less likely to react to

negative life events. Women were much less likely to become depressed after the death of a family member perhaps because women tend to have greater social support from friends. There was a common belief in the culture that the simple act, such as telling someone else about the problems is good for them. In this study, Social support from participant's family member took on a role that influenced her to be adaptive (adjust well).

How an individual deal with the problems may differ from the others because it was influenced of person factors (resource). Person factors included all characteristics of an individual, such as cognitive, e.g beliefs. Faith in God enable people to create meaning out of their life, even out of stressful experiences and maintain hope. In this study, the participant reported that lost a spouse as something was under the control of the God. It was a God's way to see how strong the participant could survive. It also meant that the situation was appraised by participant as something uncontrollable. There was a belief that an event is not contingent upon one's actions but upon fate from the God.

Beside that, the participant also assumed that source of stress, namely the death of her spouse could not removed. Then, to adapt to her condition, she tried to deal with the problems by changing her interpretation. Great faith in God changed her interpretation of stressor (the death of her spouse). She assumed that it was the God's trial to make her more stronger than before. She found an interpretation that is realistic and could minimized the source of stress.

"Now, I think that it's the God's Fate.. Allah might tested me..I could be strong or not to accept the God's trial.."

But, beside making an interpretation, when the source of stress (the death of her spouse) could not realistically removed or changed, the participant also used another ways to deal with the problems. She tried to manage her psychological reactions to stress (manage unsecure feelings). She reported that when she felt stress, she would do something that make her happy and relax. She assumed that it was a successful way for her to deal with the problems.

'If I feel stress, I will go outside, e.g playing volley...''Therefore, doing religious activities, chatting with friends, taking my youngest child to school.."

Many problems appeared after a woman became a widow. So was the participant. She had some problems related to her current conditions, namely education of children and economic problems, disabilities and prospect of children lifelong. It education of children problems was not significant because she got instrumental social support. To pay the tuition of her two normally children had financed by her family members and for the tuition of her disabled child had financed by government. It meant that she reported no problems with it.

"My family members help me for the tuition of my children, especially my oldest girl and the middle one. For my youngest child..His school doesn't receive school fees. It's free..So, I never had a problem.."

Related to economic problems, she reported that this condition was difficult for her because she has no permanent occupation.

She only had a boarding room rental business. Sometimes, her monthly income would not meet again for her fulfilling family life. So, to cope with the problems, she would choose to removed the source of stress because the source of stress could be handled by her. When she did not have enough money to pay something, she used one way to deal with. She tried to remove source of stress by doing direct something, such as negotiation. That is led to problem focused coping.

"After the death my spouse, economic conditions became a serious problems. It's so difficult... I don't work. I am only a housewife. My income just come from boarding room rental and vendibles. Certainly, it's not enough.."

"It will occur when ahead of Ied...I don't have enough money to pay in installment. I buy television on installment.

"So, I go to the his house and make negotiation..I requested time to pay in...'

Similar to adaptation process, for economic problems, she also used the same way to cope with something that could not handled by her. She would choose the other ways to cope for a uncontrallable problems. She decided to do something for minimizing this condition. Generally, she always turn to religious (Faith in God) to deal with. It meant that at first, the participant analyze situations for indentifying the problems. She analyzed that the problems. If it already could be handled by her or not. If the problems could be dealt with and considered as something controlllable, she would take a direct action, but if the problems could not be handled and considered as something uncontrollable, she would create meaning and maintain hope in difficult circumstances. A great belief in God affected to produced positive interpretation. She interpreted something positively. In the end, she returned everything to the will of the God.

Generally, theme of belief in fate always appeared as a way to deal with her problems. If the participant could not cope with her problems and she appraised as uncontrollable situation, she always turn to religious. Belief in fate meant that an individual accepted a stressful experienced and to do nothing about managing situational demands. Belief in fate could led to an appraisal of helplessness that in turn discourages relevant problem focused coping effort. It meant that she did nothing to modify stressful condition that it led to emotion focused coping effort. It was directed at regulating emotional response to the problem.

“But, I don’t concern it... I accept this conditions... Because of the God...”

The adequacy of the individual’s resources that often is conceptualization in terms vulnerability which also influenced to human adaptation to deal with the stressful problems. The vulnerability, such as psychological. The participant had good psychological aspects. First, she had a great belief and always used interpretation something positively. Second, she generally had positive feeling to response to her problems. If the positive feelings will occur, so negative feelings will be managed and led her to be adaptive. Beside that, she also had a strong motivation. The will to live for her children generated to survive or “fight feeling”. Overall, it was directed at her coping behaviors are adaptive

Source of stress was not only arised from her life events, but also because of conflict. Conflict occurs when two or more motives cannot satisfied because they interfere with one another. When one of family members gave a negative response about her disabilities of child, actually the participant would be angry but she could not express her emotion because of a reason, namely family relationship. It meant that actually the participant had the need to be with other people and to have personal relationships. In this case, the participant impressed to have aggressive motive (angry as a response) and affiliation motive. Both of this motive could not meet together. If the participant distributed her aggressive motive, it would produced a negative impact on affiliation motive. If the participant expressed her anger, it would be a negative impact on social relationship, whereres essentially, she had a strong affiliation motive.

Finally, it caused conflict and encouraged unsecure feelings. She was undoing as a reactions because of that. According to psychoanalysis approach that when conflict arises because the superego blocks an id desire. It meant that superego is more dominan than id. It caused an individual felt unsecure. So, ego tried to find safe and realistic ways to meeting the needs of the id and to depend individual from a bulid up of uncomfot feeling, that is the functions of ego and the process called defense mechanism. In this case, undoing as one of defense mechanism. She did it only to regulate emotional response. It was aimed at reducing or managing the emotional distress that is associated with the situation.

For some occasions, resources are in fact adequate, but the individual does not use them to their fullest because to do so might create distress. According to coping theory, the terms of superego is similar to cultural values. Internalizing cultural values proscribe certain type of action or feeling. Culturally derived values serve as norm that determine when certain behaviors and feelings are appropriate or they are not. The cultural values restricted the ways the participant to distribute her anger or used aggressive behavior to cope with.

“My youngest child was singing. At the same time, my niece was hearing him and made a crack. She said “it’not good..You can’t sing well..’After hearing it, I cry. I can’t scold my niece...’ I’m not comfort if I scold her.. Because, she is my niece. We are family...”

Beside that, actually the participant ever showed negative reactions associated to her unnormal child, like the previous findings. She felt sadness, self-pity, and sometimes became annoyed. She also complained about her child condition that has not been independently. But she did not show some behaviors like conceal or refuse to admit the child as hers. Even, based observation data, she always bring her handicapped child to go everywhere. She also entered her child on extraordinary educational program. Significant development of the child make her happy. These positive behaviors appear motivated by her love and concern.

“My youngest son has a weakness (she’s pointing at him)..Stupid..I feel sad and pity. Sometimes, I feel annoyed..”

“He isn’t nomally child..He hasn’t been independently. But after taking my child to attend studies, there was a significant development. That’s it, I’m grateful, I’m happy..He has followed the lessons in school for a long time..He’s a special school student..”

Similar to prospect of children lifelong problems, actually, she felt anxiety. It was same with the previous study. But she make an interpretation about what she can do with the child’s condition like that. She appraised that with the child’s disabilities, just can be acceptance. The previous research found that an individual who accepts the reality of a stressful situation would seem to be an individual who is engaged in the attempt to deal with the situation. First, individual appraised that the stressor was as real

evident, but after that she did nothing to cope with. It was done only for minimizing negative emotions. In this case, disabilities problems was viewed as reality that could not be removed and acceptance was a way to survive. This reactions was predicted because of her great belief in God. Belief in fate encouraged her to accept it, but actually it was impressed her helplessness reaction that could not be removed the problems.

“About my youngest child’s future..How else would, with his disabilities, I just accept..”

#### 4. DISCUSSION

There was a contrast between the result of this study and the previous research findings. This study found that the participant did not require a long period to cope with her condition. She absolutely took a time but she did not need much time to adapt. She only took a shorter time to adapt than widows in the previous research. The adaptation process from having a husband to became a widow occurred in a short time than the others. It was influenced by social support, either emotional or instrumental support, resources and a great belief in God. There was a common belief in the culture that the simple act, such as telling someone else about the problems make them felt good. Social support took on a role as assistance, providing advice and someone in whom to confide private feelings encouraged her to rise up or to be adaptive (adjust well). It is supported by Lahey’s statement that having someone to talk to, receive advice from and be cheered and reassured by is an important factor determining individual’s reactions to stress. Individuals with good social support are less likely to react to negative life events.

The others factors that also determined the way an individual deals with the problems is motivation. Motivation is a term applied to explanations of why individual behave the way she do, why she start some activity, choose its direction and persist in it. This factor also was had by the participant. She had a strong motivation, e.i the will to live for her children, the will to survive or “fight feeling”. Similar to the great belief, especially Faith in God. This belief always encouraged her to make interpretation positively. Belief in God created meaning out of her life, even out of stressful experiences and maintain hope.

The way an individual copes with the problems is influenced by many factors. Problem solving skills is one of them. Ability to search for information, analyze situations for the purpose of identifying the problem in order to generate of action that are referred to problem solving skills<sup>9</sup>. In this study, a good problem solving skills was existed by the participant. To deal with the problems, at first, she would do analyzing and identifying. If the problems was considered as something controllable, she would take a direct action, but if it could not be handled or considered as something uncontrollable, she would create meaning and maintain hope in difficult circumstances. In other words, she always turned to religious that led her to produce positive interpretation, that is everything to the will of the God.

The participant had many factors that encouraged her to cope with adaptively so she could survive until now. But, on this participant, belief in God took on a major role. That is also a major theme in this case. So, to discuss belief in God, it required other approaches to produced a deeper findings. Because, belief in God as a coping was not only involved cognition and emotions, but also spiritual aspects. Maybe, there is other approaches that could explain the aspect, deeper than the coping theory. Maybe, the transcendental approach could be used for that.

#### 5. CONCLUSION

This study found that the widow was caring for a moderate mental retardation child had many problems. Changing in the status of having a spouse then became a widow with a moderate mental retardation child. All, it required adaptation process. But, all of the problems could be dealt with adaptively. She used problem and emotional focused coping to deal with her problems. Coping adaptively also was influenced by many factors. The participant had many factors that encouraged her to cope with adaptively so she could survive until now. The factors are motivation, belief, problem solving skills and social support, either emotional and instrumental support. But, on this participant, belief in God took on a major role.

This study also found that source of stress was not only arised from her life events, but also because of conflict, but her internalizing cultural values proscribe certain type of in-effective (in-adaptive) coping.

## ACKNOWLEDGMENT

I thank to my participant who was so willing to talk to me. I am also grateful to my supervisions for her/his suggestions on my paper.

## REFERENCES

- [1] Gass Sternas, K.A. (1995). Single parent widows: Stressors, appraisal, coping, resources, grieving responses and helath. *Journal of Marriage and Family*. New York, Vol.20, Iss. 3-4; pg.411, 35 pgs.
- [2] Hurlock, E.B. (1999). *Psikologi perkembangan: Suatu pendekatan sepanjang rentang kehidupan* (Edisi Kelima). Alih Bahasa: Istiidayanti & Soedjarwo. Jakarta: Erlangga.
- [3] Mangunsong, F. (1998). *Psikologi dan pendidikan anak luar biasa* (Cetakan I). Jakarta: LPSP3 UI.
- [4] APA. 2000. *Diagnostic & Statistical Manual of Mental Disorder (fourth edition)*-Text Revision. Washington: APA.
- [5] Adams, R.A. (1999). Maternal stress in caring for children with feeding disabilities: Implications for health care providers. *Journal of the American Dietetic Association*, 99,5.
- [6] Floyd, F. J., Erin M. G. (1997). Parental stres, care demands, and use of support services for school age children with disabilities and behavior problems. *Journal of Family Relations*, 46,4.
- [7] Little, L. (2002). Differences in stress and coping for mothers and fathers of children with Asperger's syndrome and nonverbal learning disorders, *Journal of Pediatric Nursing*, 28,565.
- [8] Walker, L.A. (1989). The role of maternal employment and depression in the phyhological adjustment of chronically ill, mentally retarded and well children, *Journal of Pediatric Psychiatry*, 14, 357-370.
- [9] Lahey, Benjamin, B. (2004). *Psychology: An Introduction (eighth edition)*. New York: McGraw Hill Companies.
- [10] Lazarus, R & Folkman, S. (1984). *Stress, appraisal and coping*. New York: Springer Publishing Company.
- [11] Dunn, M.E. (2001). Moderators of stress in parents of children with autism, New York. *Community Mental health Journal*, 37,1,39,14.
- [12] Sarafino, Edward P. (2002). *Health Psychology: Biopsychosocial Interactions (fourth edition)*. New York: John Wiley & Sons, Inc.
- [13] Weintraub, J. K., Carver, C.S., Scheier, M.F. (1989). Assessing Coping Strategies: A Theoretically Based Approach. *Journal of Personalitu and Social Psychology*, 56, 2, 267-283.

## COPYRIGHT

This paper was my original research. It never had been unpublished. The authors are responsible to obtain all necessary permission for the data.

## Corporate *Waqf* – An Islamic Model CSR for Community Development

Budi Santoso<sup>a</sup>

<sup>a</sup>Faculty of Law, Brawijaya University, Malang 65145  
 Ph.D Student at Faculty of Law, National University of Malaysia  
 E-mail : budi.santoso@ub.ac.id

### ABSTRACT

Many development institutions perceive corporate social responsibility (CSR) as a potential mechanism to improve development. As a highly influential economic organization in the international development, multinational companies have moral obligation to practice their CSR in order to reduce negative impact of the development and created prosperous society. A multinational company in Malaysia, Johor Corporation (JCorp), proposed a corporate waqf mechanism to develop other business as an approach to sustain CSR. Through the corporate waqf mechanism, JCorp pledges to dedicate some of its annual dividend, payout from the shares transferred into waqf, to support charitable causes. While, some others are reinvested to ensure continuous growth of the waqf assets thus translate it into higher distributable income for the benefit of society at large. The corporate waqf can be considered as a CSR model based on Islamic business ethics, including for community development. This is due to the principle that property is a trust where its earnings and utilization should be accountable to ensure shared prosperity, social justice, community balance and stronger community.

### Keywords

Corporate social responsibility, waqf, community development

### 1. INTRODUCTION

Development is a key focus concerned by all countries in the world, both developed countries and developing countries. This issue is mainly concerned with the development of the domestic economy of developing countries [1]. According to United Nations Development Programs (UNDP), the poorest 40 percent of the world population—the 2.5 billion people who live on less than \$2 a day—account for five percent of global income, while the richest 10 percent account for 54 percent. Never before has the goal of abolishing poverty been within our reach: there are no longer any insurmountable technical, resource or logistical obstacles to achieving it. Yet, more than 800 million people suffer from hunger and malnutrition, 1.1 billion people do not have access to clean drinking water and, every hour, 1,200 children die from preventable diseases. Despite a growing world economy and significant advances in medicine and technology, many people in developing countries are not reaping the potential benefits of globalization [2].

The above situations require a significant contribution of development actors, including multinational companies. The company's activities give impact on development, but profit-maximizing motives are often incompatible with good development practice [3]. Therefore, companies are required not only to maximize profits, but also should pay attention to social and environmental aspects. Company is not just an economic entity, but also a social institution that is in a social environment as well as have a great social responsibility towards all stakeholders. Company has to practice CSR.

Nevertheless, CSR field presents a proliferation of approaches, which are controversial, complex and unclear. CSR theories related approaches in four groups: *first*, instrumental theories, in which the corporation is seen as only an instrument for wealth creation, and its social activities are only a means to achieve economic results; *second*, political theories, which concern themselves with the power of corporations in society and a responsible use of this power in the political arena; *third*, integrative theories, in which the corporation is focused on the satisfaction of social demands; and *fourth*, ethical theories, based on ethical responsibilities of corporations to society. In practice, each CSR theory presents four dimensions related to profits, political performance, social demands and ethical values [4].

in this context, a multinational company in Malaysia, Johor Corporation (JCorp), was being promoting Islamic model CSR through the implementation of the concept of corporate *waqf*. JCorp argue that the concept can ensure sustainable and equitable development. JCorp's corporate *waqf* concept is also a new concept in *waqf* development for enhancing the value of community.

Therefore, this article specifically is to analyse the concept of JCorp's corporate *waqf* as an Islamic model CSR for community development on international development perspective. Model elements of JCorp's corporate *waqf* will be analysed to understand the concept of corporate *waqf* and to show how relevant the concept as an Islamic model CSR to contribute to sustainable community development.

## 2. THE ROLE OF CSR IN DEVELOPMENT

Development has been defined as the process which facilitates for every human person and all peoples the enjoyment of economic, social, cultural and political development [5]. Thus, development is a comprehensive process, aimed at the improvement of the entire population and all individuals [6]. It can be done through activities to eradicate poverty, increase society health and education and so on. It is a fundamental goal of the international community, and is a clearly stated objective of The United Nations. The UN is enjoined in its Charter to promote higher standards of living, full employment, and generally conditions for economic, social and development progress [7]. This open-ended concept of development has now been given a more concrete content by the international community in the form of the United Nations assembly Resolution – The Millennium Declaration or The Millennium Development Goals (MDGs).

The MDGs is commitment of international community to achieve sustainable social and economic development by creating and expanding global cooperation. The MDGs constitute eight goals to be achieved by 2015, that are : halve extreme poverty and hunger; achieve universal primary education; empower woman and promote equality between women and men; reduce under-five mortality by two-thirds; reduce maternal mortality by three-quarters; reverse the spread of diseases, especially HIV/AIDS and malaria; ensure environmental sustainability; create a global partnership for development, with targets for aid, trade and debt relief [8].

To achieve the development goals, the commitment of international community is needed to expand global cooperation, including role which claimed to multinational companies. This is because multinational company has been regarded as part of development actors. Multinational company was very strong development actor compared other development actors. Their strength of capital have made they own great influence in world economy, even in political. They have penetrated political economy conditions strongly both in developing countries and developed countries. Their investments strengthened his capital through much profit and their contribution would be vital for costing political campaign [9].

Their extraordinary capital and their willing to continue resulting long-term profit cause the multinational companies must be involved in international development which can ensure all as well, namely sustainable development. According to The World Commission on Environment and Development (WCED), as in 1987 Brundland Report, sustainable development was defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs [10]. That development paradigm was explained again in The World Summit on Sustainable Development (WSSD) in Johannesburg, Africa, year 2002, that development must be including sustainable development concept as a new approach based on consideration of intersection and interdependency among economic development, social development and environment development [11].

Involvement forms required from multinational companies in sustainable development is through their CSR practices. CSR is a concept which contains understanding that a company must be responsible on social and environmental impact, sometimes conducted beyond law. On the other hand, the company must be responsible on code of behavior other parties with who the company trade. Also, the company must cooperate and make relationship with society, whether for business purposes or to increase society's value, or both [12]. Due to this, CSR would be a powerful way for the company to participate in improving development and contribute actively to sustainable development.

Theoretically, in the concept of CSR, the relationship between business and society is embedded with ethical values. This leads to a vision of CSR from an ethical perspective and as a consequence, firms ought to accept social responsibilities as an ethical obligation above any other consideration [13]. It is because at least three reason: firstly, company indeed shaped and managed by individual or those people derived from civil society; second, accumulation of the company investment is impossible be achieved without civil society which is their market; third, the company activity cause impact to society [14]. It means that company must do activity its business well in order to do not cause negative impact to social and environment, even could help create society is more prosperous. Through distribution some profit achieved by a company to society will raise positive impact to create social justice. Thus, in the concept of CSR, a company not only has responsible to gain profit but also to carries welfare for society and to ensure existence of nature persistence [15].

One aspect of CSR is community development. It is seen as the key corporate responsibility in some developing countries [16]. Community development is a process conducted by community members. It is a process where local people can not only create more jobs, income and infrastructure, but also help their community become fundamentally better able to manage

change. The “concrete” benefits of community development, such as employment and infrastructure, come through local people changing attitudes, mobilising existing skills, improving networks, thinking differently about problems, and using community assets in new ways. Community development improves the situation of a community, not just economically, but also as a strong functioning community in itself [17].

### 3. ISLAMIC VIEW OF CSR

A being stated that business organization has always played a vital role in the economic and social life of all people throughout the ages. In Islam, business activities are not undertaken to satisfy only material needs and wants but more importantly it should be undertaken to fulfill religious obligation and to achieve other non-material objectives such as to secure social needs. Social responsibility refers to the obligations that an organization has to protect and contribute to the society in which it function. Social responsibility in Islam stems from the concept of brotherhood (*ukhuwwah*) and social justice. The practice of social justice will prevent Muslims from doing harm. Social justice is strengthened through the concept of brotherhood. Brotherhood makes Muslims responsible to each other. The commitment of Islam to justice and brotherhood demands that Muslim society take care of the basic need of the poor [18].

The Islamic view of CSR takes a rather holistic approach. It offers an integralistic spiritual view based on the teachings of the *Qur'an* and the *Sunnah* providing a better alternative philosophical framework for man's interaction with nature as well as his fellowmen. In fact, the moral and ethical principles derived from divine revelations are more enduring, eternal, and absolute [19]. Thus it may serve as better guidelines for corporations when exercising their business and social responsibilities simultaneously.

Comparing with CSR concept of Western, CSR concept of Islam is not novelty. In the past the more secular approach of western capitalism with its focus on materialism, competition, profit maximisation and shareholder primacy [20]. More recently, western capitalism has begun a transition toward a model which recognise the business case for socially responsible behavior. This transition has been widely documented and researched and is well known amongst both academics and practitioners. It opens up the prospect that differences in management styles may become less acute and less of a barrier to successful international business ventures. In turn this might lead to positive returns as the opportunities of closer integration deliver wider benefits all round [21]. Whereas from Islamic perspective, CSR concept being long and becoming guide for who involved in business. Even, development goals in Islam give several points on CSR, such as human resource development, useful production, quality of life and balanced development [22]. Thus. It can be said that CSR concept which campaigned by current Western corporate governance is a part of Islamic corporate governance concept.

CSR for Muslims assumes a broader and more holistic significance. Obviously, the concept is not merely perceived as a strategic or instrumental initiative, which the corporations undertake for the sake of enhancing goodwill or boosting long-term financial performance. It is also not just an act to legitimize the existence of corporations in society and others within the framework of the legitimacy theory or the social contract theory. Instead, the concept of CSR in Islam encompasses a broader meaning embracing the *taqwa* dimension (God-consciousness) by which corporations as groups of individuals, assume the roles and responsibilities as servants and vicegerents in all situations. By so doing, they are ultimately responsible to God, the Owner of their selves as well as the resources they are utilizing and managing. This responsibility to God is, in fact, a function of the intrinsic quality of the Muslims' lives as a trust from God [23].

An example of CSR practice in Islamic perspective is in Turkey. It undertaken through *waqf* mechanism. Among multinational companies in Turkey which conduct activities of Islamic CSR are K09 Group, which is Turkey company first entered in Fortune 500, and Sabanci Group, has 50,000 employees and has USD10.6 total asset billion in year 2005. Those companies actively involved in the programs of through partial distribution their profit directly to hospital, school, and so on [24]. Whereas in Malaysia, there is a multinational company, Johor Corporation (JCorp), which introduce a corporate *waqf* mechanism as a new approach to Islamic model CSR particularly to contribute to sustainable community development.

### 4. JCORP CORPORATE WAQF: TOWARDS REACHING OUT TO THE COMMUNITY DEVELOPMENT

*Waqf* is an Islamic system that stems from the idea of institutionalising voluntary giving in order to guarantee sustainability. It has strengthened and empowered communities since the early days of Islamic history. Inspired by the spirit of *waqf*, on 3rd August 2006, JCorp took the first bold step into totally uncharted territory towards transforming itself into a full fledged Trust Corporate Institution via the Islamic *waqf* approach. This "Corporate *Waqf*" move involved the transfer to *Waqf* RM200 million (on net asset value basis) of JCorp's shareholdings in its public listed subsidiaries [25]. The Corporate *Waqf*, a first ever undertaken by a corporate business institution in the world, can be considered as an Islamic CSR program initiated by JCorp to

integrate business into serving a higher social cause. The aim is to institutionalize the link between the wealth creation and value addition effort of JCorp as a corporate entity with meeting the needs of the marginalized and the alienated in society on a structured and sustainable basis.

This corporate *waqf* concept may be carried out by creating firm and company organization which not possessed by particular individual. Nevertheless, Muslim community actually have not many aware about it even though it has long in Islamic. For example, Taj Mahal building is actually *waqf* building and when India is independent, the government has taken over. Similarly is Turkish government which built many large and aesthetical mosques, those used *waqf* approach. Also, Al-Azhar University in Egypt is even *waqf* practice which later copied by West people which established foundation enable those build Oxford University [26].

JCorp's corporate *waqf* is also testimony to JCorp's commitment towards ensuring 'giving back' to society and reaching out to the community. Through the *waqf* mechanism, JCorp pledges to dedicate 25% of the annual dividend payout for the shares transferred to *waqf* to be spent towards supporting charitable causes and religious institutional activities to meet the needs of the larger community of all ethnic and religious backgrounds, particularly for the benefit of the disenfranchised and the less privileged in society. Then, as much as 70% of the dividend is distributed to reinvestment, while its 5% is distributed to Johor Islamic Council [27].

Underlining its role as an 'Amanah' (Trust) Corporation, JCorp is conscious of its responsibilities to ensure that its business objectives and corporate successes are achieved based on methods and approaches that are aligned with Islamic and universal values that will, in the long run, benefit the society at large. Right from the start, JCorp has always adopted a much broader dimension to its corporate obligations in meeting with the aims and objectives of its CSR.

As a part of the entities in society, JCorp believes that the company, including its employees, morally should take an active participation in community and social development through CSR. The active participation is not only believed will increase JCorp image, but also will help to raise economic and social development. Due to this, JCorp trusts that by conducting corporate management through the concept of corporate *waqf*, practices of JCorp's CSR will be more ascertained continuity.

JCorp makes 'no injury principle' as important principle in implementing CSR. This principle refer to the rule which motivate corporate actions in relation with society. The relationship based on 'no injury principle' can prevent or reduce corporate negative action to others or society, selfish, or actions that may cause injustice to others. It also referred to effect of product or service to consumer and environment.

At JCorp, non-profit associations and bodies are known as Amal Business Organisation (ABO). ABO functions as a medium for JCorp to contribute towards the development of the ummah through various aspects of charity, well-being and recreation as well as entrepreneurship. In 2011, a total of 27 non-profit organisations are operating under JCorp's ABO. These ABOs are divided into four categories namely Social & Public Welfare Development, Entrepreneur Development, Sports and Recreation Development and lastly, Staff Welfare [28].

For its efforts of CSR, JCorp was awarded Best Corporate Social Responsibility Award by Halal Journal, in conjunction with The World Halal Forum 2006 [29]. Then, in 2011, JCorp was awarded Outstanding Development Project Award for CSR by Association Development Financing Institutions in Asia and The Pacific (ADFIAP) [30].

## 5. CONCLUSION

Generally, *waqf* property more developed through traditional ways, for example *waqf* property used immediately for school construction, religious worship and basic needs of society by social and religious institutions. Whereas corporate institutions having tight role and influence for development.

JCorp's corporate *waqf* is a new concept to develop *waqf* property. Through the corporate *waqf* mechanism, JCorp pledges to dedicate some of its annual dividend, payout from the shares transferred into *waqf*, to support charitable causes. Whereas, some others are reinvested to ensure continuous growth of the *waqf* assets thus translate it into higher distributable income for the benefit of society at large. The concept can be considered as an approach to sustain CSR for community development based on Islamic business ethics. This is due to the principle that property is a trust where its earnings and utilization should be accountable to ensure shared prosperity, social justice, community balance and stronger community.

## REFERENCES

- [1] Qureshi & Ziegler, *International Economic Law*, London: Sweet & Maxell, 2007.
- [2] UNDP, Annual Report 2006, available at: <http://www.undp.org/content/dam/undp/library/corporate/UNDP-in-action/2006/UNDP-in-action-2006-en.pdf>, accessed on 3 October 2012.
- [3] J.G. Frynas, "The false development promise of corporate social responsibility: evidence from multinational oil companies", *International Affairs*, vol. 81, no. 3, pp. 581-598, 2005.
- [4] E. Garriga, D. Mele, "Corporate Social Responsibility Theories: Mapping the territory", *Journal of Business Ethics*, vol. 53, pp. 51-74, 2004.
- [5] Declaration on the Right to Development 1986.
- [6] Declaration on the Right to Development 1986.
- [7] United Nations Charter 1945.
- [8] United Nations, United Nations Millennium Declaration, available at: <http://www.un.org/millennium/declaration/ares552e.htm>, accessed on 5 October 2012.
- [9] M. Hopkins, *Corporate Social Responsibility and International Development*, London: Earthscan, 2007; S. Zadek, *Third Generation Corporate Citizenship*, London: The Foreign Policy Centre, 2001.
- [10] M. Claire and A. Khalfan, *Sustainable Development Law: Principles, Practices and Prospects*, Oxford: Oxford University Press, 2004.
- [11] Ibid.
- [12] M. Blowfield, J.G. Frynas, "Setting new agendas: critical perspectives on corporate social responsibility in the developing world", *International Affairs*, vol. 81, no. 3, pp. 499-513, 2005.
- [13] E. Garriga, D. Mele, *Op. Cit.*
- [14] S. Wheeler, *Corporations and the Third Way*, Oregon: Hart Publishing, 2007.
- [15] J. Elkington's, *Cannibals with Forks: the Triple Bottom Line of twentieth Century Business*, in Isa Wahyudi, B. Azheri, *Corporate Social Responsibility: Prinsip, Pengaturan dan Implementasi*, Malang: In-Trans Publishing, 2008.
- [16] J.G. Frynas, *Op. Cit.*
- [17] Jim Cavaye, *Understanding Community Development*, available at: <http://www.communitydevelopment.com.au/Documents/Understanding%20Community%20Development.pdf>, accessed on 11 October 2012.
- [18] Mohd Rizal Muwazir et. al., *Corporate Social Responsibility Disclosure: A Tawhidic Approach*, available at: [http://myais.fsktm.um.edu.my/6934/1/Corporate\\_Social\\_Responsibility\\_Disclosure\\_A\\_Tauhidic\\_Approach.pdf](http://myais.fsktm.um.edu.my/6934/1/Corporate_Social_Responsibility_Disclosure_A_Tauhidic_Approach.pdf), accessed on 20 October 2012.
- [19] Khalik Ahmad, *Islamic Ethics in a Changing Environment for Managers*, in A.W. Dusuki, "What Does Islam Say About Corporate Social Responsibility?", *Review of Islamic Economics*, vol. 12, no. 1, pp. 5-28, 2008.
- [20] Al-Qordawi, *Al-Halal wal Haram fil Islam (The lawful and the prohibited in Islam)*, in G. Williams & J. Zinkin, *Doing Business With Islam: Can Corporate Social Responsibility Be a Bridge Between Civilizations?*, Kuala Lumpur: Nottingham University Business School, 2005.
- [21] Stiglitz, *Globalization and Its Discontents*, in G. Williams & J. Zinkin, *Ibid.*
- [22] Muhammad Hisyam, *Islam Galak Korporat Laksana Tanggungjawab Kemasyarakatan*, available at: [http://www.ikim.gov.my/v5/index.php/index.php?lg=1&opt=com\\_article&grp=2&sec=&key=813&cmd=resetall](http://www.ikim.gov.my/v5/index.php/index.php?lg=1&opt=com_article&grp=2&sec=&key=813&cmd=resetall), accessed on 18 November 2012.
- [23] A.W. Dusuki, *Op. Cit.*
- [24] Ceyhun Gocenoglu and Isil Onan, *Turki Corporate Social Responsibility Baseline Report*, Ankara: UNDP, 2008.
- [25] Utusan, *Jadikan wakaf JCorp kajian kes global*, available at: [http://www.utusan.com.my/utusan/info.asp?y=2008&dt=0812&pub=Utusan\\_Malaysia&sec=Dalam\\_Negeri&pg=dn\\_12.htm](http://www.utusan.com.my/utusan/info.asp?y=2008&dt=0812&pub=Utusan_Malaysia&sec=Dalam_Negeri&pg=dn_12.htm), accessed on 7 October 2012.
- [26] G. Makdisi, *The Rise of Colleges Institutions of Learning in Islam and the West*, in S.A. Arjomand, "The Law, Agency and Policy in Medieval Islamic Society: Development of the Institutions of Learning from the Tenth to Fifteenth Century", *Comparative Studies in Society and History*, vol. 41, no. 2, pp. 263-293, 1999.
- [27] Berita Harian, *Johor Corporation Jana Aset Wakaf Melayu*, available at: <http://www.bharian.com.my>, accessed on 4 October 2012.
- [28] Johor Corporation, *Corporate Social Responsibility*, available at: <http://www.jcorp.com.my/introduction-32.aspx>, accessed on 4 October 2012.
- [29] The Halal Journal, *The Halal Journal Awards 2006*, available at: <http://www.halaljournal.com/index.php?page=article&act=show&category=4&pid=6&PHPSESSID>, accessed on 4 October 2012.
- [30] Berita Harian, *JCorp menang dua anugerah ADFIAP*, available at: <http://www.bharian.com.my/articles/JCorpmenangduaanugerahADFIAP/Article/>, accessed on 24 October 2012.

# The Influence of Service Quality on The Satisfaction of Regular Patients in The In-Patient Wards in Putri Hijau Hospital Kesehatan Daerah Militer I/Bukit barisan Medan

Alamsyah Lukito<sup>a</sup>, Juanita<sup>b</sup>, Siti Khadijah Nasution<sup>c</sup>

<sup>a</sup>Faculty of Medical, Islamic University of North Sumatera, Medan 20143  
E-mail : alamsyah.lukito@yahoo.com

<sup>bc</sup>Faculty of Community Development, University of North Sumatera, Medan 20155

## ABSTRACT

*This study has been done in Putri Hijau Hospital Kesdam I/BB Medan to the regular patients in the in-patient wards. The purpose of this explanatory survey study was to analyze the influence of service quality on the satisfaction of in Putri Hijau Hospital Kesdam I/BB Medan. The data for this study were obtained from 140 regular patients through questionnaire-based interviews and then were analyzed through multiple linear regression tests. The result of this study showed that the quality of service measured based on the aspects of tangible, reliability, responsiveness, assurance and empathy had influence on the satisfaction of regular patients in Putri Hijau Hospital Kesdam I/BB Medan. Empathy dimension was the variable that had the biggest influence on the satisfaction of regular patients ( $\beta = 1.402$ ). The Putri Hijau Hospital Kesdam I/BB Medan is suggested to improve their quality of service for the regular patients to pay attention to the dimension of service quality that can improve the satisfaction of regular patients. The dimension of empathy needs to be especially paid attention because it is the most dominant aspect influencing the satisfaction of regular patients.*

## Keywords

*Service quality, satisfaction, patient*

## 1. INTRODUCTION

Patient satisfaction is a function of the assessment of patients for health services that provided by the hospital in the hope before the patient receiving of health care from the hospital as a provider; the patient will be satisfied if the quality of hospital services is higher or at least equal to the expected patient.

Advances in science and technology is rapidly causing the changes in the external environment and internal hospital, so the hospital managers must change the paradigm or worldview that hospitals today is not merely a social organization, but is oriented towards profit organization . Increased medical technology with other components force hospital managers to think and applying socioeconomically in hospital management in the face of market competition [7].

According Tjiptono [6] along with the progress of science and technology, in which changes take place rapidly, the higher education community, so that the needs, desires and demands of the community as an hospital customers are also increasingly complex. To achieve and sustain patient satisfaction, hospital organization must do the following four things: First, identify who are the customers. Second, understand the level of customer expectations for quality. Third, understand the strategy of quality customer service. And the fourth is to understand the cycle of measurement and feedback of customer satisfaction.

Level of customer satisfaction is highly dependent on the quality or the quality of a product or service offered [5]. According to Parasuraman *et al.* in Shahin [4], the quality of a service is determined by the 5 (five) dimensions, namely direct evidence (tangible), reliability, responsiveness, guarantee (assurance), and empathy. These dimensions were used to evaluate the performance of the company's customer service, so as satisfaction and dissatisfaction will depend on the fifth dimension.

Parasuraman *et al.* in Shahin[4], the anticipation of the quality or quality must be made by the hospital to survive and thrive is to increase the income of the patient, because the patient is the source of income of the hospital either directly (out of pocket). Without the patient, the hospital cannot survive and thrive given the cost of hospital operations is very high. Therefore, in order to increase patient visits to the hospital then the hospital should be able to display and give satisfaction to the patient.

One way to differentiate primary health care services, including inpatient services is to provide quality health care services than the competition consistently. The key is to meet or exceed the expectations of patients about the quality of care delivered. After receiving the health care services the patient will compare the service they experienced with the services expected. If the service is experienced under the expected service, the patient no longer interested to the health care provider. If the services of experienced meet or exceed expectations, patients will use the same healthcare provider in the future [5].

Parasuraman *et al.* in Shahin[4] identifies the gap between consumer perceptions and perceptions of service providers resulting in failure of the delivery of quality services. Services providers do not always understand exactly what the customer wanted. Furthermore Parasuraman *et al.*, in Shahin [4] states that the assessment of the patient's quality is determined by two things: the quality of patient expectations (expected quality) and the patient's perception of quality (perceived quality).

Based on these considerations, the measurement of the success of a company's services in this hospital are determined by assessments and patients' perceptions about the quality of services provided by hospitals with all the elements that exist in the internal and external environment which interact and influence the success of the hospital in achieving patient satisfaction.

According to Kotler [1] sense of satisfaction as feeling happy or upset someone who is experienced after comparing the perception of a product performance or results to expectations. Nevertheless, Supranto [5] states that many referred to the definition of satisfaction is based on the *disconfirmation paradigm* concept. Under this paradigm, satisfaction is formed from a reference comparison is to compare the results received with a certain standard. Comparison of the three possible forms: first is when the perceived service exceeds expectations where services received or perceived exceed expected service, the second when the quality of service to meet the service expectations if perceived as expected and the latter if the services received under expectations when service perceived worse than expected service.

In the goal-oriented patient satisfaction, as well as aspects of the role of the hospital facility resources such as doctors and nurses both medical and non-medical are very important because they will determine the performance of the patient's perception of the services provided. Perceptions of the patient toward the quality delivered will continue in the formation process of the general perception of the hospital.

According Wasisto [8] quality of health services is influenced by many factors in the hospital as a system. These factors are hospital management, health care, finance, healthcare facilities and technologies that used, and interaction-driven activity through certain processes and procedures by utilizing existing resources to produce a service.

According Puti [2], the quality and satisfaction are inseparable like two sides of a coin that are interconnected and influence. Quality gives an impulse to the patient to establish a strong relationship with the hospital. Relationships like this in the long run allow hospitals to understand thoroughly the needs and expectations of patients. Thus, hospitals can improve patient satisfaction in hospitals through a pleasant patient experience and minimize or eliminate unpleasant experience. Patient satisfaction in the end will be affect to the fidelity of patients to hospitals that provide a satisfactory quality.

One effort that patient satisfaction can be met will require information about what is considered important by the patient's perception and how the performance of the hospital today, whether better meet patient expectations or not. According Ranguti [3] level of customer expectations (patients) is one way of measuring patient satisfaction compared with the interests of the hospital, is expected by the necessary information will be known and what factors should be improved in order to give higher satisfaction to the patients.

Putri Hijau Hospital Kesdam I BB Medan is one of the hospitals owned by the Indonesian National Army in the city of Medan who receive public patients. Based on the strategic plan of the Putri Hijau Hospital Kesdam I BB Medan in 2010-2014 within Chapter III of the duties and functions of the hospital stated that in improving health services to the community as a whole, the targets are not limited to members of the army and their families, but also organizing health services for the general public.

The problem faced is the low level of satisfaction of patients using the hospital because of the quality of service provided does not meet the expectations of patients.

Based on a preliminary survey in January 2012, the general patient visits hospitalized at the Putri Hijau Hospital Kesdam I BB Medan in 2010 and in 2011 has decreased, from 2826 people to 1865 people so a decline of 34.01 %.

The results of interviews with 10 people hospitalized patients generally there were 8 people who complain about the patient's general health services such as hospitalization, medication services are not satisfactory, a consultation with the doctor is very limited, less comfortable wards, not firmly visit time of doctors to a hospitalization patient and nurses being less friendly to patients. The results of interviews with the patient to describe the phenomenon of regular patient dissatisfaction associated with the dimensions of quality of health care in hospitals.

Based on the description above and the low satisfaction of general patient that hospitalized at the Putri Hijau Hospital Kesdam I BB Medan the researchers would like to know "The Influence Perceptions of Service Quality on Patient Satisfaction Of Regular in the Inpatient wards in Putri Hijau Level II Hospital Kesdam I / BB Medan "

## 2. METHODOLOGY

This study was an *explanatory* survey, which aims to analyze the influence of perceptions of service quality on patient satisfaction of regular patient in the inpatient ward in Putri Hijau Hospital Kesdam I / BB Medan that conducted on a sample research of 140 people.

Method of data collection for the primary data in this study was obtained through direct interviews and secondary data from other official documents, especially the data in Putri Hijau Hospital Kesdam I / BB Medan. The data analysis processed was using multiple regression tests.

## 3. RESULT AND DISCUSSION

### 3.1. Perceptions of Quality of Care in the Putri Hijau Hospital Kesdam I / BB Medan

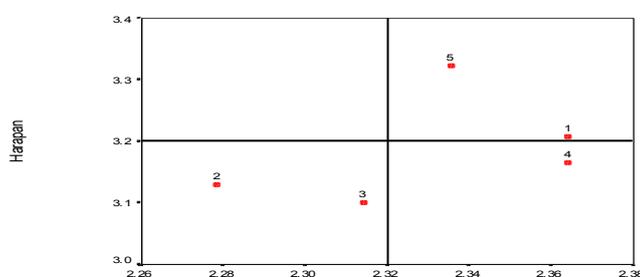
- 3.1.1. Dimensions of physical evidence (tangible) in the quality of care at the Putri Hijau Hospital Kesdam I / BB Medan by the results showed neatness of administrators uniform in accepting hospital patients is not well stated by 89(63.6%) respondents, neatness of physician in examinations and treatment is not well stated by 70 (50.0%) of respondents, the cleanliness and neatness of nurses in the treatment to the patient is not well stated by 59(42.1%) of respondents, the availability of equipment and health facilities in hospital is not well stated by 55(39.3%) respondents and comfort around the hospital environment is not well stated by 44(31.4%) of respondents.
- 3.1.2. Dimensions of reliability in the quality of care at the Putri Hijau Hospital Kesdam I / BB Medan based on the study indicates that the administrative management does very well stated by 92 (65.7%) of respondents, the ability of physicians to provide services examination and treatment are not well stated by 70(50.0%) of respondents, the ability of nurses to provide nursing services is not well stated by 56(40.0%) of respondents, suitability and adequacy of prescription drugs is not well stated by 52(37.1%) respondents and nurses timelines of the work is not good stated by 46 ( 32,9 %) respondents.
- 3.1.3. The dimensions of responsiveness (responsiveness) in the quality of care at the Putri Hijau Hospital Kesdam I / BB Medan based on research shows cost transparency, and the ability of administrators to explain about the fees charged to the patient in detail is not well stated 88(62, 9%) of the respondents, the ability of physicians to be responsive in resolving complaints of patients is not well stated by 68(48.6%) of respondents, dexterity (responsiveness) of nurses in helping patients at the time of need is not well stated by 56(40.0 %) of the respondents, dexterity (responsiveness) laboratory personnel in conducting laboratory tests on patients is not well stated by 60(42.9%) of respondents and dexterity (responsiveness) hospital janitor in a hospital environment does not handle well stated by 56 (40.0 %) of respondents.
- 3.1.4. Dimension of guarantee (assurance) in the quality of care at the Putri Hijau Hospital Kesdam I / BB Medan by the results showed that treatment guarantees given to patients is not well stated by 83(59.3%) of respondents, the ability of clinicians to establish diagnosis and cure the patient's complaint is not well stated by 72(51.4%) of respondents, courtesy and friendliness of clinicians are not well stated by 64(45.7%) of respondents, the ability of nurses to provide care is not well stated by 56(40.0 %) of the respondents and the courtesy & friendliness of nurses to serve patients is not well, stated by 67 (47 %) of respondents.
- 3.1.5. The dimensions of empathy in the quality of care at the Putri Hijau Hospital Kesdam I / BB Medan based on the results of the study showed concern administrative staff in providing information to patients about hospital services is not well stated by 68(48.6%) of respondents, attention physicians in dealing with patients and physician willingness to provide a special time for consultations to patients is not well stated by 57(40.7%) of respondents, the attention of the nurse in providing care services is not well stated by 61 (43.6%) of respondents, treatment of the hospital to the patient is not well stated by 65 (46.4%) of respondents and sympathetic physician in calming anxiety to the patient's illness experience is not well stated by 62(44.3%) respondents

### 3.2. General Patient Satisfaction for Service of Putri Hijau Hospital Kesdam I / BB Medan

- 3.2.1. Respondents expectations of administrative services at the Putri Hijau Hospital Kesdam I / B Medan discovered: as many as 55(39.3%) respondents expect neatness of officers uniform, 66 (45.7%) of respondents stated they were quite expecting compliance with service procedures in serving patients, 51(36.4%) of respondents stated they were quite expecting the response that given by officers in serving patients, as many as 78 (54.9%) of respondents stated that they were quite expecting certainty patients to obtain administrative services, 82 (58.6 %) of respondents stated that they were quite expecting the attention and attitude of administrative officer.

The reality of administrative services at the Putri Hijau Hospital Kesdam I / B Medan discovered: as many as 62 (44.3%) respondents were less satisfied neatness clothes officers, 53 (37.9%) respondents were less satisfied about the suitability of the procedure for the serve patients, as many as 62 (44.3%) of respondents said less than satisfied about the response of a given officer in the service of patients, as many as 47 (33.6%) respondents were less satisfied about the certainty of the patient to obtain administrative services, as many as 44 (31.4%) of respondents expressed concern the lack of satisfaction about attention and attitudes of the administrative officer.

*Cartesian analysis of administrative services*



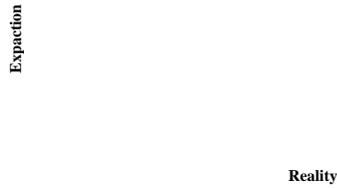


Figure 1 : Cartesian diagram of Administrative Services

3.2.2. Respondents' expectations of physician services at the Putri Hijau Hospital Kesdam I / BB Medan was found: 44.3% of respondents expect the neatness of clothing doctors, 37.9% of respondents stated they were quite expecting conformity with the procedure for physicians to serve patients, 33.6% of respondents stated they were quite expect the response given by the doctor in the service of patients, 40.7% of respondents stated they were quite expecting certainty physician services, 47.9% of respondents stated they were quite expecting attention and physician attitudes.

The reality of physician services at the Putri Hijau Hospital Kesdam I / BB Medan discovered: as many as 75 (53.6%) respondents were less satisfied neatness of attire doctors, as many as 67 (47.9%) respondents were less satisfied about the suitability of the procedure for doctors in serving patients, as many as 66 (47.1%) of respondents stated are not happy about the response given by the doctor in the service of patients, as many as 51 (36.4%) respondents were less satisfied about the certainty of the patient to obtain medical service, as many as 52 (37.1%) of respondents expressed the lack of satisfaction of attention and physician attitudes concern.

*Cartesian analysis of physician services as in the following diagram:*

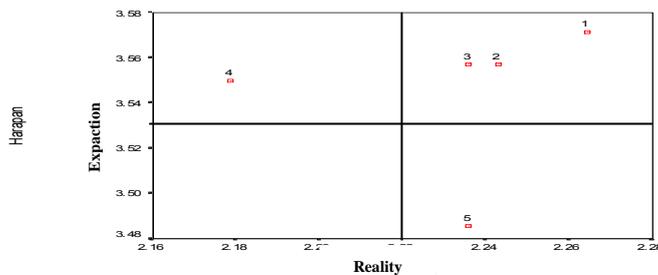


Figure 2: Diagram Cartesian of Physician Services

3.2.3. Respondents expectations of nursing services at the Putri Hijau Hospital Kesdam I / BB Medan discovered: as many as 53 (37.9%) of respondents expect neatness nurse outfit, as many as 44 (31.4%) of respondents stated they were quite expecting conformity with the procedure for nurses in serve patients, as many as 48 (34.3%) of respondents stated they were quite expecting the response given nurses in serving patients, as many as 68 (49.6%) of respondents stated they were quite expecting certainty patients to get care nurses by 76 (54.3 %) of respondents stated they were quite expecting attention and attitude of nurses.

The reality of nursing services at the Putri Hijau Hospital Kesdam I / BB Medan discovered: as many as 55 (39.3%) of respondents were less satisfied with the neatness nurse outfit, as many as 66 (47.1%) of respondents were less satisfied about the suitability of the procedure for nurses in serving patients, as many as 57 (40.7%) of respondents stated are not happy about the response given nurses in serving patients, as many as 46 (32.9%) of respondents were less satisfied about the certainty of the patients to get nurse services, as many as 36 (25.7%) of respondents expressed concern about the lack of satisfaction and nurse attitudes

*Cartesian analysis of nursing care as in the following diagram.*

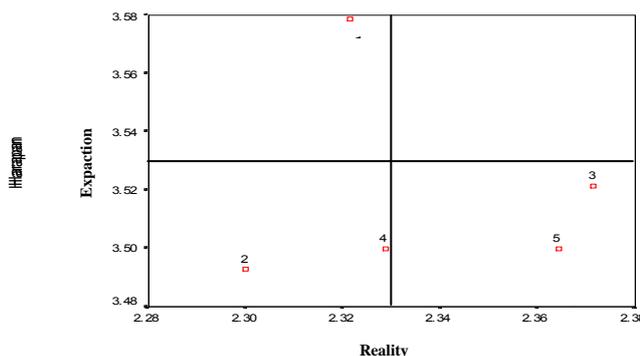


Figure 3: Cartesian Diagram of Nurses care

3.2.4. Respondents expectations of laboratory and pharmacies officer services at the Putri Hijau Hospital Kesdam I / BB Medan discovered: as many as 62 (44.3%) of respondents expect neatness of uniform of laboratory and pharmacies workers, as many as 59 (42.2%) of respondents stated they were quite expecting compliance with procedures of laboratory and medicine services officer in the service of patients, as many as 56 (40.0%) of respondents stated they were quite expecting the response that given by laboratory and pharmacies officials in serving patients, 60 (42.9%) of respondents stated they were quite expecting certainty patients for laboratory and pharmacies workers care as much as 86 (61.4%) of respondents stated they were quite expecting attention of laboratory and pharmacies workers attitudes.

The reality of the service of laboratory and pharmacies officer at the Putri Hijau Hospital Kesdam I / BB Medan discovered: as many as 47 (39.3%) respondents were less satisfied with the neatness of uniform of pharmacies and laboratory workers, as many as 53 (38.1%) of respondents said less satisfied about the suitability of the procedure for laboratory and pharmacies officials in serving patients, as many as 49 (35.0%) respondents are not happy about the response that delivery of laboratory and pharmacies officials in serving patients, as many as 49 (35.0%) of respondents stated not happy about the certainty of the patient to receive care of laboratory and pharmacies workers, as many as 48 (34.4%) of respondents stated they were quite satisfied about the care of laboratory and pharmacies worker attitudes.

Cartesian analysis of laboratory and pharmacies workers services such as the following diagram:

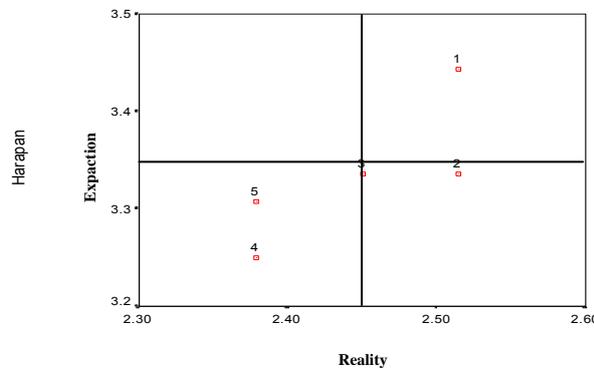


Figure 4 : Cartesian Diagram of Laboratory and Pharmacies Services

### 3.3. Perceptions of Quality of Service to the General Patient Satisfaction

3.3.1. Based on the *Pearson* statistical correlation values obtained  $r = 0.641$ ,  $p = 0.000$ , indicating a significant relationship between the dimensions of physical evidence to the satisfaction of the general patient at the Putri Hijau Hospital Kesdam I / BB because the value of  $p = 0.000 < 0.05$ . *Pearson* statistical correlation between the dimensions of reliability and general patient satisfaction obtained value of  $r = 0.699$ ,  $p = 0.000$ , indicating a significant relationship between the dimensions of reliability and satisfaction of general patients at the Putri Hijau Hospital Kesdam I / BB Medan due to the value of  $p = 0.000 < 0.05$ .

3.3.2. *Pearson* statistical correlation between the dimensions of responsiveness with the general patient satisfaction obtained value of  $r = 0.710$ ,  $p = 0.000$ , indicating a significant relationship between the dimensions of responsiveness with the general patient satisfaction of the Putri Hijau Hospital Kesdam I / BB Medan due to the value of  $p = 0.000 < 0.05$ . *Pearson* statistical correlation between the dimensions of patient satisfaction with general insurance obtained value  $r = 0.699$ ,  $p = 0.000$ , indicating a significant relationship between dimensions of security with the general patient satisfaction of the Putri Hijau Hospital Kesdam I / BB Medan due to the value of  $p = 0.000 < 0.05$ . *Pearson* statistical correlation between the dimensions of empathy with the general patient satisfaction obtained value of  $r = 0.738$ ,  $p = 0.000$ , indicating a significant relationship between the dimensions of empathy with the general patient satisfaction of the Putri Hijau Hospital Kesdam I / BB Medan due to the value of  $p = 0.000 < 0.05$ .

## 4. MULTIPLE REGRESSION ANALYSIS

Based on the multiple regression test results obtained the variables in the regression line equation becomes:  $Y = -73,235 + 0,860X_1 + 1,114X_2 + 1,075X_3 + 1,115X_4 + 1,402X_5$

For maximum value  $X_1 = 20$ ,  $X_2 = 22$ ,  $X_3 = 19$ ,  $X_4$  and  $X_5 = 20 = 19$ , then the equation can be established as follows:  $Y = -73,235 + 0,860(20) + 1,114(22) + 1,075(19) + 1,115(20) + 1,402(19)$

$$Y = -73,235 + 111,931$$

$$Y = 38,696$$

Based on the regression equation settlement calculations showed that the level of General patient satisfaction for Putri Hijau hospital Kesdam I / BB Medan of 38.696. If the calculation of the equation assumed in units of percent, the level of General patient satisfaction is 38.696%.

Regression determination of coefficient ( $R^2$ ) = 0.679 indicates that all independent variables can explain the variation in the dependent variable (general patient satisfaction) of 67.9%.

## 5. CONCLUSION AND SUGGESTION

### 5.1. Conclusion

Perceptions of service quality dimensions measured from the physical evidence (tangible), reliability, responsiveness, guarantee (assurance) and empathy influence on general patient satisfaction in Putri Hijau Hospital Kesdam I / BB Medan. Dimensions of the most dominant influence general patient satisfaction is dimensions of empathy ( $\beta = 1.402$ ).

### 5.2. Suggestion

5.2.1. The Services of the Putri Hijau Hospital Kesdam I / BB Medan (administration, physicians, nurses and medical support) need to consider the dimensions of service quality (tangibles, reliability, responsiveness, assurance and empathy) in conducting health services so as to improve general patient satisfaction.

5.2.2. The dimensions of empathy for the patient should be of particular concern to the health officials at the Putri Hijau Hospital Kesdam I / BB Medan, due to the attention that delivered to the patient is the most dominant aspects that affect the general patient satisfaction. Efforts to increase the dimensions of empathy can be done by carefully monitoring each patient and immediately fulfill the things that are required of patients, for example, administrators can provide information to patients, physicians were able to perform the treatment according to the patient's condition, the nurse able to perform services in accordance with the stages of the nursing care and medical support personnel capable of carrying out laboratory and pharmacy services (drugs) in accordance with the doctor's prescription made.

## REFERENCES

- [1] Kotler, P. "Manajemen Pemasaran (Edisi Milenium)". (diterjemahkan oleh Benyamin Molan). PT. Prenhalindo, Jakarta.2002
- [2] Puti, P.. "Pengaruh Persepsi Pasien Partikular Tentang Kualitas Pelayanan Terhadap Tingkat Loyalitas di Ruang Rawat Inap di RS Islam Malahayati Medan Tahun 2007", Tesis Program Pasca Sarjana Universitas Sumatera Utara, Medan, www.pdpersi.co.id (di download tanggal 3 Juni 2010).2007.
- [3] Rangkuti, F.. "Measuring Customer Satisfaction (cetakan ketiga)". PT.Gramedia Pustaka Utama, Jakarta.2002
- [4] Shahin, A.. "SERQUAL and Model of Service Quality Gaps. A Framework for Determining and Prioritizing Critical Factors in Delivering Quality Services". Department of Management, University of Isfahan Iran. 1994
- [5] Supranto, J.. "Pengukuran Tingkat Kepuasan Pelanggan Untuk Menaikkan Pangsa Pasar". Penerbit Rineka Cipta, Jakarta.2001
- [6] Tjiptono, F."Strategi Pemasaran". Penerbit Andi diterjemahkan oleh Hendra Teguh dkk.,PT. Prenhallindo,Yogyakarta.2002
- [7] Trisnantoro, L.. "Pelayanan Prima Rumah Sakit, Indikator Mutu Pelayanan dan Clinical Governance". Pusat Manajemen Pelayanan Kesehatan FK-UGM: MMR UGM, Yogyakarta.2000
- [8] Wasisto, B."Peningkatan Mutu Pelayanan Rumah Sakit". Cermin Dunia Kedokteran, Edisi Khusus, No. 90, Jakarta.2000

# Participatory Approach to Support Community Development of Rural Craftspeople

Ellya Zulaikha<sup>a</sup>, Margot Brereton<sup>b</sup>

<sup>a</sup>Faculty of Science and Engineering, Queensland University of Technology, Brisbane 4000  
Industrial Design Department, Faculty of Civil Engineering and Planning, Institut of Technology of 10 Nopember  
Surabaya 60111

E-mail : [ellya.zulaikha@student.qut.edu.au](mailto:ellya.zulaikha@student.qut.edu.au) / [e\\_zulaikha@prodes.its.ac.id](mailto:e_zulaikha@prodes.its.ac.id)

<sup>b</sup> Faculty of Science and Engineering, Queensland University of Technology, Brisbane 4000  
E-mail : [m.brereton@qut.edu.au](mailto:m.brereton@qut.edu.au)

## ABSTRACT

*This paper presents a case study of the participatory project in the Jombang glass bead craft industry. Economic instability has brought significant business challenges in the community. The involvement of outsiders to collaborate with craftspeople in order to support business innovation as well as strengthen the social capital in the community is essential. However, facilitating a rural community to formulate and implement bottom-up planning needs an integrated approach. In this paper, we explain a participatory project in the rural craftspeople community that resulted in a collective action. The project aimed at uniting and empowering rural craftspeople focusing on the unique skills and knowledge of participants. There are some aspects influencing the success of collective action: the ability to understand the local political situation; the role of facilitators to respect and support the unique potential of craftspeople; and the economic benefit of the program.*

## Keywords

*Participatory, Rural, Craftspeople*

## 1. INTRODUCTION

Traditional craft industries in Indonesian rural areas are decreasing significantly. One of them is the traditional glass bead craft industry in Jombang, East Java. Only 20 industries operate today while 200 existed in early 2000. To prevent the situation from worsening a community development program is needed. Previous programs organized by government and other institutions, such as forming clusters, organizing training about management/design/marketing, providing capital loans and supporting exhibition for craftspeople, have less contribution to community development. In addition, government financial support for craft association has triggered conflict among members in it. Instead of developing rural craftspeople community, some programs have lead to social jealousy.

This paper describes a case study of a collaborative project between designers and rural craftspeople. The project aimed at uniting and empowering rural craftspeople focusing on the unique skills and knowledge of participants. It assumes that participants must know better about themselves. However, these people need to be facilitated to “speak”.

## 2. THE CASE

Jombang glass bead craft industry was initiated by 3 local craftspeople in the middle of the 1970s in Plumbon-Gambang village, Gudo District, East Java, Indonesia. Initially, they produced eye-rings. In order to deliver orders on time, they employed family and relatives as craft workers. As the craft workers knew the glass-bead-making technique and the market, later, they ran their business. However, they had limited knowledge about the glass bead market. When most of the craft owners produced the same products and delivered them to the same market destination, the market immediately became oversupplied. It caused stagnancy of glass bead craft industry for about a decade.

In the middle of the 1990’s a lover of ancient beads came to the village and learned to create replicas of ancient beads with some craftspeople. The bead lover was also a mineral expert. He already had a potential market for the ancient beads. Therefore, he conducted an intensive collaboration with craftspeople to explore ways of producing replicas of ancient beads to sell. The collaboration brought about the insight of mixing material, innovative techniques and a new potential market for

craftspeople. Craftspeople gained significant earnings by selling replicas of ancient beads to antique lovers and Indonesian tribes at a much higher price than its production cost. It was a significant point of improvement in the industry.

However, the market shortly became oversupplied causing a drastic decreasing in bead price. Only craftspeople with extraordinary bead making skill focusing on high quality beads got orders, while craftspeople with average skills found it difficult to gain any market.

Fortunately this situation did not take a long time to improve. As Bali is a main entrance to overseas buyers, one craft person attempted to sell his product to Bali. At this time, around 2000, the beads were exposed as a world fashion trend. Accordingly, there was an enormous demand of glass beads from Bali. Therefore, the industries grew rapidly, and reached the peak number of 200 craft industries, not only in Plumbon-Gambang village, but also in the six surrounding villages.

Those glass bead craft industries are small industries with a small production capacity. While a big demand of bead came from Bali retailers, craft owners were encouraged to fulfil the demand by involving their families and close friends. That situation led to the exchange of knowledge about how to make beads, get material resources, share orders or market among friends and families. The supportive economic situation reinforced social relations between craftspeople and fostered the development of the community significantly.

As the glass-bead-craft-business knowledge was spread within the village and surroundings, there were more and more craftspeople who selected Bali as the only prospective market destination. Consequently, the market once again became saturated. Most of The craftspeople chose a low-pricing strategy to face a saturated market, instead of seeking innovative attempts. In addition, as the matter of fashion trend, the bead was no longer exposed and it gradually became obsolete. Bead price inevitably fell. In this situation, the transactions between craftspeople and Bali retailers gave no contribution to increase craftspeople's wealth except for a quick return of their investment [5].

Meanwhile, selling products in a local market also brought another challenge. Local buyers preferred to buy the imported beads than local glass beads. The economic demographic background of local buyers influences the attitude of price-sensitive-purchasing. Local buyers have little information about the uniqueness of local glass beads provided by craftspeople. In the meantime there were abundant supplies of cheap imported beads by local traders, they tend to buy cheaper imported beads. This situation caused some craftspeople prefer to trade the cheap imported bead rather than continue to produce glass bead while the others mix local and imported beads.

Facing those difficult situations, some craftspeople took fraudulent attitudes to save their business, such as: the tendency to avoid payment to take advantage of the proximity of family relationships (this tendency was also notified by Geertz[18]), copying design and taking over other people's order without permission [14], selling products at a far lower price or hijacking smart craft worker. Those attitudes broke the social relationship among craftspeople, therefore, hampered the development of the community.

Portes notified that there will always be an internal competition in a homogeneous community [18]. In this case, when craftspeople faced a difficult economic situation as the result of saturated markets, changing trends and the abundance of cheap imported products in the market, there was an internal competition weakened the social relationships of craftspeople community. The nature of cohesiveness as a result of a close-relationship in rural society, enabled the bigger possibility of leaking information about markets and design, then resulted in unfair practices.

Some craftspeople took unfair practices other than innovation because of their limited educational and cultural background to save their business. On the other hand, craft expertise is a synthesis of cognitive, social, technical and aesthetic skill. In order to follow the rapid dynamics of the current business situation, craftspeople must have complex skills such as business, design and manufacturing. Considering this difficulty, the cooperation or collaboration among craftspeople and stakeholders, such as entrepreneurs and professionals in the design, tourism or other sectors, is needed [15].

### **3. THEORETICAL FRAMEWORK**

Scholars have warned of some current challenges to the survival of a business in a traditional craft industry. This section explores these notions in addition to ideas for the development of the rural handicraft industry. In order to understand the context of rural Indonesia, or more specifically Java, we examine some theories that elaborate on the nature of social relationships in rural Java and how these will influence community development.

Unlike most of the industries based on natural resources, a craft industry is based on culture. As a craft industry produces material goods using traditional techniques that have been employed for a long time, a craft industry is based on material culture. Friel stated that goods based on material culture are more likely to be sustained. This is because a traditional craft industry is closer to local resources and traditional knowledge, and is less demanding of financial capital and technological innovations. In addition, this industry should be more concerned with intellectual property rights to protect their intellectual value [7].

However, uniqueness and skillful expertise of making things may not guarantee business survival in the current era of tight business competition. Succeeding in business in a craft industry takes complex skill in the fields of technology, business and design. Girón et.al examined there were 23 key factors of success in a handicraft industry [9]. They used a quantitative method to analyze success factors of a Mexican handicraft industry. They found that the most influential factors are a pricing strategy oriented to profit, personal recommendations to promote products, product diversification and the information given to customers [9]. Similarly, Fillis observed that internal managerial skills and a supportive personality affect the performance of a craft business enterprise [6]. Furthermore, Friel argued that for the traditional handicraft industry to be able to compete in the era of globalization, changes were needed. A traditional handicraft industry usually produces low quality and low quantity products and this should be transformed into soft industrial design with the ability to produce “design-based goods” of high quality and in high quantity [7].

Despite the potential uniqueness of craft industry as material culture, in order to succeed, traditional craftspeople face complicated challenges. Competition with cheaper products that offer new patterns, new trends or customized design for a niche market, and the weakness to master the rapid development of information technology [5] are some of the challenges to be overcome. Furthermore, as observed by Kamara, rural craftspeople often lack confidence, professionalism, information and specialization and have a weak survival mentality, business and managerial skills and short-term strategies [11]. These factors mean that craftspeople are prone to be exploited by others who aim to gain a larger return, beyond trade purposes [5].

In consideration of the difficult situations that traditional craft industries face for their survival, many advisory programs have been provided by external agencies [16,20,23]. However, the lack of attention to local issues in most of the top-down advisory programs, such as short-term training [10], frequently does not necessarily reflect craftspeople’s needs. Therefore, providing bottom-up programs in which participants could be involved in deciding the program is considered important. A bottom-up program using a participatory approach respects the participant’s uniqueness and considers that participants know their own contexts better than an outsider. Therefore, as specified by Chambers [4], in participatory projects, outsiders have roles as convenors, catalysts and facilitators rather than planners.

Nonetheless, a bottom-up program does not guarantee the increasing possibilities of participation [3]. Scholars have noticed that only in rare circumstances would groups of individuals act in a co-ordinated and co-operative manner, unless there is coercion to force them to do so. This is because they fail to see direct individual benefit for the time and cost they must share, and because of a “free-rider” mentality. However, Olson as cited by Beard [1], concedes that with smaller groups, the free-rider problem is reduced.

Moreover, cultural tensions in the internal community, as well as different interests, could hamper the effectiveness of the program. Since most rural societies are relatively ‘integrated’ [3,12], in order to undertake an effective advisory program for rural craftspeople, we should consider more comprehensive aspects, such as economic and political situations, rather than focus on single aspects, such as design alone. Hence, some scholars implied that encouraging innovations for rural craftspeople is complicated [8,14].

A conscientious understanding of the social network in the community is the first important step in undertaking a bottom-up program [3,13]. In particular, the type of social network affects the success of community development. Scholars investigated social capital as one type of social network that could affect a significant outcome for the development of community [17, 18]. Social capital is characterized by trust, reciprocity and cooperation within the social network [1].

Coleman as cited by Beard [2], stated that the existence of social capital in the community is influenced by closure, stability and the presence of communitarian ideology. Closure is the situation in which there is pressure on a social system, such as a sanction, to maintain the mutual interest of each person. It is more likely to occur in a rural area, when people know each other’s extended families and personal histories very well. Stability is related to the wealthiness of the people in terms of socioeconomic conditions, while communitarian ideology is something or someone that encourages the individual to act, beyond his own interest.

In summary, to succeed in the craft business, complex skills in areas such as management, design and technology are needed. Rural craftspeople with a limited educational background have difficulties in environment of tight business competition. Their social capital that reflected mutual cooperation in the past was broken by the economic difficulties. Top down programs that focus only on one aspect such as management or design, contribute less to the re-development of the community. A comprehensive understanding of the local situation, followed by a bottom-up participatory project has a greater prospect of supporting a community's development.

#### 4. METHOD

The researchers have conducted the participatory project in two fieldworks. The first fieldwork was in 2011. We used an ethnographic technique by visiting the village a few times prior to living there for a month, attending community events and conducting door-to-door interviews. This step was followed by a collaborative design learning project between the designers and a group of craftspeople to explore innovative design participation. This activity resulted in revealing new glass bead designs [22].

In the next fieldwork in 2012, to have a better impact in the community, we broadened the scope of participants by involving craftspeople from different groups in the community as inclusively as possible. Over 2 months there were community meetings on a weekly basis to design the bottom-up participatory project. Two on-going and two newly-graduated design students from a local university facilitated the project.

During the fieldwork, the researcher spoke in the local language (Javanese), and preserved a feeling of equality and closeness with rural craftspeople. The researcher also had a chance to speak in a community forum along with the village head. This moment provided a significant impact as researchers implicitly receive legitimacy from the village leaders. As noted by Puri [19], in some cultures it is very important to involve senior figures to give the project legitimacy and to persuade people to engage.

The craftspeople agreed to meet on a weekly basis to plan programs enhancing the glass bead craft industry. One of the craftspeople suggested, "*Cangkrukan Manik*" as the name of the meeting and this was agreed on by the others. *Cangkrukan* is a Javanese term which has a similar meaning with "hang out", but it means to sit together for no specific purpose. *Cangkrukan* is usually filled with chatting. People usually do *cangkrukan* after work for relaxing. *Manik* (Javanese) means bead. So, *Cangkrukan Manik* means sit together informally, to discuss any issues related to beads.

The *Cangkrukan Manik* meeting brought up the issue of local buyers preferring to buy cheaper imported beads than the local glass beads. Craftspeople and facilitators shared ideas on how to attract the local market. Some craftspeople expressed the opinion that people viewing the glass bead making process would be more likely to buy the products than if they did not directly observe how the beads were made. From this, a question emerged about the possibility of going to the target market instead of waiting for visitors to come to the site. This would be a good opportunity for disclosing the techniques on making beads to the potential local buyers. That idea would be a marketing strategy to increase local awareness of the glass bead craft industry. The participants crystallized this idea in the third *Cangkrukan Manik* meeting as a glass-bead-making workshop. Next, the facilitators assisted the craftspeople to refine their detailed planning of the implementation of the project. After considering the three important aspects, safety issues, purchasing and the power of word-of-mouth to spread the information, the participants decided to select senior high schools surrounding the industry as targets of pilot projects. Facilitators assisted craftspeople to draw up a proposal and approach targets.



Figure 1: Craftspeople showed their expertise of making glass bead in the workshop (doc: author).

After 3 weeks of planning and preparation, participants and facilitators held the pilot project. All the craftspeople contributed to the program in accordance with their ability or the resources they had. Only 5 to 6 craftspeople had available time to be the workshop instructors. The craftspeople who were unable to go to the workshop, contributed their products to be sold and lent equipment.

The craftspeople collaborated with the facilitators, performing the glass-bead-making workshop to four high schools in three cities surrounding the industries. Each workshop took approximately 3 hours, and was attended by 30-60 students. The workshop began with a 30 minute presentation by the craftspeople about beads as ancient jewelry and Indonesian cultural heritage in a talk-show format. The facilitator acted as a moderator. After that, there was an explanation about Jombang glass bead craft industries and a brief story of the entrepreneurial journey of each craftsperson.

Subsequently, the main session was a glass bead making demo by the craftspeople, followed by bead making practice by the students. This session continued with the practice of weaving beads into ready-to-use products such as bracelets, brooches and necklaces. Meanwhile, students and teachers bought many products during the workshop. Moreover, there was immediate feedback from the students and teachers about product preferences, the affordable price and the design idea.



Figure 2: Craftspeople supervised students who learned to make glass beads (doc: author).

## 5. RESULTS

All four glass-bead-making workshops were completed in a week, in the beginning of Ramadhan month. All of the craftspeople are Muslims, and as such, were not allowed to eat or drink during the day in the Ramadhan month. Nevertheless, the craftspeople delivered the workshops successfully. This situation was a sign that they have a strong willingness to succeed in the program. Without such a will, it would be unlikely to happen.

### 5.1 The participants

A total of 18 craftspeople attended 8 meetings of *Cangkrukan Manik*. However, only 7 of them actively participated in the meetings and conducted the glass-bead-making workshops. They attended at least 5 times, while the rest attended just once or twice. The two community leaders, who are the most respected successful business persons in the community, and the leader of the glass bead association, were among those who came 3 times or fewer. Nevertheless, they supported the workshops by contributing materials and some products to be sold at the workshops. They could not come consistently because they were busy.

Although it seems that there were few craftspeople actively involved in the program, this program must not be seen as trivial. Considering that the number of craft owners in the last decade has decreased to numbers in the 20s, the active involvement of 8 craft owners and 1 craft worker in the program was not necessarily a small achievement. Moreover, the backgrounds of the active participants were quite varied. The ages of the participants were between the 20s to 60s. As we stated initially, the local political situation showed an implicit grouping among craftspeople. However, quite diverse groups of craftspeople came and collaborated in this project.

We found that there were only a few craft workers involved in the project. From the total of 3 craft workers who came to the meetings, only one craft worker was actively involved in the program. This active craft worker had a strong personality, made apparent by his courage to share ideas and propose initiatives. The other craft workers who did not continue to attend the Cangkrukan Manik were quite passive. However, the involvement of a craft worker depends on his employer. If the employer supports the program, the craft owner will be more likely to join and be involved.

Interestingly, the craftspeople in relatively stable business conditions were more enthusiastic to join the program than craftspeople who currently struggled for their business to survive. There were two reasons for the lack of participation of craftspeople whose businesses were currently unsuccessful. First, the less successful craftspeople had already changed their jobs; second, they were pessimistic about the future of the glass bead business; third, there were other issues such as their reluctance to join the program because there was no close friend joining or there was another activity that should have been done on that day. This fact shows that the way to involve the less successful in the bottom-up program remains unsolved.

## **5.2 The benefit of the program**

The glass bead making workshop, along with the Cangkrukan Manik meetings prior to the workshop showed some positive signs of support for community development, as it brought social and economic benefit. At least the 9 craftspeople, who actively involved in the program, gained social benefit through knowledge sharing to pursue innovation with the designers as facilitators. In order to pursue the success of the glass-bead-making workshop to build awareness of the local buyers, there was a process of knowledge-sharing between the designers and craftspeople during the Cangkrukan Manik meeting, by collaboratively designing a new brand as part of a marketing strategy as well as a new product design development. The workshop also strengthened the internal social relationship among craftspeople. Craftspeople from different implicit groups worked together, in which this kind of situation is rare, after they experiencing the tight competition. The involvement of outsiders as a trusted third party to enable the collaboration is essential.

Later, craftspeople also made a new network with 4 high schools. The new network can increase the awareness of the industry, as the total of 160 students who participated in the workshop are prospective local buyers. Besides, since there was immediate feedback from students after each workshop, the designers and craftspeople could learn and discuss the feedback directly. This mechanism allows for effective knowledge sharing.

Meanwhile, the program also delivered economic benefit directly and indirectly. The craftspeople took direct economic benefit from the products sold during the workshop as well as the payment for their services as tutors in the workshops. The products sold were about 40%, which is enough to pay the resources (such as the LPG cost and patterned stick glass material). In addition, raising the local buyer's awareness brought an indirect economic benefit.

## **6. DISCUSSION**

The craftspeople community had strong social capital when the glass bead business reached its peak. During that time, craftspeople exchanged material, shared orders and new designs. However, as the bead trend passed, causing significantly decreasing orders, it caused economic difficulty to craftspeople. This situation has triggered tension among craftspeople and altered the mutual sharing into an uncooperative situation with cheating and stealing.

With reference to Coleman's notion that the existence of social capital in the community is influenced by closure, stability and the presence of communitarian ideology [2], we learned that economic instability destroys social capital. As the glass-bead-craft industries' association does not have enough power to apply sanctions, this worsens the situation.

The economic instability of rural craftspeople is due to the occurrence of globalization in many places [5]. Many of the limitations of poor educational and economic backgrounds and limited networks have caused difficulties for rural craftspeople to follow the rapid movements in the globalized era [5,7]. Nevertheless, they must have complex skills to succeed in their businesses. The assistance of outsiders is essential to help craftspeople [15]. However, the assistance must consider the context and preserve the unique potential of these craftsmen [21].

As presented in section 3, many scholars have argued that facilitating a community to formulate a bottom-up program into a collective action will face many challenges [2,3]. That possibility is also likely to occur in rural areas with strong social cohesiveness characteristics. However, in this case, the rural craftspeople of Jombang performed their glass-bead-making workshops collaboratively. This fact indicates positive signs of rebuilding the social capital of the craftspeople's community to support community development.

We studied some aspects which encourage collective action; first, the ability to understand the local political situation; second, the role of facilitators to respect the unique potential of craftspeople as well as back up the required skills to succeed in the program; and third, the economic benefit of the program.

We proved Knop's argument that understanding cultural sensitivity when initiating a participatory project is essential [13]. The approach to community leaders, building a close and friendly relationship with craftspeople, as well as setting up the program to be as inclusive as possible allowed the craftspeople to engage in and easily join the project. The role of the facilitator in encouraging the craftspeople to talk and share ideas in bottom-up planning and then finalize it in a detailed program was also crucial. The glass-bead-making workshops presented the craftspeople's expertise to students and teachers. The expertise of making beads is the craftspeople's passion as they have worked in this field for years. Moreover, the craftspeople gained economic benefit from the sale of products and their service as tutors. This program is more likely to be sustainable as it enabled the self-help potential of craftspeople to get their economic benefit, and not depend on external funding. Furthermore, since the glass-bead-making workshop is a collaborative program, it has the potential to restore the strength of social capital in the community.

## ACKNOWLEDGMENT

The authors appreciate the work of the Jombang craftspeople along with the students and teachers of SMAN 2 Pare, MAN Jombang, SMAN 2 Jombang and SMA Kertosono who were enthusiastically involved in the workshop. We would like to thank the village head and staff of Plumbon Gambang village, the design students (Intan Cheria and Lia Puji), alumni (Arif Dwi Putranto and Ilham Bagus H.), the head and staff of Industrial Design Department – ITS Surabaya, for their cooperation during the project; also Praya Media for the documentation and valuable contribution. This work is supported by a scholarship from the Directorate General for Higher Education (DGHE) on behalf of the Ministry of National Education, Republic of Indonesia.

## REFERENCES

- [1] Beard, V. A., "Individual determinants of participation in community development in Indonesia," *Environment and Planning C: Government & Policy*, vol. 23, no.1, pp. 21-39, 2005.
- [2] Beard, V. A., Dasgupta, A., "Collective action and community-driven development in rural and urban Indonesia," *Urban Studies*, vol. 43, no.9, pp. 1451-1468, 2006.
- [3] Bebbington, A., L. Dharmawan, E. Fahmi, S. Guggenheim, "Village Politics, Culture and Community-Driven Development: Insights from Indonesia," *Progress in Development Studies*, vol. 4, no. 3, pp. 187-205, 2004.
- [4] Chambers, Robert. "The origins and practice of participatory rural appraisal." *World development*, vol. 22, no.7, pp. 953-969, 1994.
- [5] Dhamija, J., "Globalization and Craft in South Asia," in *Cultures and Globalization : The Cultural Economy*, Ed. Anheier, H.K., Y.R. Isar., London : SAGE Publications Ltd, 2008, ch. 9, pp. 135-140.
- [6] Fillis, I., "Barriers to Internationalisation : an investigation of the craft microenterprise," *European Journal of Marketing*, vol. 36 no.7/8, pp. 912-927, 2002.
- [7] Friel, M., and W. Santagata. "Making Material Cultural Heritage Work: From Traditional Handicrafts to Soft Industrial Design," in *Cultures and Globalization: The Cultural Economy*, SAGE Publications Limited, 2008, ch.24, pp. 274-283.
- [8] Geertz, Clifford. *Agricultural Involution*. No. 11. Univ of California Press, 1963.
- [9] Girón, J. P. H., Hernández, M.L.D., Castañeda, M. C., "Strategy and factors for success: The mexican handicraft sector," *Performance Improvement*, vol. 46, no. 8, pp. 16-26, 2007.
- [10] Huang, T.-C., "The relation of training practices and organizational performance in small and medium size enterprises," *Education + Training*, vol. 43, no. 8/9, pp. 437-444, 2001.
- [11] Kamara, Y., "Keys to Successful Cultural Enterprise Development in Developing Countries." Unpublished paper prepared for The Global Alliance for Cultural Diversity, Division of Arts and Cultural Enterprise, Paris : UNESCO, 2004. [http://www.acpcultures.eu/\\_upload/ocr\\_document/UNESCO-Kamarra\\_KeysToSuccessfulCulturalEnterprise\\_2004.pdf](http://www.acpcultures.eu/_upload/ocr_document/UNESCO-Kamarra_KeysToSuccessfulCulturalEnterprise_2004.pdf)
- [12] Kerr, K, "The Economic Potential of Handicrafts Enterprises in Rural Development: Focus on Indonesia," in *Unasylva* no. 42, 1991.
- [13] Knop, S.A., Knop, E.C., "Rural Development in International Setting: Some Principles and Practices," *International Social Work*, vol. 28, no. 15, pp. 15-20, 1985. <http://isw.sagepub.com/content/28/4/15>
- [14] Kristiansen, S., "Small-scale Business in Rural Java: Involution or Innovation?," *Journal of Entrepreneurship*, vol. 12, no.1, pp. 21-41, 2003.
- [15] Luutonen, M., "New Craft Policy in Finland," *The Design Journal*, vol. 10, no.2, pp. 49-61, 2007.

- [16] Millward, H., Byrne, C., Lewis, A., "Enhancing the design capabilities of small and medium-sized enterprises through knowledge transfer," *The Design Journal*, vol. 9, pp. 3-13. 2006.
- [17] Narayan, D., Pritchett, L., "Cents and sociability: Household income and social capital in rural Tanzania," *Economic development and cultural change*, vol. 47, no. 4 , pp. 871-897, 1999.
- [18] Portes, A., Mooney, M., "Social Capital and Community Development," in *The new economic sociology: Developments in an emerging field*, NY : Russell Sage Foundation, 2002, ch. 12, pp. 303-329.
- [19] Puri, S. K., Byrne, E., Nhampossa, J. L., Quraishi, Z. B., "Contextuality of participation in IS design: a developing country perspective," 2004 the Proceedings of the eighth conference on Participatory design: Artful integration: interweaving media, materials and practices, Toronto Ontario, Canada, 2004.
- [20] Tung, F-. W., "Weaving with Rush: Exploring Craft-Design Collaborations in Revitalizing Local Craft", *International Journal of Design*, vol. 6, no.3., pp.71-84, 2012.
- [21] Vencatachellum, I., "Building alliances between artisans and designers" in *Cultures and Globalization: The Cultural Economy*, SAGE Publications Limited, 2008, Box 24.1, pp. 277-278.
- [22] Zulaikha, E., Brereton, M., "Participatory innovation to develop traditional Indonesian craft industries," 2012 *Participatory Innovation Conference Digital Proceedings*, Swinburne University, 2012.
- [23] <http://www.aidtoartisans.org/>

## COPYRIGHT

All papers submitted must be original, unpublished work not under consideration for publication elsewhere. Authors are responsible to obtain all necessary permission for the reproduction of tables, figures and images and must be appropriately acknowledged. The paper is not defamatory; and the paper does not infringe any other rights of any third party.

The authors agree that the Technical Committee's decision on whether to publish the paper in the Conference's proceedings shall be final. The authors should not treat any communication from the Technical Committee members who reviewed their work as an undertaking to publish the paper.

Prior to final acceptance of the paper, authors are required to confirm in writing that they hold all necessary copyright for their paper and to assign this copyright to the Conference Organizer.

# Strengthening Social Capital on Agricultural Development Lesson from *Subak* of Guama, Marga Subdistrict, Tabanan, Bali Province-Indonesia

Gede Sedana<sup>a)</sup>, Wayan Windia<sup>b)</sup> and Ketut Wirawan<sup>c)</sup>

<sup>a)</sup> Faculty of Agriculture, Dwijendra University, Bali  
E-mail: gedesedana@yahoo.com

<sup>b)</sup> Faculty of Agriculture, Udayana University, Bali  
E-mail: wayanwindia@ymail.com

<sup>c)</sup> Faculty of Law, Udayana University, Bali  
E-mail: wirawan\_dj@yahoo.co.id

## ABSTRACT

*Agriculture has still played significant roles in economic development of Indonesia. In Bali province, the existence of subak as customary community for managing traditional irrigation system with a hydrological boundaries basis is very important since the agricultural development programs implementations of government are always conducted through it. However, subaks have faced some problems in the relation to farmers' income gained from their own farming activity on the paddy field. The purposes of this study are to describe social capital performance on subak system in subak system and to explain the ways to strengthen social capital on agricultural development. Subak of Guama was purposively selected for the study since government implemented pilot project of agribusiness development on this subak in 2002. Key informants and samples were drawn during the survey and observation for data collection. These were fully analysed by using descriptive method. Results of study showed that the mutual trust within Subak of Guama (among subak members and cooperative of subak) was very high concerning agribusiness development and other related activities of subak. This mutual trust was based on the subak's philosophy, locally called Tri Hita Karana that mostly based on the harmony life in running farming activities on the rice land. Social norms (called awig-awig) of subak was very strong to govern members and management board of subak in practicing the agricultural, irrigation and agribusiness activities including ritual ceremonies within subak system. Social networking within subak system consisted of social interaction among subak members and management board and the other external sides, such as agricultural extension workers. This social networking is relatively high. The ways to strengthen social capital in subak system for agricultural development, particularly on rice field are: (i) conducting intensively extension and training activities by using participatory approach; (ii) providing economic stimulant for encouraging farmers in sustaining agribusiness program; and (iii) facilitating partnership activity between subak and other agribusiness institutions.*

## Keywords

*Social capital, agribusiness, cooperative, participatory*

## 1 INTRODUCTION

Agriculture has still played significant roles in economic development of Indonesia. It has highly absorbed employment and supported the availability of food for the rural and urban population as well. In Bali province, the existence of *subak* as customary community which manages traditional irrigation system with a hydrological boundaries basis is very important since the agricultural development programs implementations of government are always conducted through it. Nowadays, *subaks* have faced some problems in the relation to farmers' income gained from their own farming activity on the paddy field. Low income of farmers problems are mainly caused by limited purchasing power, availability of market, access to resources [1]. In order to support government's agriculture development program, it has been developed the cooperative based on sub-district administrative, called Village Unit Cooperative since the beginning of 1970s. This was integrated into the Mass Guidance Program for achieving self-sufficient of rice [2]. Such cooperative had functions to provide agro-inputs (seeds, fertilizers, pesticide), credit for members (farmers) aside from rice processing and marketing. Similar to other cooperatives in developing countries, however, the growth of the cooperatives in Indonesia was not good enough wherein these could not sustain their activities with some reasons. Bhuyan [3] assumed that the failure of cooperative is caused by negative attitude of members due to unclear communication between members and management, or lack of educational and operating matter. Sarafshani, et.al [4] found that the agricultural production cooperative in Iran is unsuccessful in achieving the members' goals because of some reasons, such as weak coordination among farmers, little support from government, high prices of inputs, low financial power of farmers, and others. Low participation of members, capital, management skill, controlling, disloyalty of

members because of ignorance, lack of training, conflict among members, are also the problems in achieving the successful cooperative [5] [6].

In Indonesia, the farmers as *subaks*' members, particularly in Bali province were also a part of Village Unit Cooperative together with the other *subaks* located within a sub-district. Awareness of the failure of Village Unit Cooperative, the government was initiated to encourage *subak* to be an agricultural cooperative. Owing to this cooperative was established on the *subak* basis, it is fully expected to raise motivation for gaining mutual benefit and the expectation of collective actions among the members of *subak*. Like in many other developing countries, agricultural cooperatives operate in the context of rural communities, and therefore they are subject to norms and values of social inclusion and solidarity. *Subak* was established with the Balinese cultural basis as a social capital in which this has been still performed in the economic activities.

As a pilot project on agricultural development, the only one *subak* in Bali involved in this program, namely *Subak* of Guama located within three villages scattered in Tabanan district, as a centre of rice farming in Bali province. The cooperative is called KUAT Guama (*Koperasi Usaha Agribisnis Terpadu*=Integrated Agribusiness Cooperative) with the first economic activities for an integrated crops management; crops livestock system; and economic households small credit. These are fully aimed at increasing the productivity and income of farmers as a part of agricultural development goals. The experiences found in several countries wherein the existence of agricultural cooperative established by government seemed to be unsustainable after a couple year operated [7]. In the relation to cooperative on the *subak* basis in established Bali, the purposes of this study are to describe social capital performance on *subak* system in *subak* system and to explain the ways to strengthen social capital on agricultural development for its sustainability.

## 2 REVIEW OF LITERATURE

### 2.1 Existence of *subak* and social capital

*Subak* system is well known in Bali (Indonesia) and other countries as a traditional irrigation system with a particular additional activity, that is, ritual ceremony that has been carried out since the water fetching till harvesting. This performance is a part of Balinese culture in farming activities on irrigated land (rice field) [8]. In general, the main activities of irrigation organization (water users association) are related to distribution of irrigation water, mobilization of resources, operation and maintenance of irrigation facilities, and conflict management [9]. Meaning to say that *subak* is a unique organization with ritual activities. *Subak* could be regarded as a customary institution which is a form of social capital for managing collective resources as they provide structure and develop trust and norms of reciprocity for cooperation and coordinated actions [10].

Social capital is simply defined as "the norms and networks that enable people to act collectively", in which it is regarded as features of social organizations, such as social networks, norms, and trust that facilitate coordination and cooperation for mutual benefits [11]. It can be simply defined as the existence of a certain set of informal values or norms shared among members of a group that permit cooperation among them [12]. Gittel and Vidal [13] tried to have the distinction of bonding and bridging social capital. Trust is defined formally as expectation about the actions of others that have a bearing on one's own choice of actions [14]. Fafchamps and Bart [15] argued that social networks enabled traders to reduce transaction cost under a situation of imperfect information and then have higher margins. Social capital is an important resource for the agricultural cooperative.

### 2.2 Sustainability of farmers cooperative

Based on the Indonesian Law No.25/1992 about Cooperative, the sustainability of cooperative could be achieved by implementing its functions and roles as follows: (i) to develop potential and capacities of members in particular and the community in general in order to improve their welfare; (ii) to actively take a part in enriching the quality of the community's life; and (iii) to strengthen local economic for supporting national economic. Furthermore, it is clearly also mentioned that the principle of cooperative are: (i) open and voluntary membership; (ii) democratic management; (iii) proportional returns to each members; and self-help institution. A cooperative is meant to: 'embody the values of self-help, self-responsibility, democracy, equality, equity and solidarity. In the tradition of their founders, co-operative members believe in the ethical values of honesty, openness, social responsibility and caring for other [16]. These are likely part of social capital within the small institution owned by small farmers. The general activities of agricultural cooperative are marketing cooperatives; farm supply cooperatives; and service cooperatives [5]. and providing other services such as insurance, contract work, accountancy and farm relief [17]. However, it was also found that most of the agricultural cooperatives have relatively small businesses with lower margin.

The agricultural cooperative has important role in rural economic and social organizations with its activities for providing the farmers with production inputs, such as fertilizers, seeds and chemical substances [7]. making lower transaction costs in getting loans, and better access to information; Motiram, and Vakulabharanam [18] Barton [19] clearly mentioned that the primary purpose of cooperative is to gain economic benefit to its members. The sustainability of local institution requires participation of the members [20] [21]. Participation is very important in the successful program of collective actions, such as in the management of irrigation and forestry as natural resources [8] [22]. Participation is regarded as people's involvement in decision-making processes, in implementing programmes, their sharing in the benefits of development programmes and their involvement in efforts to evaluate such programmes [23]. Local people would participate in the program if they assume that their needs could be fulfilled [24]. Thus, they will have sense of belonging and sense of responsibility towards their institution

[25]. In term of cooperative, the its sustainability could be seen from to what extent the participation of members to sustain the cooperative's activities. Sustainability refers to something continues to work over time [26].

### 3 METHODS OF STUDY

In order to achieve the aims of this study that was conducted in *Subak* of Guama, data were gathered by employing semi-structured interviews with 70 farmers out of 544 members of cooperatives and its management officers and using questionnaire. The farmers were drawn by using proportional random sampling, with the basis of sub-*subak* members. It is worth to note that *subak*'s members are members of cooperative, too. The survey had been done from April-August 2012. Collected data was analysed with qualitative method. Measurement of social capital indicators was done by using scale of likert in which the answers of samples towards every question are scored by 1, 2, 3, 4, 5. The score of 1 is given if the answer is not too expected and the score of 5 is given if the answer is very expected. The total score is converted to percentage to make the categorization of social capital indicators that have five categories. The interval of categories is formulated by:

$$i = \frac{\text{Maximum percentage} - \text{minimum percentage}}{\text{categories}} = \frac{100 - 20}{5} = 16$$

Based on the interval cited above, the categories of social capital indicators (trust, social norms and social networking) are shown in Table 1.

Table 1 Categories of trust, social norms and social networking

No	Categories	Score (%)
1	Very high	> 84 – 100
2	High	> 68 – 84
3	Moderate	> 52 – 68
4	Low	> 36 – 52
5	Very low	20 – 36

### 4 RESULTS AND DISCUSSIONS

#### 4.1 General description of site research

*Subak* of Guama with 172 ha rice land is situated in Tabanan regency, Bali Province. Tabanan is a central for paddy growing in Bali. The source of irrigation water of *subak* is from Cangi weir in which this also irrigates the other 7 *subaks*. It is easy to reach the site by public and private vehicles, so it is a good potential to develop agribusiness cooperative in the *subak*. Similar to other *subak* in Bali, *Subak* of Guama is also divides into sub-*subaks*, (locally called *tempek*), that is six sub-*subak* namely: (i) Manik Gunung; (ii) Pekilen; (iii) Kekeran Desa; (iv) Kekeran Carik; (v) Belusung; (vi) Guama. Total members of *subak* is 544 farmers, and the average of rice land holding is relatively small, it is about 0.32 ha/farmer.

#### 4.2 Characteristics of cooperative's members

The average paddy land hold by farmers is relatively small, that is 0.34 ha with its interval between 0,26 to 0.56 ha (see Table 2). This condition is similar to the farmers within Indonesia who are working on paddy land. Some analysed that the small scale of farming system (less than 0.35 ha) for rice crop is economically inefficient. This is one of the dominant problems in Indonesia for the improvement of farmers income. Noteworthy, the farmers are cultivate the land inherited by their own parents. Nobody bought new paddy land for their farming. In the relation to age of farmers, it is approximately 48 years old with an interval between 36 to 56 years. They are still relatively productive persons to work on the larger size of rice field than they own. In term of innovation, they might support the process of extension and training conducted by government field workers, particularly in agricultural innovation such as agribusiness, because they are not too old.

Formal educational background of farmers is relatively low (9.77 years) in which this is equal to graduate from junior high school (in Indonesia, the people go to elementary school for six years and junior high school for three years). Some of them (44.29 %) graduated from senior high school (another three years after graduated from junior high school). The consequence of this, the extension agents should have particular techniques or methods of extension in order that they might be able to easier to understand, thus adopt the innovation disseminated.

Table 2 Characteristics of members

No	Items	Average	Interval
1	Paddy land (ha)	0.34	0.26 – 0.56
2	Age (year)	48	36 – 56
3	Educational background (year)	9.77	6 – 12
4	Family size (person)	5.06	3 – 7
	a. < 15 years	1.36	0 – 3
	b. 15 – 64 years	3.10	2 – 6
	c. > 64 years	0.6	0 – 2

5	Status of farmers (person)		
	a. Land owner	88.64 %	
	b. Sharecropper	11.36 %	

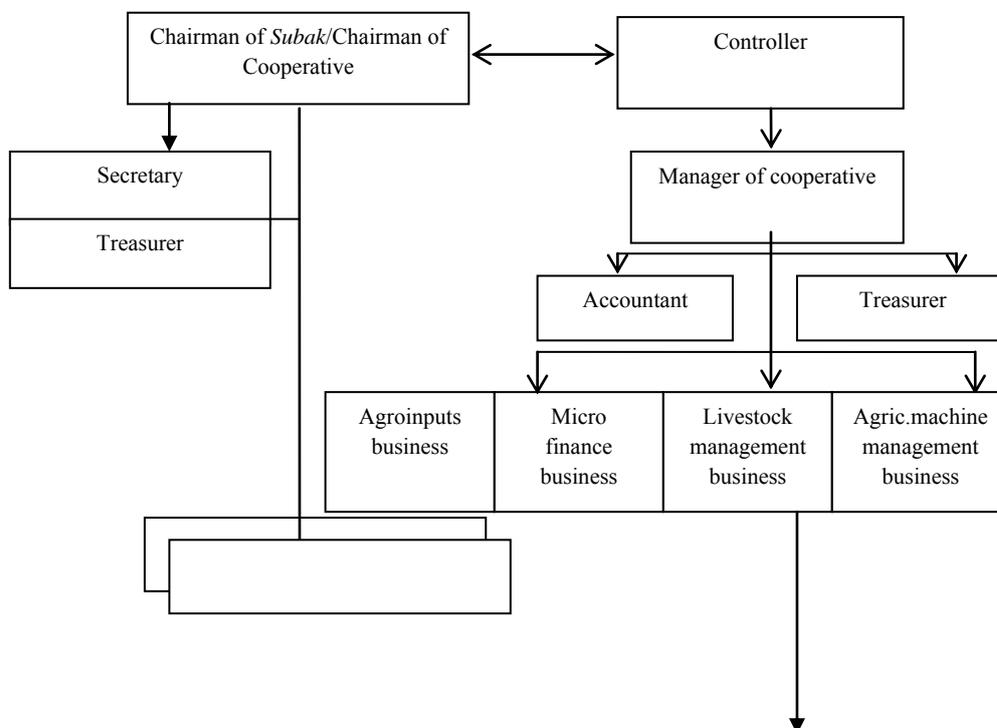
The small size of land of farmers strongly push them to have other jobs for gaining additional revenue of household. All of farmers in the site research have livestock farming as a livelihood source. They make it integrate with the crops they plant, wherein kinds of livestock are mostly cattle and pig. The two are very important for farmers because these are regarded as a saving. The other jobs of some farmers are wager (construction works), local retailer (daily needs of community), and teacher and employee at non-government office. Most of farmers (88.64 %) is the land owner who cultivate their paddy land and the remain is sharecropper. In the research site, there is no legal contract for the land cultivation between the owners of the land and the sharecroppers. They only base on the trust even though this might pruned to a conflict.

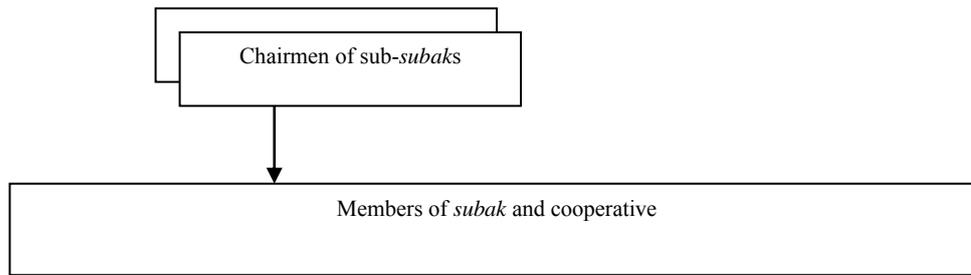
### 4.3 Performance of *Subak* Cooperative

*Subak* of Guama firstly initiated by the government (The Agency of Research and Development for Agriculture-Bali) for having a group for running integrated agribusiness activities. This group had been intensively empowered by providing extension and training on agricultural practices, management, entrepreneurship and agribusiness. This was further developed to be a *subak* cooperative for managing the agribusiness activities within *Subak* of Guama, called *Koperasi Usaha Agribisnis Terpadu (KUAT) Subak Guama* established on April 1, 2002. Based on the national law about cooperative as cited above, this must be strengthen by having legal aspect of cooperative with fulfilling some prerequisites. Finally the government (The Cooperative Service) issued the legal aspect of cooperative with the reference number: 22 / BH / DISKOP/VIII / 2003 dated on Agust 14, 2003. The cooperative management is still under control of *subak* of Guama with some principles, such as openness, togetherness, fair, honesty. The chairman of *subak* has intensively controlled and supervised the cooperative management.

The cooperative manages productive assets and capital granted by external source (the Agency of Research and Development for Agriculture-Bali) and encourages members of *subak* to utilize the services, such as micro credit, agro-inputs provision including livestock inputs, agricultural management and agricultural machine uses, etc. These activities are directly managed by manager appointed by *subak* member as members of cooperative. The organizational structure of cooperative in *Subak* of Guama and relationship between *subak* and cooperative is show in Figure 1. Seeing the structure above, the chairman of *subak* is also being a chairman of cooperative. The management of agribusiness activities within *subak* is professionally handled by a manager with some assistants, such as secretary, treasurer and other officers for some business (agro-inputs, micro finance/loan; livestock management and agricultural machines). They run the cooperative under the internal regulations as a consensus of members in which it is still referred to the national law as guidance.

For the initial agribusiness activities, the Agency of Research and Development for Agriculture-Bali gave grant for the Guama cooperative in 2002 under the Project of Integrated Farming Development for (i) Integrated Crops Management/ICM; (ii) Crops-Livestock System/CLS; and (iii) Home industry credit.. Another activity conducted by cooperative is rice seed production under the supervision of *subak* and government institutions (Rice Seeds Certification Agency, Bali Province and Agency of Research and Development for Agriculture-Bali). *Subak* has responsibility in defining which farmers would be join in the program, while the government institutions strongly takes responsibility in controlling the treatment of rice seeds production. Cooperative, then, makes good package for the seeds before selling to *PT Pertani* (Agricultural Firm owned by government) and other retailers.





Figur 1: Organizational structure of cooperative in *Subak* of Guama

#### 4.4 Social capital within *subak* cooperative

##### 4.4.1 Trust

Trust is a belief of people to others' willingness within a group. In this study, the trust was measured on mutual trust among the members of cooperative/*subak*, members and management boards of *subak* and cooperative. The average score of trust within *subak* cooperative is 84.02 % of maximum score indicating high trust with the interval of 77.39 % to 91.30%. Most of members' trust (72.86 %) are categorized very high (see Table 3). Mutual trust among members of *subak* cooperative is based on the *subak* philosophy, locally called Tri Hita Karana that mostly based on the harmony life in running farming activities on the rice land. As a traditional irrigation system, *subak* organizes their own members to have good togetherness, for instance, in the irrigation management. They always entrust the other farmers regarding the water distribution and allocation flowing to their own rice fields. There is no permanent gate block in the division structure on the canal, even no security for controlling the irrigation water. This means that they have high trust to the others. Trust of members is also strongly influenced by the belief to the God which is reflected on the ritual ceremonies activities for the irrigation and farming activities. The *subak's* members have high trust to the management board for their ways to manage irrigation and farming as well as economic activities. This, furthermore, strongly encouraged members to agree with the plan for the *subak* cooperative establishment. Members ensured that management board could manage well the *subak* cooperative initiated by the government for improving the agricultural productivity and economic benefits of them. In other side, the management board also trusted the members that they could support the new cooperative. They finally agreed to have new management board of *subak* cooperative, in which the chairman of *subak* is being a controller (see the Figure 2 above). In the operation of *subak* cooperative, the members also have high trust to the management board (manager and his staff), especially in distributing and returning of loans, financial management responsibility, and others.

##### 4.4.2 Social norms

Social norms strongly contain the specific actions that are regarded by a set of persons as proper or correct, or improper and incorrect and have potential rewards and punishments for them. In *subak* system, social norm (called *awig-awig*) as an internal regulations is significantly influenced the behaviour of members in irrigation and farming activities as well as economic activities. At least, this contains water distribution and allocation, cropping pattern, cropping schedule, ritual ceremonies, regular and irregular meetings, economic activities, mechanism of credit/loan, membership and management tasks, etc. The social norms of *subak* and cooperatives are written and legalized by the government. Actually, the *awig-awig* of *subak* is very strong without any legalization of government, but the new regulation of government forced *subaks* in Bali to register their own *awig-awig* to be legalized by government. Social sanctions of *subak* have significant influences to farmers for not doing wrong things, such as stopping irrigation water, isolated by the others, etc.

Table 3 Distribution of farmers' frequencies relied on trust, social norms and social networking

No	Category	Trust		Social norm		Social networking	
		Frequency (person)	Percentage (%)	Frequency (person)	Percentage (%)	Frequency (person)	Percentage (%)
1	Very high	51	72.86	54	77.14	26	37.14
2	High	19	27.4	16	22.86	35	50.00
3	Moderate	0	0	0	0.00	9	12.86
4	Low	0	0	0	0.00	0	0
5	Very low	0	0	0	0.00	0	0
	Total	70	100	70	100	70	100

Source: Analysis of primary data

In irrigation matter, members must follow the regulations regarding water distribution and allocation, mutual works for rehabilitation, operation and maintenance of irrigation facilities. Even in farming system, all of members must properly do regulations concerning seeds variety planted, planting schedule, cropping patterns, etc. In addition, the ritual ceremonies must also be followed by the farmers based on the regulations and other consensus decided in the *subak* meeting. In this study, social norms as component of social capital was measured on knowledge, attitude of members toward internal regulation in

*subak* and cooperative, strength of internal regulations to govern members and obeisance of norms. The average score of social norms power within *subak* and cooperative is approximately 85.34 % of the maximum score or categorized as very strong with the interval between 83.00 % to 89.50 %. Most of members have very high score or very strong, that is 77.14 % as shown in Table 3 above.

#### 4.4.3 Social networking

Social networking is regarded as the ties of people in their interaction for achieving the share purposes. In this study, social networking comprises interactions among members, between members and board of *subak*, between members and board of cooperative, and between members and outsiders. Based on survey conducted toward 70 samples of cooperative members, it is pointed out that the average of networking is high category, that is 79.04 % out of the maximum score with the interval between 67.00 % to 86.00 %. Most of them (50.00 %) has high networking. Distribution of farmers' frequencies relied on social networking is shown in Table 3 above.

In general, it is 12.86 % of farmers has moderate interaction among the members and boards of *subak*, cooperative and the outsiders, particularly the agricultural extension agents. For interaction among the farmers, specifically they expect to have benefits for agricultural activities since the network among them could be function as a channel for information and media for informal and formal discussions. In this study, farmers are intensively involved in day to day communication with the others as they stay near each other and have social relationship regarding social activities in the village. The interaction among members might take place in the community hall belong to village and sub-village, and *subak*, coffee shop, and other places such as the individual farmers' house. Interactions between members and boards of *subak* and cooperatives are very useful in the channeling process of information coming from outsider and members, too. This makes two way traffic of communication among members and boards of *subak* and cooperative, such as about the agricultural innovation, the needs of agro-inputs, etc. The interactions cited above are conducted on the local values basis within *subak* and village. Besides, the *subak* and cooperative also have internal regulations as a consensus of themselves. This strengthen the interaction ties among the members and management boards for the *subak* and cooperative activities.

#### 4.5 Ways to strengthen social capital on agricultural development

Sustainability of agricultural development, especially on the program of agricultural cooperative in *subak* system needs some ways to be done by *subak* and other external institutions, such government and private sectors concerning social capital. Based on the research and experiences of Guama *subak*, the ways for sustaining and developing agricultural development consist of (i) conducting intensively extension and training activities by using participatory approach; (ii) providing economic stimulant for encouraging farmers in sustaining agribusiness program; and (iii) facilitating partnership activity between *subak* and other agribusiness institutions.

##### 4.5.1 Intensive extension and training

Even though mutual trust within *subak* of Guama is high, it is still needed to be increased in order to sustain the agricultural program that had been implemented. This could be done through intensive extension and training by the facilitators. This might be fully participatory approaches in which the farmers should be actively involved in the activities relating to agribusiness development. Aside from agricultural practices, the extension and training activities should be on the management and personality development to *subak* and cooperative.

As a component of social capital, mutual trust has a significant role to ensure members and management boards in supporting agricultural development. Mutual trust might strengthen social networking among the farmers and management boards and the external institutions, such as agricultural extension workers under the social norms of *subak* and cooperative. Openness management of *subak* cooperative keep the trust of members to join in the cooperative. Meaning to say that, mutual trusts among the members and management boards of *subak* and cooperative are regarded as a collective energy of *subak* and cooperative for the its sustainability.

##### 4.5.2 Providing economic stimulant

Agribusiness constitutes a new paradigm of agricultural development introduced within *subak* system. This is needed economic capital as resources for its management, such as agro inputs provision, credit and the like. Therefore, economic stimulant is significantly important to start agribusiness activities in *subak* system. Provision of economic stimulant such as seed money might be very beneficial for the *subak* to be motivated in taking the agribusiness program. This, of course, should be followed by the intensive facilitation in order that *subak* could have well understanding of program and seize it into productive activities for improving the productivity of farms and increasing the income of *subak* and its members, through the agricultural cooperative establishment. Experiences in *Subak* of Guama pointed out that the seed money provided by the government could be used properly for the agribusiness activities, such as ICM, CLS and micro credit. Management boards of *subak* and cooperative were intensively encouraged by the government staff for having togetherness in implementing the economic stimulant provided. Meetings and discussions among the members and management boards of *subak* and cooperative were facilitated by government staff to define internal regulation as social norms for its management.

##### 4.5.3 Facilitating partnership

Agribusiness system is an agricultural business that consists of inter-related subsystems, such as farm inputs provision and distribution, on-farm activities, processing and marketing and other supporting one. Owing to complex activities, implementation of agribusiness within *subak* system requires external parties to support the program. Provision of farm inputs (fertilizers and pesticides), for instance, the cooperative of *subak* could not produce by itself, so it has to establish the partnership with a distributor of farm inputs. The agricultural extension workers could facilitate the cooperative to prepare proper partnership with PT Pertani (an agricultural enterprise). By this partnership, cooperative has authority to retail fertilizers for fulfil the needs of famers within Subak of Guama. Another partnership which might be established is with government institution (The Seed Control and Certification Agency) for producing certified seeds. Seed produced by *subak* could be sold to other farmers in Bali after getting certification label from the agency and then cooperative could get profit. Seed production is one of the business activities run by *subak* cooperative under the supervision of government institutions (Rice Seeds Certification Agency, Bali Province and Agency of Research and Development for Agriculture-Bali). In order to produce the seeds, cooperative invited farmers under the *subak* recommendation to join in the program of rice seed production. The willingness of farmers in the program is to have higher price of their product.

## 5 CONCLUSION

One of the agricultural development introduced by government is agribusiness program within *subak* system. In *Subak* of Guama, the main activity for this program was done by establishing agricultural cooperative (KUAT) that managed the ICM, CLS and micro credit, and other activities. The mutual trust within *Subak* of Guama (among *subak* members and cooperative of *subak*) was very high concerning agribusiness development and other related activities of *subak*. Social norms (called *awig-awig*) of *subak* was very strong to govern members and management board of *subak* in practicing the agricultural, irrigation and agribusiness activities including ritual ceremonies within *subak* system. Social networking within *subak* system consisted of social interaction among *subak* members and management board and the other external sides, such as agricultural extension workers. This social networking is relatively high. In order to sustain the agribusiness program, there are some ways that should be conducted, especially to strengthen social capital in *subak* system. These consist of (i) conducting intensively extension and training activities by using participatory approach; (ii) providing economic stimulant for encouraging farmers in sustaining agribusiness program; and (iii) facilitating partnership activity between *subak* and other agribusiness institutions.

## ACKNOWLEDGMENT

In this opportunity, we would like to say thank to Rector of Dwijendra University (Ketut Wirawan) and the Chairman of Dwijendra Foundation (Mr. Ida Bagus Gede Wiyana) for his financial support to conduct the study, and the management boards of Subak of Guama and its cooperative for their cooperation during the data collection and doing participatory approach to their members.

## REFERENCES

- [1] F.Ashok, Fisseha T, and Carmen L. S., "The Impact of Participation in Cooperatives on the Success of Small Farms". *Journal of Agribusiness* 22,1, pp. 31-48, 2004.
- [2] K. Suradisastra, "Agricultural Cooperative in Indonesia" 2006 FFTC-NACF International Seminar on Agricultural Cooperatives in Asia: Innovations and Opportunities in the 21<sup>st</sup> Century, Seoul, Korea, 11-15 September 2006
- [3] S. Buyan, . The "People" Factor in Cooperatives: An Analysis of Members' Attitudes and Behavior" , *Canadian Journal of Agricultural Economics* 55, pp.275–298, 2007
- [4] K.Zarafshani, Farough R., Gholam H.H., Morteza A and Hossein A. , Are Agricultural Production Cooperatives Successful? A Case Study in Western Iran". *American-Eurasian J. Agric. & Environ. Sci.*, 8 (4):pp. 482-486, 2010
- [5 ] G.F. Ortmann and King, RP. "Agricultural Cooperatives II: Can They Facilitate Access of Small-Scale Farmers in South Africa to Input and Product Markets?" *Agrekon*, vol. 46, no. 2, 2007.
- [6] B. Thomas and Martha M.H. "Reviewing Theory, Practices and Dynamics of Agricultural cooperatives: Understanding cooperatives' Development in Namibia", *Journal of Development and Agricultural Economics* vol. 3 no.16, pp. 695-702, 2011.
- [7] F.Aref."Agricultural Cooperatives for Agricultural Development in Iran" *Life Science Journal*, vol.8, Issue 1, pp.84-85,2011.
- [8] N. Sutawan, N., "Farmer-managed Irrigation Systems and the Impact of Government Assistance: A note from Bali, Indonesia", *selected paper at the Conference on public intervention in farmer-managed irrigation systems. Kathmandu, Nepal, proceedings published by IIMI, Colombo, Sri Lanka.*
- [9] E.W. Coward, *Irrigation Development: Institutional and Organizational Issues*, in *Irrigation and Agricultural Development in Asia: Perspectives from the Social Sciences*. E. Walter Coward Jr. ed. Ithaca: Cornell University Press, 1980.
- [10 ] G.R. Dahal and Krishna P.A.. "Bridging, Linking and Bonding Social Capital in Collective Action, The Case of Kalahan Forest Reserve in The Philippines" *CAPRI Working Paper No. 79.pp.10-11, May 2008.*

- [11] R.Putnam. "The prosperous community: Social capital and public life", *American Prospect* 13, 35–43, 1993.
- [12] F.Fukuyama, "Social capital and the global economy", *Foreign Affairs* 74, pp. 89-103, 1995.
- [13] Gittel and Vidal. 1998. *Common Organizing: Social Capital as a Development Strategy*, Thousand Oaks: Sage
- [14 ] T.F. Carrol, *Social Capital, Local Capacity Building, and Poverty Reduction*. Michigan: Michigan University Press. 2001
- [15 ] M. Fafchamps and Bart, "Social Capital And Agricultural Trade", *American Journal of Agricultural Economics*, vol. 83, no. 3, pp. 680-685, 2001
- [16] ICA (International Co-operative Alliance) (2005). <http://www.ica.coop/>
- [17 ] J. Bigman, " Essay on Agricultural Co-operative, Governance Structure in Fruit and Vegetables Chains", *ERIM Ph.D. Series Research in Management* 15, ISBN 90 – 5892 – 024 – 0, 2002
- [18] S.Motiram and Vakulabharanam, "Corporate and Cooperative Solutions for the Agrarian Crisis in Developing Countries", *Review of Radical Political Economics*, pp.360-467, 2007
- [19] D.G. . Barton, *What is Cooperative? In Cobia D.W (ed) Cooperatives in Agriculture*. Prentice Hall, New Jersey, 1986, pp. 1-21.
- [20] Uphoff, N, *Understanding Social Capital: Learning from the Analysis and Experience of Participation*. In: *Social Capital: A Multifaceted Perspectives*, G. Parthadas and S. Serageldin, eds. Washington D. C.: World Bank, 2000.
- [21] D.C. Korten, *People-Centered Development Alternative for a World in Crisis*, in Bauson (ed), *Development and Democratization in the Third World*. Washington, pp.53-77, 1992.
- [22] M. Hobley, *Participatory forestry: The process of change in India and Nepal*, London: Overseas Development Institute, 1996.
- [23] . Cohen and L. Prusak, *In Good Company: How Social Capital Makes Organizations Work*. Boston, MA: Harvard Business School Press., 2001.
- [24] I.A. Shah and Baporikar, N, "Participatory Approach to Development in Pakistan" *Journal of Economic and Social Studies*. vol. 2 no. 1, 2012.
- [25] A.B.A.Munasib and Jeffrey L.J, "The Effect of Social Capital on the Choice to Use Sustainable Agricultural Practices" *Journal of Agricultural and Applied Economics*, vol.2, no. 43, pp.213–227, 2011.
- [26] R.C. Carter, Sean F.T. and Peter H., Impact and Sustainability of Community Water Supply and Sanitation Programmes in Developing Countries, *Journal of the Chartered Institution of Water and Environmental Management*, Vol 13, pp 292-296, August 1999.

## Vertical Housing for Low-Income People in Urban Areas

### Case Study: The Vertical Simple Housing (Rusunami / Rumah Susun Sederhana Milik) Project of Kalibata Area

El Khobar M. Nazech<sup>a</sup> and Henki W. Ashadi<sup>a</sup>

<sup>a</sup>Department of Civil and Environmental Engineering Faculty of Engineering University of Indonesia

E-mail: [elkhobar@eng.ui.ac.id](mailto:elkhobar@eng.ui.ac.id)

E-mail: [henki@eng.ui.ac.id](mailto:henki@eng.ui.ac.id)

#### ABSTRACT

*Some areas in the urban centers are the informal, unplanned and until recently un-serviced housing areas, which form a large part of most Indonesian cities. Population density in several areas in urban centers exceeds 1,000 persons per hectare, reducing the opportunity for decent living. Most of the physical conditions of housing and habitat do not fulfill the requirements for a healthy environment. Housing affordability for most of urban population is low. The price of urban land is too high and there is limited and private capacity to develop the necessary infrastructure and facilities for housing. The problem cannot be solved by adopting conventional housing approaches. Government and private companies have started providing vertical housing to solve the problems in urban areas in Jakarta. The aim of the vertical housing projects was to provide houses for low-income people and to improve their living conditions. This study aims at an evaluation of the vertical simple housing (Rusunami / Rumah Susun Sederhana Milik) project of Kalibata area, through an analysis of the prevailing conditions and of the opinion of the inhabitants who owned the housing unit. The main finding of the study is that none of the inhabitants are categorized as low-income people. There was a cross subsidy but the sales price of the unit housing was still too high and most low-income people could not afford the unit. The unit housing inhabitants were satisfied with the living conditions and the strength of the building structure, but the degree of acceptance of units' design was low, so that most of them renovated the flat. A rental system may be an alternative for low-income people to have access to healthy housing units in the urban center areas.*

#### Keywords

*urban area, vertical housing, low-income*

## 1. INTRODUCTION

Shelter is one of the human basic needs, important for human physical well-being. Adequate housing contributes to the achievement of the physical and moral health of a nation and stimulates the social stability, the work efficiency and the development of the individuals. It is also one of the best indicators of a person's living standard and of his place in the society.

The housing problem in Jakarta is mainly caused by urbanization and natural population growth. The increase in population has created severe shortage of houses and has placed burden on the municipal services. According to figures released in "Jakarta dalam angka 2011", Jakarta has a population of 9,607,787 in 2010, with population average density of 13,157 people per square kilometer. The average population growth is 4% per annum.

Jakarta needs around 70,000 housing units every year to cater to its growing population, however the city administration is only able to provide 20 percent of that figure. Since Jakarta has very limited space, housing is very expensive and not always accessible to all the people, especially the low income people. This situation forced the government to develop housing program to solve the housing scarcity. In 2007, President Susilo Bambang Yudhoyono announced the building of 1,000 low cost apartment blocks to accommodate the low income people. So far, more than 200 apartment blocks designated as low income rental units has been built in Jakarta. Each of the apartment blocks can accommodate between 800 to 1,000 units.

## 2. STUDY OBJECTIVE

The objective of the study is to assess the use of vertical simple housing as housing alternative for low income people, especially on how the housing area can improve their living condition and what are their opinions on living in a vertical simple housing area.

## 3. RESEARCH METHODOLOGY

### 3.1 Study Subject

The study subject is people living in rusunami units in Tower A, Kalibata Residence, Kalibata City, South Jakarta. There are fifty people involved, 60% are owner while the rest are tenant.

### 3.2 Study Area

Kalibata City is the biggest super block apartments in South Jakarta, consists of 7 Kalibata Residence (rusunami) towers, 3 Kalibata Regency towers and 8 Green Palace towers. The area is designated for modern city living, equipped with 24 hour security services, shopping area, restaurants, fitness centre, swimming pool, jogging park and adventure park. The apartment area is built in 2008 and started to be inhabited in 2011.



Figure 1: Kalibata City apartment block as the study area, rusunami Tower A is located north-east of the area.

### 3.3 Data Collection

Data is collected by giving a set questionnaire to the study subject. The questionnaire is designed to determine the subject response on the following categories:

- Respondent's identity and household characteristics
- Socio-economic background of the household
- Duration of residence and tenure

- Physical conditions and facilities
- Attitude towards the environmental condition of the apartment
- Preference for type of housing
- Satisfaction and preferences with regards to the house design.

The survey was performed in September 2012.

### **3.4 Data Analysis**

The Microsoft Excel program was used to obtain the sum of values, percentages, counts and frequencies. Based on these, the respondent's household characteristics, attitude towards the flat environment and the general indication of satisfaction, their impressions and opinions can be determined.

## **4. RESULTS AND ANALYSIS**

### **4.1 Socio-Economic Characteristics**

All of the flat units are privately owned, owners purchased their units by paying a down payment and monthly mortgage installments. Some of the owners rented out their units, because they purchased the unit for investment purposes. Eighty percent of owners stated that the security of the units' tenure status is good, while the rest is unsure. The reason for their feeling of security of the tenure status is that the unit ownership is guaranteed by the government's regulation.

The average family size in the unit is 4. The household monthly income varies, but there is no low-income household found living in the flats. Each household has to pay for monthly service charge, solid waste disposal, waste water and ground management. Other extra expenditures consist of cost of potable water, electricity and contribution to community associations. Most of the respondents (91%) stated that living in flats has increased their monthly expenditures.

### **4.2 Physical Conditions and Facilities**

Most of the respondent stated that the apartment living area has better facilities than their previous housing area. There are accessible play-ground, kindergarten, school, a meeting hall, mosque, restaurants, public services and a public hydrant. The quantity and quality of facilities are sufficient, it can be said that the inhabitants' quality of life has improved since living in the apartment area. Respondent stated that the environmental conditions in the apartment area are good, and the available basic infrastructures are also better than their former houses. They believed that the structures of the apartment building are strong enough, and has been built based on Indonesia's building code.

All of the units are served by pipe water, but some of the respondents stated that the piped water is insufficient, and have low quality. Each apartment block is equipped with sewerage treatment plants (STP), and the STP maintenance is performed by the management unit. Solid waste disposal is also managed by the management unit. The inhabitants' opinions on the STP and solid waste services are positive, 74 percent said it was efficient, 7 percent was indifferent and 19 percent claimed it was inefficient.

Every flat has electricity supply, only 6 percent of the flats respondents stated that the electricity supply was inefficient, while 4% was indifferent and the rest of respondents said it was sufficient. Sixty-one percent of the respondents think that the condition of the outdoor lighting in the flat was adequate, however 32% said it was inadequate and 7% was indifferent. Most of the respondents said that the road network is sufficient, but the parking facility is insufficient. Most of respondents think that their floor area has decreased compared to their former housing, and stated that they also lost private yards.

### **4.3 Preference for Type of Housing**

The occupants of the flats were asked if their living conditions had improved or deteriorated compared to their former houses. Fifty-four percent of the respondents said it was closer to their work places, 38% said that the Kalibata apartment has better accessibility than their former houses. Seventy-two percent said that the flats have a better public order and 83% said they have better sanitation; 67% of respondents felt the flats are safer; 63% felt the flats are more convenient, and 47% felt the flats are more pleasant than their former houses, but 24% stated that the flats are the same as their former houses. Sixty-nine percent of them stated that they needed larger housing size than their present house.

#### **4.4 Preference with Regard to Design Features**

Around 66% of the household in the flats were dissatisfied with the size and the lay-out of the rooms in the unit, while 34% of them were satisfied. Eighty-two percent were dissatisfied with the size and lay-out of the kitchen, while the rest was satisfied. Seventy-seven percent of the respondents stated that they were dissatisfied with the size and the lay-out of the bathroom and toilet. Fifty-seven percent said they prefer a larger size and 45% of them said they prefer to separate the toilet and bath. Most of the flat dwellers stated that the available space and number of rooms is not sufficient. There is not enough space for drying clothes, so the back façade is used for drying clothes, and also there is no storage space, because they need space for storing things that are not daily used. Most of the flat owners had modified the lay-out and equipped the unit with air conditioning and kitchen tools.

## **5. CONCLUSION**

Flat inhabitants need time to adjust to their new living conditions, living off the ground is still a new and strange life-style for them. However they felt at ease in their new living conditions, because they had a better environment, in particular access to available infrastructures and good building structure. The degree of acceptance of the units' design was low, so that most of them renovated the flat.

Most of government housing program are designed for owner-occupation. This is, however one of the barriers for inhabitants to have access to adequate housing, because the monthly installments are quite high and low-income people cannot afford them. Rental housing may be a solution for low-income groups to have access to a healthy dwelling unit. It is a more realistic approach, because every citizen has a fair chance of securing a decent and adequate house at affordable costs.

## **REFERENCES**

- Richard Arnott, *Housing Policy in Developing Countries: The Importance of the Informal Economy*, The International Bank for Reconstruction and Development / The World Bank On behalf of the Commission on Growth and Development, 2008
- A Regional Housing Affordability Strategy for the Capital Region, Prepared by: Urban Aspects Consulting Group Ltd. Lumina Services Inc.  
G.P. Rollo & Associates Ltd., Land Economists For Regional Planning Services, 2003
- HOUSING IN INDONESIA: EXPANDING ACCESS, IMPROVING EFFICIENCY, the study was funded by AusAID and the World Bank, 2008
- Housing Finance Mechanism in Indonesia, the Human Settlements Finance Systems Series, published in Nairobi in 2008 by UN-HABITAT, Copyright @
- Demographic Transition, Economic Crisis and the Housing Deficit in Indonesia, paper by Paavo Monkkonen, Assistant Professor, Room 840, Knowles Building; Department of Urban Planning and Design, The University of Hong Kong, Pokfulam, Hong Kong, 2012
- The Jakarta Globe Newspaper, November 04, 2009

\*Submitted to: The 13<sup>th</sup> International Conference on QIR (Quality in Research) Yogyakarta, 2013.

# Measurement of Education Quality with KANO Model : A Case Study on Elementary School

Ig. Jaka Mulyana<sup>a</sup>

<sup>a</sup>Industrial Engineering Department Widya Mandala Surabaya Catholic University  
Jl. Kalijudan 37 Surabaya 60114 Indonesia  
e-mail :  
jmulyono@mail.wima.ac.id  
mulyonjoko@yahoo.co.id

## ABSTRACT

Quality is the important and necessary to get serious attention of the company in running its operations strategy including in the elementary school. Measuring the quality of services is more complicated because of the is intangible that each customer has different perceptions about the quality of services. KANO's model has been widely applied in measuring service quality. The purpose of this study is to measure the level of satisfaction of expectation of parents towards education and perform the classification of the KANO model of educational service attributes. Measurement of education based on 5 dimension of services quality Zeithaml, Parasuraman, dan Berry (1990), that is tangible, reliability, responsiveness, assurance dan empathy. The result showed that there is still a gap between the level satisfaction and expectation that are the completeness of the library books, cleanliness of toilets and computer laboratory. Furthermore, the results of the classification attributes using KANO model of education services found that 25 attributes in the category of One Dimensional, 4 attributes in the category of Attractive and 1 attribute is categorized in Indifferent

## Keywords

service quality, customer satisfaction, elementary school, KANO model

## → 1. INTRODUCTION

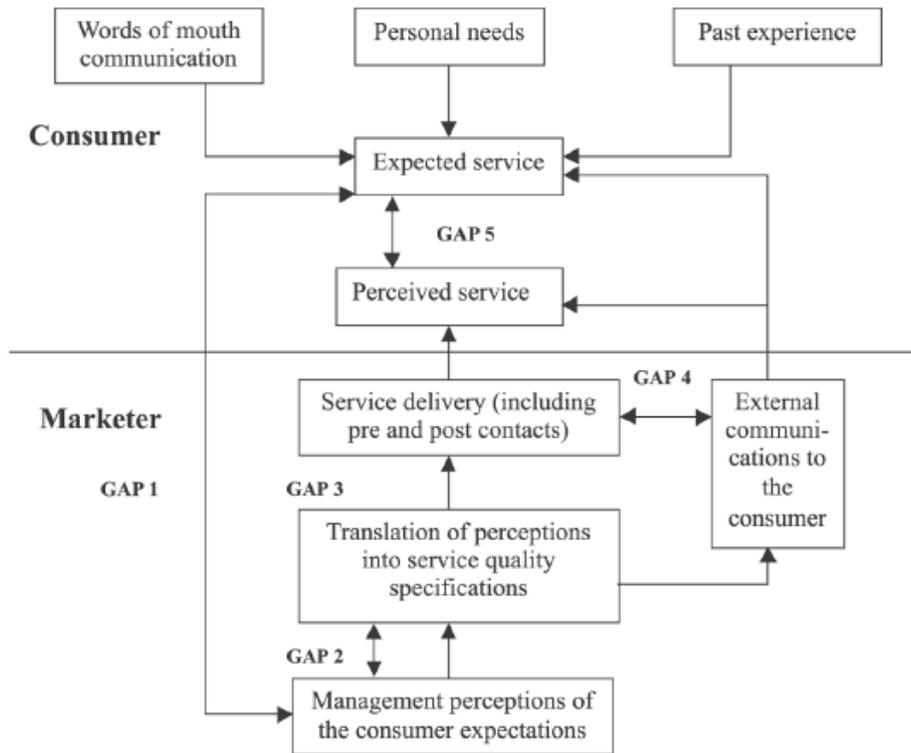
Based on Herzberg's 'Motivator-Hygiene Theory', Kano *et al.* [1] defined the product quality element of different categories that impact customer satisfaction in different ways. Which namely: attractive quality attribute, must-be quality attribute, one-dimensional quality attribute, indifferent quality attribute and reverse quality attribute. Using Kano's model, quality attributes that have the greatest influence on customer satisfaction can therefore be identified, and these can then be used to focus on priorities for product or service development and improvement [2]. With such advantage, Kano model is widely used in quality management [3], logistics services [4] product development [5-7] as well as QFD integration [8-10]. Kano model also used to evaluate quality evaluation of education [11-13]. Quality in education is as important as the quality of business. Elementary school is an important stage of education, where basic values instilled child begins. Basic education in elementary school will influence the child's subsequent development of thinking. Thus every school, including elementary schools, should improve the quality of education services. Considering on this, to understand customer satisfaction of the education institution, we need to understand the customer's need and the expectation. Improving the quality of education would have to focus on customer satisfaction. Kano *et al.* [1] developed a model to categorize the attributes of a product or service based on how well they are able to satisfy customer. Mostly service qualities have both poor and versatile characteristics because service quality is based on the customers' feelings. Therefore, the evaluation of service quality is more difficult than that of the product quality. Parasuraman *et al.* [14] developed the instrument SERVQUAL for measuring customers' perceptions of service quality needs. In this paper, service quality of elementary school was measured and analyzed by service gaps and classified by KANO's method.

## 2. CONCEPTUAL BACKGROUND

### 2.1. Service Quality

A firm in order to compete successfully must have an understanding of consumer perception of the quality and the way service quality is influenced. Managing perceived service quality means that the firm has to match the expected service and perceived service to each other so that consumer satisfaction is achieved [15]. Parasuraman *et al.* [16] proposed that service quality is a function of the differences between expectation and performance along the quality dimensions. They developed a service quality model (Figure 1) based on gap analysis. The various gaps visualized in the model are:

- Gap 1: Differences between consumers' expectation and management's perceptions of those expectations, for example not knowing what consumers expect.
- Gap 2: Differences between management's perceptions of consumer's expectations and service quality specifications, for example improper service-quality standards.
- Gap 3: Differences between service quality specifications and service actually delivered for example the service performance gap.
- Gap 4: Differences between service delivery and the communications to consumers about service delivery, for example whether promises match delivery?
- Gap 5: Differences between consumer's expectation and perceived service. This gap depends on size and direction of the four gaps associated with the delivery of service quality on the marketer's side.

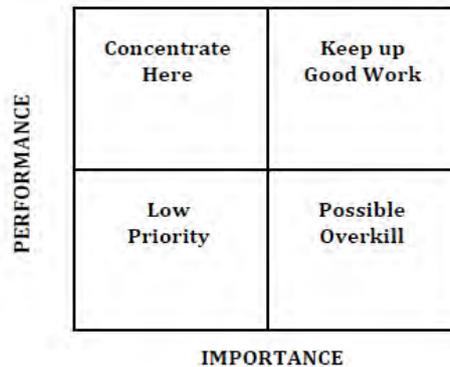


Source : Parasuraman, et.all [16]

Figure 1: Gap Analysis Model

## 2.2. Importance-Performance Analysis and KANO Model

Importance Performance Analysis (IPA) technique is Importance-Performance analysis of the underlying conceptual multi-attribute model to analyze the organization's performance. IPA model is used to measure the importance of customer satisfaction and performance, and develop relationships based on specific product attributes. The main purpose of the IPA is as a diagnostic tool to facilitate the identification of attributes, given their importance, products or services of poor performance or over perform. For this purpose, the interpretation is presented graphically on a grid divided into four quadrants, which according to the average importance and satisfaction (performance)[17]. Four quadrants and the implications of the IPA are shown in Table 1 and Figure 2. The four quadrants are identified are *Concentrate Here*, *Keep the Good Work*, *Low Priority* and *Possible Overkill*.



Source : Haeryip Sihombing, et.all[17]

Figure 2: Importance Performance Analysis Grid

Table 1. Importance Performance Quadrant

<b>Quadrant I</b> <i>Concentrate Here</i>	Attributes are perceived to be very important to respondents, but performance levels are fairly low. This suggests that improvement efforts should be concentrated here.
<b>Quadrant II</b> <i>Keep up the good work</i>	Attributes are perceived to be very important to respondents, and at the same time, the organization seems to have high levels of performance in these activities. The message here is to keep up the good work.
<b>Quadrant III</b> <i>Lower priority</i>	Attributes here are rated as having low importance and low performance. Although performance levels may be low in this cell, managers should not be overly concerned, since the attributes in this cell are not perceived to be very important. Limited resources should be expended on this low priority cell.
<b>Quadrant IV</b> <i>Possible over kill</i>	This cell contains attributes of low importance, but where performance is relatively high. Respondents are satisfied with the performance of the organization, but managers should consider present efforts on the attributes of this cell as being superfluous/ unnecessary.

Source : Haeryip Sihombing, et.all[17]

Parasuraman *et al* [14] defined the 5 attributes dimensions of service quality (SERVQUAL) as the method used to measure the quality of service as follows:

- (i) Reliability: ability to perform the promised service, dependably and accurately.
- (ii) Responsiveness: willingness to help customers and provide prompt service.
- (iii) Assurance: knowledge and courtesy of employees as well as their ability to inspire trust and confidence.
- (iv) Empathy: caring, individualized attention the firm provides its customers.
- (v) Tangibles: appearance of physical facilities, equipment, personnel, and communication materials

Kano *et al.* [1] developed a model to categorize the attributes of a product or service based on how well they are able to satisfy customer needs. The Kano model is a theory of product development and customer satisfaction developed in the 80s by Professor Noriaki Kano which classifies customer preferences into five categories: (i) Attractive, (ii) One-Dimensional, (iii) Must-be, (iv) Indifferent, (v) Reverse. The one-dimension quality model focuses on one quality element. It states that if the quality element is of sufficiency then the customer is satisfied, otherwise the customer is not satisfied. Two-dimension quality model argued that quality elements sufficiency may not enough to satisfy the customers' quality expectation. Sometimes it may result in un satisfaction or no feeling for the customer. This is the core concept of the two-dimension quality model. The concept of the two-dimension quality is proposed by Herzberg in 1987. Kano called the Herzberg's Motivator-Hygiene theory as the quality's (Motivator-Hygiene) M-H theory. Due to this terminology is too complicate to use it. Kano redefines the

quality's M-H theory as attractive quality and must-be quality, and distinguishes the service quality in terms of attractive quality elements, one-dimension quality elements, must-be quality elements, indifferent quality elements and reverse quality elements. The following are the quality elements categories:

These categories have been translated into English using various different names (delighters/exciters, satisfiers, dissatisfiers, etc.), but all refer to the original articles written by Kano (see Figure 3)[18].

1. **Attractive Quality:** These attributes provide satisfaction when achieved fully, but do not cause dissatisfaction when not fulfilled. These are attributes that are not normally expected for example, a thermometer on a package of milk showing the temperature of the milk. Since these types of attributes of quality unexpectedly delight customers, they are often unspoken.
2. **One-dimensional Quality:** These attributes result in satisfaction when fulfilled and dissatisfaction when not fulfilled. These are attributes that are spoken of and ones which companies compete for. An example of this would be a milk package that is said to have ten percent more milk for the same price will result in customer satisfaction, but if it only contains six percent then the customer will feel misled and it will lead to dissatisfaction.
3. **Must-be Quality:** These attributes are taken for granted when fulfilled but result in dissatisfaction when not fulfilled. An example of this would be package of milk that leaks. Customers are dissatisfied when the package leaks, but when it does not leak the result is not increased customer satisfaction. Since customers expect these attributes and view them as basic, then it is unlikely that they are going to tell the company about them when asked about quality attributes.
4. **Indifferent Quality:** These attributes refer to aspects that are neither good nor bad, and they do not result in either customer satisfaction or customer dissatisfaction.
5. **Reverse Quality:** These attributes refer to a high degree of achievement resulting in dissatisfaction and to the fact that not all customers are alike. For example, some customers prefer high-tech products, while others prefer the basic model of a product and will be dissatisfied if a product has too many extra features

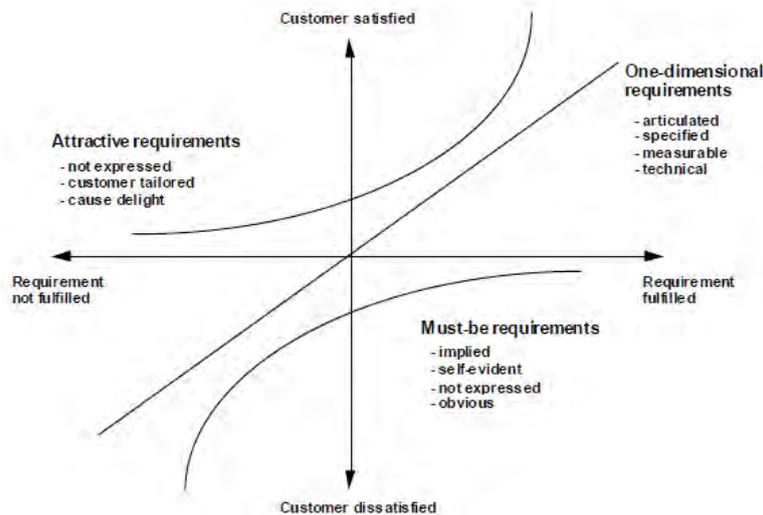


Figure 3: KANO's Model Customer Satisfaction

### 3. METODHOLOGY

The framework of this study can be seen on figure 4.

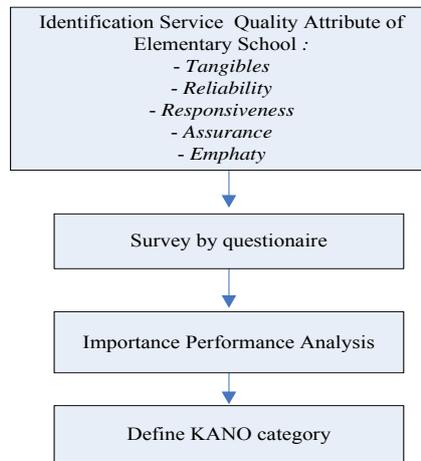


Figure 4. Framework of study

Service quality attribute of elementary school as in table 2 below :

Table 2. Service Quality Attribute of Elementary School

Dimension	Attribute	Code
Tangibles	Academic calendar availability	A1
	Academic calendar implemented as planned	A2
	Teacher have a good capability	A3
	Teachers teach subjects according to educational background	A4
	Teaching are always conducted as scheduled	A5
	Availability of the agenda book	A6
Reliability	Classrooms are clean and comfortable	B1
	Facilities and modern teaching equipment	B2
	A completely of library	B3
	Sports facilities	B4
	Availability of student activity	B5
	Cleanliness of toilets	B6
	Computer laboratory	B7
	Completed and updated school's website	B8
	Cleanliness school environment	B9
	Teachers and staff dressed	B10
	Parking area	B11
School location is easy to access	B12	
Responsiveness	Teachers respond to questions and complaints of parents well	C1
	Teachers are willing to talk to parents about child's problem	C2
Assurance	Number of teacher	D1
	The use of teaching methods	D2
	Availability of textbooks	D3
	The number of students in one class	D4
	Education about manners, responsibility and honesty	D5
Empathy	Communication between teachers and parents	E1
	Regular meetings between teachers and parents	E2
	Parent organization	E3

The survey was carried out through two type of questionnaire to analyze parent satisfaction. The first one is used for analyzing importance and performance. On the first questionnaire, respondents give rank of importance and performance for every

attribute by Likert scale between 1 and 5. The second questionnaire is used to categorize service quality attribute by KANO Model. To apply the Kano classifications to divide the quality elements into attractive, one-dimensional, must-be, indifferent, and reverse quality elements is used by table 3 [19]

Table 3. KANO Evaluation Table  
 Source : Matzler & Hinterhuber (1998)

Product requirement →		Dysfunctional form of the question				
		I like that way	It must be that way	I am neutral	I can live with it that way	I dislike that way
Functional form of the question ↓	I like that way	Q	A	A	A	O
	It must be that way	R	I	I	I	M
	I am neutral	R	I	I	I	M
	I can live with it that way	R	I	I	I	M
	I dislike that way	R	R	R	R	Q

Where : Q= questionable, A = attractive, O = one dimensional, R=reverse, I = indifferent, M =must be

To classify attribute we used Blauth's formulas :

- If (one dimensional + attractive + must be) > (indifferent + reverse + questionable) then the category is maximum [one dimensional; attractive; must be]
- if (one dimensional + attractive + must be) < (indifferent + reverse + questionable) then the category maximum [indifferent; reverse; questionable]

#### 4. RESULTS AND DISCUSSION

This study includes 150 respondents. The respondents are parents of elementary school. Summary of respondent can be seen at table 4.

Table 4. Summary of respondent

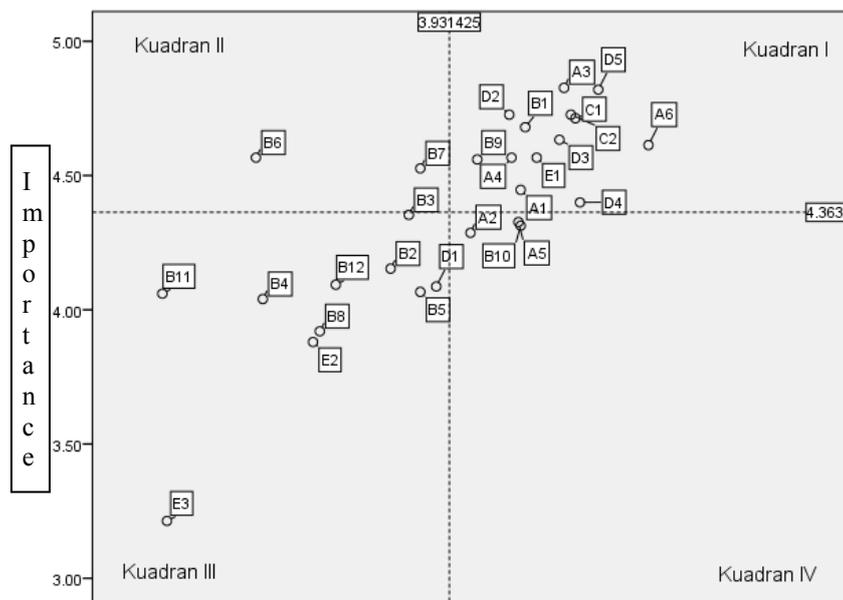
Item	Category	Amount	Percentage
Age	< 25 year	0	0.00
	25 – 30	5	3.33
	30 - 35	34	22.67
	35 - 40	47	31.33
	40 - 45	43	28.67
	>45	21	14.00
Occupation	Gov. Officer	13	8.67
	Private Officer	58	38.67
	Entrepreneur	26	17.33
	Military	13	8.67
	Doctor	1	0.67
	Teacher/Lecturer	10	6.67
	Others	29	19.33
Eductaion	High School	50	33.33
	Diploma	19	12.67
	Undergraduate	67	44.67
	Master	9	6.00
	Doctoral	0	0.00
	Military	2	1.33
	Others	3	2.00

Gap analysis conduct to analyze whether there are differences in the level of importance and performance of each service attribute. Summary of importance and performance of each service attribute can be seen in Table 5. The mean level of assessment and the level of interest then made Cartesian diagram as shown in figure 5.

Table 5. Average of Importance and Performance

Item	Average of Importance	Average of Performance
------	-----------------------	------------------------

A1	4.4467	4.1400
A2	4.2867	3.9933
A3	4.8267	4.2667
A4	4.5667	4.1133
A5	4.3267	4.1333
A6	4.6133	4.5133
B1	4.6800	4.1533
B2	4.1533	3.7600
B3	4.3533	3.8133
B4	4.0400	3.3867
B5	4.0667	3.8467
B6	4.5667	3.3667
B7	4.5267	3.8467
B8	3.9200	3.5533
B9	4.5600	4.0133
B10	4.3133	4.1400
B11	4.0600	3.0933
B12	4.0933	3.6000
C1	4.7133	4.3000
C2	4.7267	4.2867
D1	4.0867	3.8933
D2	4.7267	4.1067
D3	4.6333	4.2533
D4	4.4000	4.3133
D5	4.8200	4.3667
E1	4.5667	4.1867
E2	3.8800	3.5333
E3	3.2133	3.1067



Performance

Figure 5: Cartesian Diagram

From Cartesian diagram, grouping each attribute in each quadrant is shown in Table 6.

Table 6. Grouping attribute to Cartesian Diagram

Quadrant	Code	Attribute
Quadrant I	A1	Academic calendar availability
	A3	Teacher have a good capability
	A4	Teachers teach subjects according to educational
	A6	Availability of the agenda book
	B1	Classrooms are clean and comfortable
	B9	Cleanliness school environment
	C1	Teachers respond to questions and complaints of parents well
	C2	Teachers are willing to talk to parents about child's problem
	D2	The use of teaching methods
	D3	Availability of textbooks
	D4	The number of students in one class
	D5	Education about manners, responsibility and honesty
	E1	Communication between teachers and parents
Quadrant II	B3	A completely of library
	B6	Cleanliness of toilets
	B7	Computer laboratory
Quadrant III	B2	Facilities and modern teaching equipment
	B4	Sports facilities
	B5	Availability of student activity
	B8	Completed and updated school's website
	B11	Parking area
	B12	School location is easy to access
	D1	Number of teacher
	E2	Regular meetings between teachers and parents
	E3	Parent organization
Quadrant IV	A2	Academic calendar implemented as planned
	A5	Teaching are always conducted as scheduled
	B10	Teachers and staff dressed

To categorize service quality attribute by KANO Model is based on answers to questions functional and dysfunctional each attribute. According to KANO evaluation table 3, sum of KANO category for every attribute can be seen on table 7.

Table 7. Sum of KANO Category

Code	Attribute	Sum of KANO Category					
		O	A	M	I	R	Q
A1	Academic calendar availability	81	35	7	15	0	0
A2	Academic calendar implemented as planned	65	36	14	21	1	1
A3	Teacher have a good capability	112	13	9	4	0	0
A4	Teachers teach subjects according to educational background	65	44	9	19	0	1
A5	Teaching are always conducted as scheduled	104	12	17	5	0	0
A6	Availability of the agenda book	99	19	7	13	0	0
B1	Classrooms are clean and comfortable	115	9	8	5	0	1
B2	Facilities and modern teaching equipment	42	55	6	35	0	0
B3	A completely of library	44	68	5	21	0	0
B4	Sports facilities	46	50	6	36	0	0
B5	Availability of student activity	27	74	3	34	0	0
B6	Cleanliness of toilets	123	7	7	1	0	0
B7	Computer laboratory	70	45	8	15	0	0
B8	Completed and updated school's website	53	42	7	36	0	0
B9	Cleanliness school environment	117	11	7	3	0	0
B10	Teachers and staff dressed	76	37	12	13	0	0
B11	Parking area	49	48	11	30	0	0
B12	School location is easy to access	74	36	10	18	0	0
C1	Teachers respond to questions and complaints of parents well	96	26	8	8	0	0
C2	Teachers are willing to talk to parents about child's problem	96	17	16	9	0	0
D1	Number of teacher	70	41	10	17	0	0
D2	The use of teaching methods	104	24	8	2	0	0
D3	Availability of textbooks	96	30	7	5	0	0
D4	The number of students in one class	75	33	5	24	1	0
D5	Education about manners, responsibility and honesty	123	9	4	2	0	0
E1	Communication between teachers and parents	101	15	16	6	0	0
E2	Regular meetings between teachers and parents	39	26	23	49	1	0
E3	Parent organization	15	28	2	89	4	0

Based on the results in Table 7, the determination of KANO categories for each attribute using Blauth's formula can be seen on table 8.

Table 8. KANO Category

Code	Attribute	KANO Category
A1	Academic calendar availability	O
A2	Academic calendar implemented as planned	O
A3	Teacher have a good capability	O
A4	Teachers teach subjects according to educational background	O
A5	Teaching are always conducted as scheduled	O
A6	Availability of the agenda book	O
B1	Classrooms are clean and comfortable	O
B2	Facilities and modern teaching equipment	A
B3	A completely of library	A
B4	Sports facilities	A
B5	Availability of student activity	A
B6	Cleanliness of toilets	O
B7	Computer laboratory	O
B8	Completed and updated school's website	O
B9	Cleanliness school environment	O
B10	Teachers and staff dressed	O
B11	Parking area	O
B12	School location is easy to access	O
C1	Teachers respond to questions and complaints of parents well	O

C2	Teachers are willing to talk to parents about child's problem	O
D1	Number of teacher	O
D2	The use of teaching methods	O
D3	Availability of textbooks	O
D4	The number of students in one class	O
D5	Education about manners, responsibility and honesty	O
E1	Communication between teachers and parents	O
E2	Regular meetings between teachers and parents	O
E3	Parent organization	I

From the results of respondents' answers to the level of importance and performance of each service attribute as can be seen in Table 5, it can be seen that the average rate of importance of all attributes greater than the performance. However, to give priority to improve attribute can be seen from the Cartesian diagram in Figure 5. Attributes that need serious attention to be improved are the attributes that in quadrant II that is completeness of library, Cleanliness of toilets and computer laboratory, because these attributes are considered bad perform but it is important for parents. This causes the parents disappointed. From the categorization of KANO model in Table 8, most of the attributes as category O (One Dimensional) means the rate of satisfaction is linear-related with performance that mean if performance attributes high will result in higher satisfaction parents. In other words, if we want to increase the satisfaction of the parents is by increasing the performance its attribute.

## 5. CONCLUSION

According to Gap Analysis we can conclude that in general there is gap between expectation and satisfaction of service in elementary school. The attribute that should be improved immediately are completeness of library, cleanliness of toilets and computer laboratory. Based on KANO analysis, 23 attribute are as One-Dimensional, 4 as Attractive and 1 as Indifferent.

## REFERENCES

- [1] Kano, N., Seraku, K., Takahashi, F. and Tsuji, S., "Attractive Quality and Must-Be Quality," *The Journal of Japanese Society for Quality Control*, Vol. 41, No. 2, 1984, pp. 39-48.
- [2] K. Matzler and H. H. Hinterhuber, "How to Make Product Development Projects More Successful by Integrating Kano's Model of Customer Satisfaction into Quality Function Deployment," *Technovation*, Vol. 8, No. 1, 1998, pp. 25-38. doi:10.1016/S0166-4972(97)00072-2
- [3] Yang and C. Chow, "The Refined Kano's Model and Its Application," *Total Quality Management and Business Excellence*, Vol. 16, No. 10, 2005, pp. 1127-1137. doi:10.1080/14783360500235850
- [4] Qingliang Meng, Nongji Zhou, Jian Tian, Yijia Chen, Fen Zhou," Analysis of Logistics Service Attributes Based on Quantitative Kano Model: A Case Study of Express Delivering Industries in China," *Journal of Service Science and Management*, 2011, 4, 42-51. doi:10.4236/jssm.2011.41007
- [5] J. Fullera and K. Matzlerb, "Virtual Product Experience and Customer Participation-A Chance for Customer-Centred, Really New Products," *Technovation*, Vol. 27, No. 6-7, 2007, pp. 378-387. doi:10.1016/j.technovation.2006.09.005
- [6] C. C. Chen and M. C. Chuang. "Integrating the Kano Model into a Robust Design Approach to Enhance Customer Satisfaction with Product Design," *International Journal of Production Economics*, Vol. 114, No. 2, 2008, pp. 667-681. doi:10.1016/j.ijpe.2008.02.015
- [7] Y. Li, J. Tang, X.Luo, J. Xu, "An Integrated Method of Rough Set, Kano's Model and AHP for Rating Customer Requirements' Final Importance," *Expert Systems with Applications*, Vol. 36, No. 3, 2009, pp. 7045-7053. doi:10.1016/j.eswa.2008.08.036
- [8] T. Gerson, "Integrating the Kano Model and QFD for Designing New Products," *Total Quality Management*, Vol. 18, No. 6, 2007, pp. 599-612. doi:10.1080/14783360701349351
- [9] Y. C. Lee, Liang-Chyau Sheu and Yuan-Gan Tsou, "Quality Function Deployment Implementation Based on Fuzzy Kano Model: An Application in PLM System," *Computers & Industrial Engineering*, Vol. 55, No. 1, 2008, pp. 48-63. doi:10.1016/j.cie.2007.11.014
- [10] Li. H. Chen and W. C. Ko, "A Fuzzy Nonlinear Model for Quality Function Deployment Considering Kano's Concept," *Mathematical and Computer Modelling*, Vol. 48, No. 3, 2008, pp. 581-593. doi:10.1016/j.mcm.2007.06.02
- [11] Mean-Shen Liu, "Using the Refined Kano's Model to Measure University Education Quality: The Case Study on the Department of Food and Beverage Management in Southern Taiwan," *The Business Review*, Cambridge \* Vol. 11, Num. 1, 2008, pp.111 -117
- [12] Ya-Ching Yeh, "Evaluating administrative service quality of elementary schools: a case study of remote rural area in Taiwan," *African Journal of Business Management* vol.5(14), 2011, pp.5966-5973
- [13] HAERYIP SIHOMBING, YUHAZRI, M.Y., YAHAYA, S.H., MYIA YUZRINA, Z.A. and AINUL AZNIZA5, A.Z." REVISITED THE IMPORTANCE AND PERFORMANCE ANALYSIS (IPA) AND KANO MODEL FOR CUSTOMER SATISFACTION MEASUREMENT," *GLOBAL ENGINEERS & TECHNOLOGISTS REVIEW*, pp 22-29, 2012
- [14] Parasuraman, A., Zeithaml, A.V. and Berry, L.L., *SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality*, *Journal of Retailing*, Vol. 64, 1988, pp. 12-40.

- [15] Gronroos, C., "A service quality model and its marketing implications", *European Journal of Marketing*, Vol. 18 No. 4, , 1984, pp. 36-44
- [16] Parasuraman, A., Zeithaml, V.A. and Berry, L.L. "A conceptual model of service quality and its implications for future research", *Journal of Marketing*, Vol. 49 No. 3, 1985, pp. 41-50.
- [17] Haeryip Sihombing, YUHAZRI, M.Y., YAHAYA, S.H., MYIA YUZRINA, Z.A. and AINUL AZNIZA, A.Z., "Revisited The Importance and Performance Analysis (IPA) and KANO Model for Customer Satisfaction Measurement, *Global Engineers & Technologist Review*, Vol.2 No.1 ,2012, pp. 22-39
- [18] Parul Gupta, SRIVASTAVA, R.K., "ANALYSIS OF CUSTOMER SATISFACTION OF THE HOTEL INDUSTRY IN INDIA USING KANO MODEL & QFD", *INTERNATIONAL JOURNAL OF RESEARCH IN COMMERCE, IT & MANAGEMENT*, Vol. 2, Issue 1, 2012, pp.74 – 81
- [19] Matzler, K. and Hinterhuber, H.H. , How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment, *Technovation*, Vol. 18, No. 1, 1998, pp. 25-38.

# The Relationship between Type 2 Diabetes Mellitus with Diabetic Retinopathy Assessed by HbA1c as A Parameter of Blood Sugar Control

Irmayanti Rangkuti<sup>a</sup>

<sup>a</sup>Faculty of Medicine, Islamic University of North Sumatera, Medan 20143  
 E-mail : irma.uisu.dr.com

## ABSTRACT

*This research was an analysis cross sectional. It has been done in Sumatera Eye Centre Medan and Prodia Laboratory Medan for three months. The purpose of this study was to determine the relationship between blood sugar control with diabetic retinopathy in type 2 diabetes with HbA1c as a parameter of blood sugar control, the long-suffering relationship of DM with diabetic retinopathy, and the relationship of age with diabetic retinopathy. This study involved 30 people with type 2 diabetes by making several measurements such as blood pressure with a sphygmomanometer Hg and steteskop, blood sugar levels with a spectrophotometer, levels of HbA1c by HPLC technique, sharp visiot, intra-ocular pressure (IOP), and fundus eye examination. Between control and diabetes mellitus with diabetic retinopathy obtained,  $p = 0.195$ , controlling blood sugar does not cause the occurrence of diabetic retinopathy ( $p > 0.05$ ). Between long-suffering DM with diabetic retinopathy obtained  $p = 0.05$ , there is relationship between long-suffering DM with diabetic retinopathy, the longer suffer DM the higher risk of developing diabetes mellitus diabetic retinopathy ( $p < 0.05$ ). Between ages with diabetic retinopathy obtained  $p = 0.683$ , there is no relationship between age and diabetic retinopathy ( $p > 0.05$ ).*

## Keywords

*Type 2 diabetes mellitus, diabetic retinopathy, HbA1c*

## 1. INTRODUCTION

Diabetes mellitus (DM) is a metabolic disease characterized by hyperglycemia due to impaired insulin secretion, and or insulin resistance enhancement. Chronic hyperglycemia and other metabolic disorders will damage tissues and organs, such as in the eyes, kidneys, nerves, and vascular system [1]. Metabolic status observation of diabetes mellitus patient is the important thing. Good controlling of disease means maintaining blood glucose level in the normal range. With good controlling disease, the complications can be avoided [11]. Bruce Perkin told that there was a relationship between blood sugar level with complications [5]. Mikihiro Nakayama's research founded that the complication of DM was not only related with blood sugar level. This finding was based on the administration of hipoglikemic oral that maintain blood sugar level could not prevent the complications [3]. Retinopatya diabetic is one of the complications on eye that can cause blindness, the effect of retina defect. This complication was estimated 25 times more be suffered in DM's patients [10]. According to the researches in 26 centers in USA, and 3 centers in Canada for 10 years in patients with insulin dependent DM founded that good controlling of blood glucose could prevent and inhibit the emergence and retinopathy progressivity [11].

## 2. METHODOLOGY

This research used a cross sectional method, an analitical survey research. The technique sampling was consecutive sampling, involved 30 people with type 2 diabetes, by making several measurements and clinical examination and biochemical measurements such as height, weight and waist circumference, blood pressure, blood sugar levels, levels of HbA1c, sharp vision, intra-ocular pressure (IOP), and fundus eye examination. This research was performed in Sumatera Eye Hospital in Medan, North Sumatera, Indonesia. The formula of sampel that was used as two different sampling rates :

$$N = \frac{4 \sigma^2 (Z_{crit} + Z_{pwr})^2}{D^2}$$

$Z_{crit} : 0,05 = 1,96$

$Z_{pwr} : 0,95 = 1,645$

$D = 0,96$

Estimated standard deviation = 8

Minimum expected difference = 10

### 3. EQUIPMENTS AND MATERIAL

Blood pressure was checked by a sphygmomanometer Hg and steteskop. Blood sugar levels with a spectrophotometer, BA-88, a semi auto chemistry analyzer. Levels of HbA1c by HPLC technique, D-10. Sharp vision with a Snellen chart. Intra-ocular pressure (IOP) with computerized tonometer, and fundus eye examination with ophthalmoscopy and fundus photos by visucam NM/FA, a photograph fundus color.

This research used blood patients with type 2 diabetes mellitus to investigate blood sugar level and HbA1c, and midriaticum eye drops is a drug that be given before fundus examination.

### 4. FINDINGS AND DISCUSSION

- 4.1 Patients with more women than men (4:1).
- 4.2 Fifteen people (50%) patients with controlled diabetes mellitus and 15 people (50%) patients with uncontrolled DM.
- 4.3 Youngest diabetic patient aged 42 years, and the oldest 78 years of age. DM is most experienced at the age between 49-56 years with a number of 6 people (40%) in uncontrolled diabetes mellitus, followed by 5 people (33.33%) in the DM controlled group. DM's most lots have been experienced by patients during 7-12 years as many as 9 people (60%) in group controlled DM, and 8 persons (53.33%) in group DM not controlled.

Table 1: The distribution of type 2 diabetes mellitus patients by age.

Age (year)	Controlled diabetes mellitus (person)	Uncontrolled diabetes mellitus (person)
41 – 48	1	5
49 – 56	5	6
57 – 64	4	2
65 – 72	3	1
73 - 80	2	1
Total	15	15

- 4.4 Twenty-three people (76.7%) had no diabetic retinopathy, and 7 persons (23.3%) had diabetic retinopathy. 2 people (6.67%) with controlled diabetes mellitus had diabetic retinopathy, and 5 people (16.66%) with uncontrolled diabetes had diabetic retinopathy.

Table 2: The distribution of type 2 diabetes mellitus with diabetic retinopathy

Diabetic retinopathy	Frequency	Percentage
Negative	23	76,7
Positive	7	23,3
Total	30	100

Table 3: The distribution of controlling diabetes mellitus with diabetic retinopathy

Controlling diabetes mellitus	Diabetic retinopathy		Total
	Negative	Positive	
Control	13	2	15
Uncontrol	10	5	15
Total	23	7	30

Table 4: The analysis of relationship between controlling diabetes mellitus with diabetic retinopathy with Chi-Square Test

	Value	Df	Asymp.Sig. (2-sided)

Pearson Chi-Square	1,677 (b)	1	0,195
--------------------	-----------	---	-------

Based on statistical analysis between controlling blood sugar and diabetes mellitus with diabetic retinopathy obtained  $p = 0.195$ , this means controlling blood glucose does not cause the occurrence of diabetic retinopathy ( $p > 0.05$ ).

Bruce Perkin told that there was a relationship between blood sugar level with complications [5]. Mikihiro Nakayama research founded the complication of diabetes mellitus was not only related with blood glucose level. This finding was based on the administration of hypoglycemic oral that maintain blood sugar level could not prevent the complications [3]. This statement was based on the hypothesis that the complication of diabetes mellitus will happen by arising of polyol pathway activity, stress oxidative increased, and accelerating non-enzymatic glycation [3].

The arising of polyol pathway will form much sorbitol and fructose from glucose that absorb water into the endothel, after that the functional activity of endothel will impair, a leakage and trombosit aggregation.

HbA1c is a parameter of controlling blood sugar in diabetes mellitus patient. HbA1c is product of glycation between glucose (sugar) and blood in 2-3 months corresponding with lifetimes of erythrocyte [2,6]. HbA1c is a product that can be formed after hyperglycemia more over 24 hours, a reversible product, and can change into another product, the irreversible product called by AGEs (advanced glycosylation end products). AGEs is a toxic substance that accumulate in some tissues that can be a source of stress oxidative and relate to the complications of DM [9]. In diabetic retinopathy, AGEs can change the integrity dan the structure of capillary wall by sitocyne induction, growth factor and the arising of oxidative stress. In vitro research found the excess of VEGF (vasoproliferative endothelial growth factor), a product from the stimulation of oxidative stress and eNOS (endothelial nitric oxide synthase) abnormality. There were an increase of AGEs accumulation that were distributed around of retinal vascular of DM patients and the accumulation increased with severity of retinopathy [4].

- 4.5 Twenty-three people do not experience diabetic retinopathy after suffering from diabetes for a mean 11.22 years, and 7 people experience after suffering from diabetes mellitus diabetic retinopathy during the 16.57-year average. Twenty-three people do not have diabetic retinopathy at an average age of 56.43 years, and 7 people have diabetic retinopathy at an average age of 58.29 years.

Table 5: The distribution of type 2 diabetes mellitus patients by long-suffering of diabetes mellitus

Long-suffering of diabetes mellitus (year)	Controlled diabetes mellitus (person)	Uncontrolled diabetes mellitus (person)
1 - 6	2	2
7 - 12	9	8
13 - 18	3	3
19 - 24	1	1
25 - 30	0	1
Total	15	15

Table 6: The analysis of the relationship between long-suffering type 2 diabetes mellitus with diabetic retinopathy with T-test

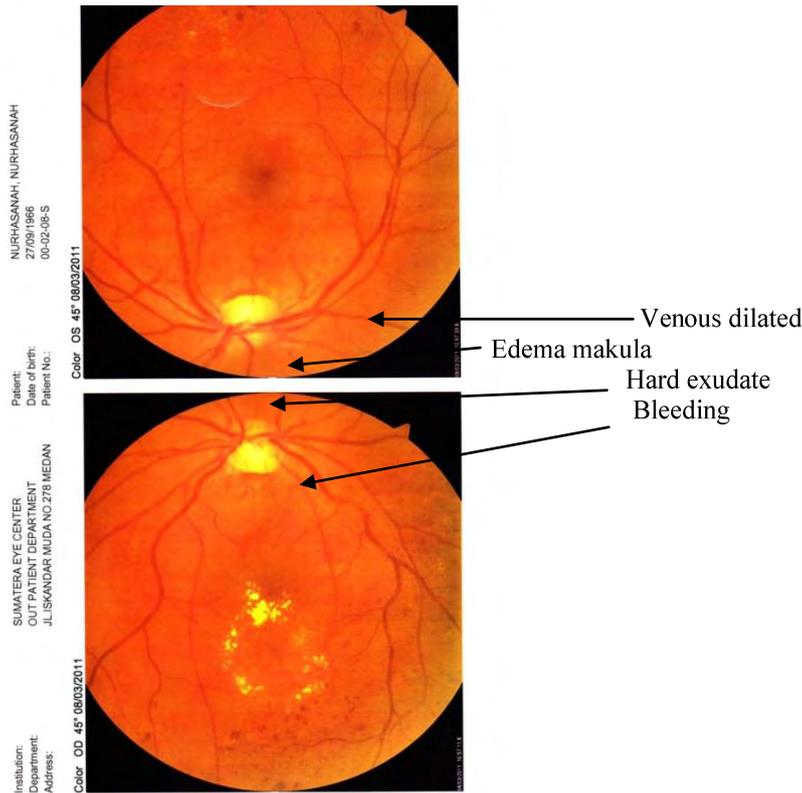
Long-suffering	Df	Sig.(2-tailed)
Equal variances assumed	28	0,05

Between long-suffering DM with diabetic retinopathy obtained  $p = 0.05$ , this means that the longer suffer the higher risk of developing diabetes mellitus diabetic retinopathy ( $p < 0.05$ ). Between ages with diabetic retinopathy obtained  $p = 0.683$ , this means there is no relationship between age and diabetic retinopathy ( $p > 0.05$ ).

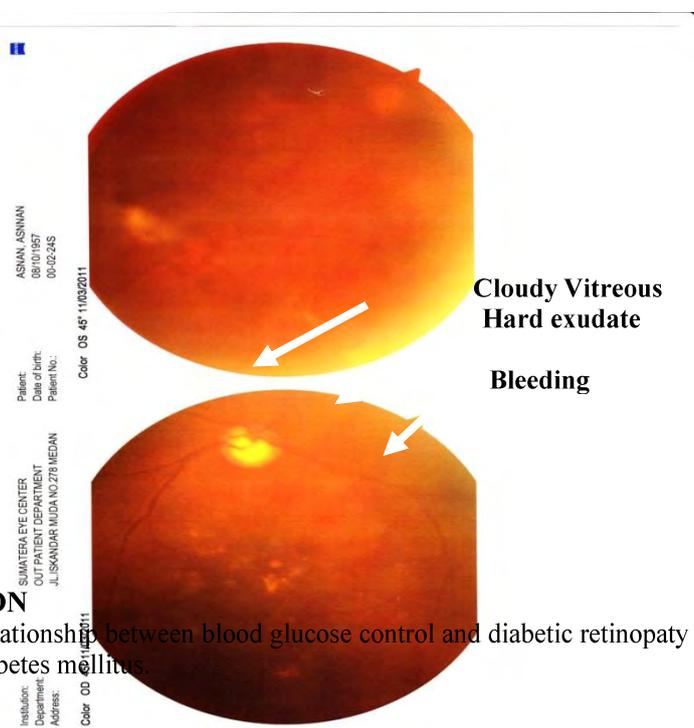
Klein research founded after 10 years suffered type 2 diabetes mellitus, 2.67% patients would be retinopathy, and 10% from all patients had been a PDR (proliferative diabetic retinopathy) patients [7]. The incidence and degree of retinopathy were more related to long-suffering than the severity of this disease, eventhough HbA1c was in a good controlled [8]. The mechanism of complication diabetes mellitus such as the enhancement of non-enzymatic glycation product ADGEs, polyol activity that product sorbitol and fructose, releasing of vasoproliferative factor by retina, endothel disfunction, basal membrane, collagen and smooth muscles, will continue by the time and damage the endothel.

#### 4.6 The fundus photo of type 2 diabetes mellitus patients

4.6.1 Mrs. N, 45 years old, has been suffered of diabetes mellitus about 18 years, non-proliferative diabetic retinopathy



4. years old, has been suffered of diabetes mellitus about 16 years, proliferative diabetic retinopathy



## 5. CONCLUSION

5.1 There was no relationship between blood glucose control and diabetic retinopathy with HbA1c as a parameter blood glucose control in type 2 diabetes mellitus.

- 5.2 There was a relationship between long-suffering DM with diabetic retinopathy.  
5.3 There was no relationship between age and diabetic retinopathy.

## REFERENCES

- [1] Cavallerano, J. (2009). *Optometri Clinical Practice Guideline. Care of the Patient with Diabetes Mellitus*. 3 Ed. St.louis:Lindbergh blvd. pp 3-4.
- [2] Darmono. (1997). *Status Glikemi dan Komplikasi Vaskuler dari Diabetes Melitus: Pendidikan Kedokteran Berkelanjutan ke II Ilmu Penyakit Dalam*. Semarang. BP UNDIP. Hal. 85-96.
- [3] Nakayama, M., Nakamura, J., Hamada, Y., Chaya, S., Mizubayashi, R., Yasuda, Y., Kamiya, H., Koh, N., and Hotta, N. (2001). Aldose Reductase Inhibition Ameliorates Papillary Light Reflex and F-Wave Latency in Patient with Mild Diabetic Neuropathy. *Diabetes care*. 24(6): 1093-1098.
- [4] Peppas, M dan Vlassara, H. (2005). Advanced Glycation End Products and Diabetic Complications: A General Overview. *Hormones*. 4(1): 28-37.
- [5] Perkins, B.A. (2001). Glycemic Control is Related to the Morphological Severity of Diabetic Sensorimotor Polyneuropathy. *Diabetes care*. 24(4): 748-752.
- [6] Price, S.A, dan Wilson, L.M. (2002). *Patofisiologi. Konsep Klinis Proses-Proses Penyakit*. Jakarta: EGC. Hal. 1202-1211.
- [7] Rosenblatt, B.J., dan Benson, W.E. (2004). *Diabetic Retinopathy: Ophthalmology*. Edisi 12. St.Louis: Mosby. Hal. 877-887.
- [8] Sanders, A.D. dan Graham, E.M. (1995). *Kelainan Mata yang Berkaitan dengan Penyakit Sistemik: Oftalmologi Umum*. Edisi 11. Jakarta: Penerbit Widya Media. Hal. 50.
- [9] Sufriyana. (2010). Peranan Advanced Glycation End Products (AGEs) Dalam Komplikasi Diabetes Melitus. *Indonesian Medical Student Journal*. 11(2): 15-21.
- [10] Taylor, R., and Williams, R. (1994). Screening for Diabetic Retinopathy: An Overview. *Diabetic Medicine*. 13(11): 946-952.
- [11] Waspadji, S. (1996). *Komplikasi Kronik Diabetes Melitus: Pengenalan dan Penanganannya : Buku Ajar Ilmu Penyakit Dalam*. Edisi 3. Jakarta: BP FK UI. Hal. 597-600.

# The Effectivity of Single Dose Albendazole to *Trichuris Trichiura* Worm Infection for One, Two and Three Days Therapy

Rusdi Yunus<sup>a</sup>

<sup>a</sup>Faculty of Medicine, Islamic University of North Sumatera, Medan 20143  
 E-mail: dr\_rusdiyunus@yahoo.com.

## ABSTRACT

This research has been done in Sekolah Dasar No. 067230, Kecamatan Medan Tembung, Medan for two months to 165 students which is separated in three groups of medicine giving. This study used Clinical Trial Prospective method with one group pre and post test design. This study was to investigate how long the Albendazole dosage giving one time in a day to get the optimum effect in the curation of *Trichuris trichiura* infection. The research used Albendazole dosage 400 mg a day for 1 day, 2 days and 3 days. There are significant difference in decreasing of eggs quantity before and after medical at 3 groups of medical giving and intensity decreasing of infection at 3 groups. ( $p=0,0001$ ). 400 mg dosage Albendazole one time a day is not effective for trichuriasis with medium and high intensity at 3 groups of medicine, but 400 mg dosage Albendazole one time a day for 3 days is effective for low intensity because it has 96,65 % Cure Rate and Eggs Reduction Rate 99,64 %.

## Keywords

*Trichuris trichiura*, infection intensity, cure rate, eggs reduction rate

## 1. INTRODUCTION

Intestinal worm infection remains a public health problem in Indonesia and some countries in the world especially in developing countries in the tropics. Although worm infections very rarely caused death, but in the circumstances may lead to chronic health problems, such as the result of severe and chronic infection can lead to malnutrition, anemia (anemia), which can indirectly cause physical, cognitive disorders, disorders growth in children, decreased work and quality of life, and the future of patient. Worm infections can affect all age groups, but particularly high prevalence in group of primary school children. Trichuriasis a worm *Trichuris trichiura* infections were estimated at 800 million cases worldwide. In tropical and humid areas in Indonesia, patients with severe and chronic infections, especially in children with typical symptoms frequently, such as dysentery syndrome, anemia, weight loss, accompanied by infectious micro-organisms, can occur even prolapse of rectum. In developing countries, including Indonesia, intestinal worm infections that are transmitted through the soil/Soil-Transmitted Helminths (STH) has a very high prevalence, especially in children aged under five years or class of primary school children.

From the study in 1995 found prevalence of soil transmitted intestinal worm by 60% to 70%. Children of primary school age are vulnerable to disease transmission [1].

The results of the 1996 study of elementary school children in North Jakarta found a prevalence of 59.6% and trichuriasis and ascariasis amounted to 79.64%. The level of disease transmission and trichuriasis and ascariasis is very closely linked to soil contamination by faeces containing worm eggs [1].

In the prevention and treatment of intestinal worms, the government has implemented various worm disease eradication programs, especially at the elementary school age children. These activities include outreach to students, teachers, and parents about the intestinal worms that are transmitted through the ground, including the causes, prevention, and ways of prevention and the provision of de-worming.

VY Belizario, ME Amarillo, WD Leon [2] in 2003 in the study a single dose of Albendazole treatment in primary school children in the Philippines to get Cure Rate for *Trichuris trichiura* 69,7%.

VJ Adam, Lombard CJ, Dhansay MA et al [3], in 2004 in the research use of a single dose of Albendazole 400 mg in primary school children in Cape Town South Africa to get Cure Rate by 23%.

Legesse M, Erko B, Medhin G, in 2004 [4] in the research use Albendazole once daily doses for one day in school children age 6 to 19 years in Ethiopia get the Cure Rate 69,8%.

Sirivichayakul C, Pojjoen Anant C, Wisetsing Pet al [5], in 2003 in the research use of albendazole 400 mg once daily for 3 days, 5 days, 7 days suggested that these of Albendazole 3 days used for mild infections of *Trichuris trichiura*, whereas for severe infection 5 to 7 day.

The report above results indicate that administration of albendazole once a day for 1 day to tackle trichuriasis not provide optimal effect. Based on this fact needs to be investigated how long delivery albendazole once a day to achieve an optimal effect on *Trichuris trichiura* infection control.

The low rate of treatment success (Cure Rate) Albendazole 400 mg once-daily dosing to *Trichuris trichiura* infection. To the above should be compared with the effectiveness of albendazole 400 mg once daily administration for 1, 2 and 3 days.

### 1.1 Objective

The objective of this study was to determine the effective dose of albendazole in preventing worm *Trichuris trichiura* infection in the general population

### 1.2 Hypothesis

There was a difference in the success rate of treatment with albendazole once daily dosing for 1 day, 2 days and 3 days.

There was a difference in intensity reduction worm *Trichuris trichiura* infection by treatment albendazole 400 mg dose once daily for 1 day, 2 days, and 3 days.

### 1.3 Benefits

Getting therapy is more effective and efficient in combating *Trichuris trichiura* infection in the community

Getting optimal drug delivery arrangement and efficient for mass treatment in STH control programs

## 2. LITERATURE REVIEW

Humans are one of the few hospes intestinal worms, most of these worms can cause health problems. Some intestinal worms are partly soil-borne worms called "Soil-Transmitted Helminths" (STH), including *Ascaris lumbricoides*, *Ancylostoma duodenale*, *Necator americanus*, *Trichuris trichiura*, *Strongyloides stercoralis*, and *Trichostrongylus* species [6]. Impact of intestinal worm infection that is transmitted through the soil and its life cycle needs to be studied in order to determine ways of prevention. The spread of infection *Ascaris lumbricoides* and *Trichuris trichiura* almost the same, so that the infection of the two worms above almost always together in the same person. Similarly, the epidemiology of the two worms are almost the same, so it is often seen with a prevalence of ascariasis and trichuriasis always pretty much the same [7]. In endemic areas with a high incidence of ascariasis and trichuriasis, transmission occurs continuously. This transmission is influenced by several things that can benefit the parasite, such as soil and weather conditions are suitable [6].

### 2.1 *Trichuris trichiura*

Humans are the definitive hospes worm and the disease is called trichuriasis. Cosmopolitan distribution of this worm, found mainly in tropical and humid areas in Indonesia and other tropical areas. *Trichuris trichiura* has a whip-like shape with the anterior/head finer than the posterior/tail section. The length of female worms approximately 4 cm by the end of the curved tail, while the female worm has a length of about 5 cm and the tail end of the straight. Adult worms live in the cecum and ascending colon with a smooth anterior part into the villi of the intestinal mucosa to take food and suck blood [8]. Adult female worms will produce as many eggs 3000-10000 a day. Egg size 50-54 microns x 32 microns, oval shaped with 2 knobs on both poles. Relatively thick eggshell, outeryellowish, clear and colored outer. The fertilized egg will come out of the body through the stool hospes. At ground level the egg will mature in 10-14 days depending on climate and suitable environment, such as soil moisture and shade. Humans are infected by swallowing eggs containing larva mature, the egg hatch in the intestine and after the adult worms will move toward the cecum and ascending colon [9]. The time required for the growth from mature eggs are ingested to be a female worm produce eggs that are ready for approximately 30-90 days. In clinical symptoms caused by the adult worms head into the intestinal mucosa and suck blood, there is irritation and inflammation of the intestinal mucosa, which can cause anemia, and easily infected by bacteria/parasites, such as *Entamoeba histolytica* and *Escherichia coli*. Patients with severe and chronic infections, especially in children often show obvious clinical symptoms such as diarrhea are often interspersed with dysentery syndrome and anemia, weight loss, and sometimes accompanied with rectal prolapse, the symptoms can run for many years. Trichuriasis Diagnosis confirmed by the eggs in the feces [6].

### 2.2 Albendazole

Albendazole is an anthelmintic with a very broad spectrum, from the benzimidazole group. Benzimidazole pharmacologically inhibits mitochondrial fumarate reductase, thereby inhibiting polymerization of work [10]. In parasitic worms albendazole and its metabolites are thought to act by inhibiting the synthesis of microtubules, thereby reducing glucose making irreversible, resulting in paralysis of worms [11].

With oral albendazole administration will quickly metabolized in the body into albendazole sulfoxide. Three hours after oral administration at a dose of 400 mg, sulfoxide having maximal concentration of approximately 113-367 ng/ml and the plasma half-life of 8-12 hours. Material removed from the metabolism of the body through the bile and urine. Absorption of albendazole will increase up to five times when administered with a fatty meal. Thus if we want to kill the worms that are in the network, the worm medicine is given with food, and if we want to eradicate worms in the lumen of the intestine, the worm medicine is given at the time before the meal/empty stomach. Albendazole can work as larvicidal and ovisid [11].

Albendazole is indicated to treat intestinal worm infection either single infection or mixed infection.

#### 2.2.1 Treatment and dose albendazole

For adults and children used 1 capsule or 10 ml suspension containing 400 mg given as a single dose. For strongly ill and immunocompromised patients given 1 pill or suspension containing 400 mg given for 3 consecutive days. Treatment does not require fasting or laxative use. Side effects of Albendazole are usually mild and temporary. Gastrointestinal disturbances, headache, dizziness, fatigue, and insomnia may occur in some cases.

### 2.2.2 Contraindicated

Pregnant women and women who are breastfeeding. Caution when used in patients with impaired hepatic function and impaired renal function. Albendazole should not be given to children under 2 years of age [11].

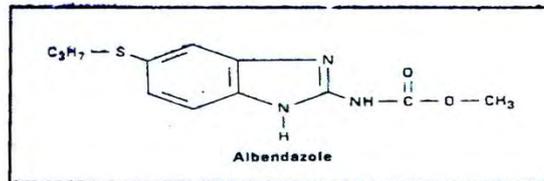


Figure 1. The chemical structure of albendazole

## 3. METHODS

This study was a prospective Clinical Trial with one group pre and post test design [12]

### 3.1 Time and place of research

The study was conducted for two months in Sekolah Dasar No.067230 Tembung Medan.

### 3.2 Criteria for inclusion

1. Willing to take medication
2. Trichuris trichiura eggs found in the feces
3. Fill out the informed consent
4. Meets protocol, prepared for stool examination at a specified time researchers.
5. No other comorbidities

### 3.3 The exclusion criteria

1. Eat anthelmintic drugs within the study period
2. Eating anthelmintic drugs two weeks before the start of the study
3. Arising side effects to the anthelmintic drugs
4. Not willing to fill the informed consent
5. Had diarrhea
6. The existence of comorbid infectious diseases that can weaken the evaluation of treatment in the study

### 3.4 Estimate the Sample [13].

$$n_1 = n_2 = n_3 = \frac{\{Z_\alpha \sqrt{2PQ} + Z_\beta \sqrt{P_1Q_1 + P_2Q_2}\}^2}{(P_1 - P_2)^2} \quad (1)$$

-  $P = 1/2 (P_1 + P_2)$

-  $P_1$ : proportion decreased cure rate of trichuriasis by Albendazole

-  $P_2$ : proportion decreased cure rate of albendazole trichuriasis by the

be expected (*clinical judgment*)

-  $P_1 = 0.542$        $P_2 = 0.825$

-  $P = 0.684$        $Q = 0.316$

$Q_1 = 1 - P_1 = 1 - 0.542 = 0.458$

$Q_2 = 1 - P_2 = 1 - 0.825 = 0.175$

$Z_\alpha = 1.96$        $Z_\beta = 0.842$

From the above calculation, the samples of each group = 41.17

The number of each treatment group are set = 42 persons

### 3.5 Work methods

Stool examination at primary school children grade 1 to grade 6 using the KATO-KAZT. All children with positive *Trichuris trichiura* eggs included in the study participants. Declared negative stool examination, stool examination 3 times if the same is not found worm eggs. Calculated density of eggs in the feces with a count of Egg Per Gram (EPG). In accordance with WHO recommendations preparations were examined based on the volume of faeces taken from thick cardboard hole diameter of 1.37 mm and 6 mm weighed 41.7 mg and the result is multiplied by 24. Classification of the severity of the patient based on guidance from the WHO are as follows:

- Light : Number of eggs 1 - 999 eggs per gram
- Middle : Number of eggs 1000 - 4999 eggs per gram
- Weight : Number of eggs more than 4999 eggs per gram [14].

Stool examination carried out at the beginning of the study and 2 weeks after administration of anthelmintic first day, with the same method.

### 3.6 Treatment group

The study consisted of 3 treatment groups as follows :

1. The group who received albendazole 1 tablet containing 400 mg given orally once daily for 1 hari.
  2. The group that received 1 tablet of albendazole 400 mg orally once daily for 2 days.
  3. The group who received albendazole 1 tablet containing 400 mg given orally once daily for 3 days.
- In this study, the data are not grouped in the intensity of infection in proportion.

### 3.7 Variable

- Independent variable : Albendazole 1 day, 2 days dan 3 days
- Dependent variable : Eggs Per Gram (EPG), Cure Rate (CR)  
 Eggs Reduction Rate (ERR)

## 4. STATISTICAL ANALYSIS

1. To see the difference in the average number of worm eggs in the treatment group for 1 day, 2 days, and 3 days at the beginning of the study population tested Anova if the same variant. If not the same variant was tested by Kruskal-Wallis.
2. To see the difference in treatment for 1 day, 2 days, 3 days, before and after treatment using paired t-test if the data were normally distributed, while the data were not normally distributed with the Wilcoxon test.
3. To see the difference in the average number of worm eggs in treatment group 1 day, 2 days, 3 days, before and after treatment using paired t-test when the data were normally distributed, while the data were not normally distributed with the Wilcoxon test.
4. To see the difference in the average change in the number of worm eggs due to the administration of drugs in each group were tested with Anova.

## 5. RESULT

From the number of students from Grade 1 to Grade 6 Elementary School District No. 067240 Tembung Medan 559 students, only 374 (66.91%) students who are willing to check their stool. While 185 students do not check their feces. In the first stool examination for 374 students before giving medication found 273 (73%) suffer from intestinal worm infections of 4 different types of intestinal worms among others, *Trichuris trichiura*, *Ascaris lumbricoides*, Hookworm, and *Hymenolepis nana*.

Table 1. The prevalence of intestinal worm infections before treatment

Parasit	Number of samples n ( % )
<i>Trichuris trichiura</i>	237(63.37 %)
<i>Ascaris lumbricoides</i>	174(46.52 %)
Hookworm	2(0.53 %)
<i>Hymenolepis nana</i>	2(0.53 %)
<i>T.trichiura</i> + <i>A.lumbricoides</i>	136(36.33 %)
<i>T.trichiura</i> + <i>A.lumbricoides</i> + Hookworm	2( 0.53 %)
<i>T.trichiura</i> + <i>H.nana</i>	2(0.53 %)
<i>T.trichiura</i> single infection	97(25.94 %)

After giving albendazole 400 mg daily dose for all patients with intestinal worm infections by the number of days according to treatment group taken at random, found these side effects such as mild headache to two students in the group of drug delivery is 3 days and the symptoms disappeared on the fourth day without drug delivery.

Two weeks after the treatment given to three groups of subjects performed a second stool examination, there were 273 students who have intestinal worm infections provided stool for the second examination, and only 165 stool students who meet the study requirements. From the results of stool examination were performed, 273 (73.00%) children suffer from intestinal

worms of various types of intestinal worms. Prevalence of *Trichuris trichiura* worm has the highest prevalence compared with other intestinal worms (63.37%), followed by *Ascaris lumbricoides* (46.52%), hookworm (0.53%) and worms *H. nana* (0.53%). Found a mixture of intestinal worm infections such as *Ascaris lumbricoides*, *Trichuris trichiura* with 136 (36.33%), *Trichuris trichiura* with *H. nana* 2 (0.53%), *Trichuris trichiura* with *Ascaris lumbricoides* and hookworm 2 (0.53%), while the number of single infections of *Trichuris trichiura* 97 (25.94%) (Table 1).

Table 2. The characteristics of the samples based on treatment group

Characteristics	1 day n(%)	2 days n(%)	3 days n(%)	Total n(%)
<b>Sex</b>				
Female	22(27.8%)	23(29.1%)	34(43.0%)	79(100%)
Male	23(26.7%)	30(34.9%)	33(38.4%)	86(100%)
Total	45(27.3%)	53(32.1%)	67(40.6%)	165(100%)

165 students who are the subject of research, found 22 (27.8%) and 23 female students (26.7%) male students for a one-day treatment group amounted to 45 students. Treatment group of students two days 53 people there are 23 (29.1%) female students and 30 (34.9%) male students. While on a three-day treatment group numbered 67 people there are 34 (43.0%) female students and 33 (38.4%) male students (Table 2).

Table 3. Characteristics of patients with trichuriasis before treated

Characteristics of the subjects	1 day n = 45	2 days n = 53	3 days n = 67	p
The number of worm eggs (Egg-1)	1276.36 ± 1435.66	789.06 ± 96.38	993.69 ± 1389.37	0.168

Test distribution is normal

The average number of eggs in a single day treatment group 1276.36+1435.66, a two-day treatment group 789.06+96.38, and a three-day treatment group +1389.37 993.69. There are differences in the average number of eggs a day treatment group with a two-day treatment group and three treatment groups 3 days, but it was not statistically significant (p=0.168) (Table 3).

Table 4. The intensity of infection in the treatment group before treatment

Intensitas	1 day n (%)	2 days n (%)	3 days n (%)	Total n (%)	p
light	25(22.3%)	41(36.6%)	46(41.1%)	112(100%)	0,137*
moderate/middle	17(36.2%)	12(25.5%)	18(38.3%)	47(100%)	
weight	3(50.0%)	0(0.0%)	3(50.0%)	6(100%)	
Total	45(27.3%)	53(32.1%)	67(40.6%)	165(100%)	

\* Chi-Square Tests

In observation of the intensity of worm infections before drug treatment is seen in the treatment group of the day there were 25 (22.3%) students with mild infection, 17 (36.2%) students were infections and 3 (50.0%) students of severe infections. At the two-day treatment group consisted of 41 (36.6%) students with mild infection, 12 (25.5%) students with moderate infection and found no severe infections. While the three-day treatment group found 46 (41.1%) students with mild infection, 18 (38.3%) students with mild infections, and 3 (50.0%) students with severe infections (Table 4)

Table 5. The average number of eggs in stool before and after treatment in the treatment group

Group	Before treatment	After treatment	ERR	P
1 day N= 45 Light Moderate/middle Weight	383.04 ± 222,94 1862.35 ± 879,85 5400.00 ± 392,90	10.40 ± 7,27 322.82 ± 197,08 1712.00 ± 121,17	97.28 % 82.67 % 68.30 %	0.001
2 days N= 53 Light Moderate/middle Weight	368.49 ± 209.26 2226.00 ± 901.57 -	15.80 ± 8,96 252.25 ± 199,96 -	95.71 % 88.50 % -	0.001
3 days N=67 Light Moderate/middle Weight	287.91 ± 196.95 2002.67 ± 895.06 5304.00 ± 197.05	1.04 ± 0,49 37.33 ± 12,08 240.07 ± 42,08	99.64 % 98.14 % 98.49 %	0.001

\*Wilcoxon Signed Rank Test

From the results of stool examination before treatment, at a day treatment group the average number of eggs in mild infection 383.04 ± 222.94, moderate infections 1862.35 ± 879.85, severe infections 5400.00 ± 392.90, and after given treatment, the average number of eggs changed, mild infection 10.40 ± 7.27, moderate infections 322.82 ± 197.08 and severe infections 1712.00 ± 121.17

At the two-day treatment group, the average number of eggs in light infection 368.49 ± 209.26, the moderate infection was 1862.35 ± 879.85, and severe infections are not found eggs. After given treatment, the average number of eggs changed, for light infection to 15.80 ± 8.96, and moderate infection was 252.25 ± 199.96.

For the three day treatment group the average number of eggs in light infection was 287.91 ± 196.95, moderate infection was 2002.67 ± 895.06, and severe infections 5304.00 ± 197.05. After treatment the average number of eggs in light infection 1.04 ± 0.49, moderate infection was 37.33 ± 12.08 and severe infections was 240.07 ± 42.08 (Table-5)

Table 6. Heal-Do not cured by the intensity of worm infection treatment group

Group	Before n (%)	After n (%)	C R	P
One day, n=45 light Moderate/middle Severe	25(55.6%) 17(37.8%) 3(6.7%)	Heal : 21(46.7%) light : 4 (8.9%) Heal : 5(11.1%) Light : 9(20%) Moderate : 3 (6.7%) Heal : 0 (0.0%) moderate : 3 (6.7%)	84 % 29.41 % 0 %	0.0001
Two days , n=53 Light Moderate/middle Severe	41(77.4%) 12(22.6%) 0	Heal : 29(54.7%) Light : 12(22.6%) Heal : 1(1.9%) Light : 11(20.8%) -	70.73 % 8.30 % -	0.0001
Three days , n=67 Light Moderate/middle Severe	46(68.7%) 18(26.9%) 3(4.5%)	Heal : 44(65.7%) Light : 2 (3%) Heal : 5(7.5%) Light : 13(19.4%) Heal : 1(1.5%) Light : 2 (3.0%)	95.65 % 27.78 % 33.33 %	0.0001

\* Chi-Square Tests\* \* Significant

From these results we can see, in the treatment group of the day with a number of 45 people, 25 (55.6%) people is a mild infection, 17 (37.8%) people were infections, and 3 (6.7%) people were serious infections, occur conversion after treatment in

group mild infection, recovered 21 (46.7%) people and 4 (8.9%) were still mild infection, the group recovered five moderate infections (11.1%) people, a mild infection 9 (20%) and those whose infection still was 3 (6.7%) persons, while in the group of severe infections encountered no cases were cured, 3 (6.7%) people to moderate infections.

In the two days of treatment with a number of 53 people, 41 (77.4%) persons were light infections, 12 (22.6%) people are moderate infection and no severe infections, the conversion after treatment, in light infection group 29 (54.7%) people were cured, and 12 (22.6%) the infection remains mild, moderate infection in group 1 (1.9%) people were cured and 11 (20.8%) people are still moderate infection.

In the three days of treatment with a number of 67 people, 46 (68.7%) of light infection, 18 (26.9%) of moderate infections and 3 (4.5%) of severe infection, the conversion occurs after treatment, the light infection group 44 (65.7%) people were cured and 2 (3.0%) people become light infection, moderate infection in group 5 (7.5%) people were cured and 13 (19.4%) people were light infection, severe infection whereas in group 1 (1.5%) people healed, 2 (3.0%) people get a light infection (Table 6).

## 5. DISCUSSION

From table-1 we can see whipworm prevalence of 63.37%. There is a difference with the results obtained Subahar Ret alin 1996 amounted to 79.64%. For roundworm infection prevalence roundworm researchers gain of 46.52%, lower than that obtained by Subahar Ret alin 1996 amounted to 59.60%. Most researchers obtain the prevalence of intestinal worms is lower than previous researchers. This is possible because from time to time increase people's knowledge of health, disease worms, and the worm treatment program in school children.

*Ascaris lumbricoides* and *Trichuris trichiura* has a way of infection, and the optimum growth temperature is almost the same culture, so often occurs in patients with concurrent infection and the prevalence is almost the same. From the results of research conducted in primary school children of primary schools sub-field No.067240 Tembung whipworm found a higher prevalence than the prevalence of roundworm, this is possible because of the government's program provides for regular worming of primary school pupils using the helminthic preparations pyrantel pamoate for 1 day, as we know whipworm pyrantel pamoate less sensitive preparations.

Hookworm infection found in elementary schools in the district of Medan Tembung very low (0.53%), this can be made possible because of the neighborhood and children's playground consisting mostly of students from the cement floor or the ground is solid, less suitable for growth hookworm larvae. Similarly, the behavior of the students in their daily lives are always barefoot, it is difficult to hookworm infection through the skin. From this research we have encountered a mixed infection roundworm and whipworm prevalence is high (36.33%). This is possible because both these worms have properties similar either way infection or optimal breeding temperature.

The number of men and women who participated in each drug group no significant difference. This happens just by chance, due to random sampling (Table 2).

The intensity of worm infection medication groups before treatment is seen in one-day treatment group, there were 25 (22.3%) people with light infection, 17 (36.2%) of moderate infections and 3 (50.0%) of severe infections. In the two-day treatment group consisted of 41 (36.6%) people with light infection, 12 (25.5%) people with moderate infections, and no severe infections. While the three-day treatment group consisted of 46 (41.1%) people with light infection, 18 (38.3%) people with moderate infections, and 3 (50.0%) people with severe intensity. Overall light infection intensity has the greatest number, that is 112 people, as many as 47 people moderate and severe intensity only 6 people from a total of 165 people. Statistically there is no significant difference in the intensity of the number of each group in each drug group ( $p=0.137$ ) (Table 4).

The average number of eggs in the feces per gram students who participated in the study for the treatment of one-day, two-day treatment group, and the three-day treatment group decreased significantly after drug administration ( $p=0.001$ ), both for the group of severe infections, moderate or light infection. Based on the calculation of the ERR obtained for the treatment of 1 day, light intensity ERR=97.28%, moderate intensity ERR=82.67%, and for severe intensity ERR=68.30%. For the treatment of two days, light intensity ERR=95.71%, moderate intensity ERR=88.50%. For the three days of treatment, light intensity ERR=99.64%, moderate intensity ERR=98.14%, and severe intensity ERR=98.49%. From observations decrease the average number of worm eggs a result of treatment, the high ERR above 90% in the three days of treatment for an infection light, moderate or severe infections. As for the treatment of one-day and two-day high ERR only to light intensity, while for moderate and severe intensity ERR remains low (below 90%) (Table 5).

Based on the rate of healing (Cure Rate) as a result of treatment in a group 1-day treatment on the intensity of light is CR=84.0%, moderate CR=29.41%, and the intensity of CR=0.0% by weight. Cure rate (CR) as a result of treatment in group two days of treatment at a light intensity of CR=70.73%, moderate CR=8.30%, recovery rate (CR) as a result of treatment in the three days of treatment at a light intensity of CR=95.65%, moderate CR=27.78% and severe intensity CR=33.3%.

From the cure rate (CR) is seen, the highest value reached above 90% are on medication three days at a light intensity of infection, while for moderate and severe intensity values infection cure rate (CR) is low in both treatment arms one day, two days and three days. Value cure rate in the treatment arm for two days of moderate intensity less than the cure rate in the treatment arm one day of moderate intensity, it is probably caused by technical errors in the field, such as the existence of some students eat at home before taking the medication at school, despite being told by investigators for no breakfast at home (Table 6).

Compared with previous studies, researchers get Cure Rate for treatment day at 55.6%, lower than the research VY Belizario et al, in 2003 amounted to 69.7% and M. Legesse et al, in 2004 amounted to 69.8%. But when compared with the research VJ Adamet alin 2004 in South Africa by 23% for once-daily doses of albendazole treatment. There are differences in numbers for different cure rates obtained VJ Adamet al with the results obtained by previous investigators and researchers, this can occur by different technical field

From the results obtained in all three treatment groups, the treatment of one day and two days having a high ERR for all levels of intensity of infection, but have a low CR rate, especially for moderate intensity of infection and severe intensity. As for the three day treatment group with ERR reached 99.64% and 95.65% Cure Rate in a light intensity of infection, is expected to be effective to address whipworm infection with mild intensity. This is consistent with previous studies conducted by Sirivichayakul Cet al, in 2003, who suggested the use of albendazole for 3 days to cope with whipworm infection light intensity, while for severe infections requiring treatment for 5 days to 7 days.

## 6. CONCLUSION

1. The use of albendazole dose of 400mg daily for 1 day, 2 day and 3 day can significantly reduce the intensity of infection.
2. Use of albendazole worming dose of 400mg once daily for 3 days only effective for the treatment of light intensity trichuriasis, because having high Cure Rate and ERR.
3. Side effects of the drug found in two of the students (0.73%) and mild headache that arise on the third day of drug administration, and lost in 1 day without treatment.

## REFERENCES

- [1] Subahar R; Mahfudin H; Ismid IS. 1995. *Pendidikan dan pengetahuan orangtua murid sehubungan dengan upaya pemberantasan penyakit cacing usus di Duren Sawit Jakarta Timur*. Majalah Kesehatan Masyarakat Indonesia; p:4-21
- [2] V.Y. Belizario; M.E. Amarillo; W.U. de Leon; et al. 2003. *A comparison of the efficacy of single dose of Albendazole, Ivermectin, and Diethylcarbamazine alone or in combinations against Ascaris and Trichuris spp.*, World Health Organization Bulletin of the World Health Organization; 81, 1; Proquest Medical Library, pg. 35
- [3] Adams, V.J.; Lombard, C.J.; Dhansay, M.A.; Markus, M.B.; Fincham, J.E.; 2004; *Efficacy of albendazole against whipworm Trichuris trichiura – a randomised controlled trial*; South African Medical Journal; 94(12): 972 – 976
- [4] Legesse, M; Erko, B; Medhin, G; 2004; *Comparative efficacy of Albendazole and three brands of mebendazole in the treatment of ascariasis and trichuriasis*; East African Medical Journal; 81(3) : 134 – 138
- [5] Sirivichayakul C, Pojjoen-anant C, Wisetsing P, Praevanit R, Chantavanish P, Limkittikal K; 2003; *The effectiveness of 3, 5 or 7 days of albendazole for the treatment of Trichuris trichiura infection*; Ann trop Med Parasitologi, 97(8): 647-53
- [6] Gandahusada, S; Ilahude, Herry D; Pribadi, W; 1998; *Parasitologi Kedokteran*; Third edition, the Faculty of Medicine, University of Indonesia; . Page 20 - 23
- [7] Beaver P C, Jung R C, Eddie Wayne Cupp; 1984; *Clinical Parasitology*; Lea & Febiger; Philadelphia; 9<sup>th</sup> Edition; p. 240 – 245
- [8] Brown, H.W. 1979. *Dasar Parasitologi Klinik*, Edisi ke-3, Penerbit Gramedia Jakarta p. 183 – 189
- [9] Miyazaki I, ; 1991; *An Illustrated Book of Helminthic Zoonoses*; Shukosha Printing Fukuoka, Jepang; First edition; p 442 – 445
- [10] Goodman G A; 1996; *The Pharmacological Basis of Therapeutics*; Mc Grow-Hill; International Edition; ninth edition; p. 1012 – 1015
- [11] Bertram G. Katzung . 2004. *Farmakologi Dasar dan Klinis*, Section of Pharmacology Faculty of Medicine Universitas Erlangga, Salemba Medika Publisher, Mc Graw Hill, 8<sup>th</sup> edition, p. 261 – 269
- [12] Pratiknya A W; 2001; *Dasar-Dasar Metodologi Penelitian Kedokteran & Kesehatan*; PT Raja Grafindo Persada; Jakarta; First edition ; p. 117 – 163
- [13] Sastroasmoro S; Sofyan Ismail; 2002; *Dasar-dasar Metodologi Penelitian Klinis*; fourth edition; Sagung Seto Publisher; p. 273
- [14] Montresor, S ; Crompton, D.W.T.; Hall, Brundy, D.A.P.; Savioli, L; 1998; *Guideline for the evaluation of soil-transmitted helminth and Schistosomiasis at community level*. WHO / CTD / SIP / 98.1

# Mobile Pet Health Care Services for Preventing Zoonoses Spreading

Aulanni'am<sup>a</sup>, Manik Eirry Sawitri<sup>b</sup>, Masdiana C. Padaga<sup>a</sup>, Maryani<sup>c</sup>

<sup>a</sup>School of veterinary medicine, University of Brawijaya

E-mail: [aulani@ub.ac.id](mailto:aulani@ub.ac.id)

E-mail : [mpadaga@ub.ac.id](mailto:mpadaga@ub.ac.id)

<sup>b</sup>Faculty of Animal Husbandry, University of Brawijaya

<sup>c</sup>Faculty of Agroindustry Technology, University of Brawijaya

## ABSTRACT

Public awareness regarding the importance of healthy living has become of major concern in recent year. This affect pet owners to be very concerned about animal health. Consequently, the field of animal health business become an important issue and has a good opportunities and prospects. Ipteks bagi inovasi dan kreativitas kampus (IbIKK) program on Car's services for grooming and pet health care has been done for 3 years. This project aims to facilitate the need to increase attention and awareness of healthy living, so that pet owners concerned about animal health. IbIKK program is the unique and professionally managed program that provide mobile grooming van for health care, disease prevention programs (immunization) and animal hygiene programs under supervision of veterinarian, the grooming van always standby and ready for some remedial action even in the case of an acute illness. IbIKK program has opened a new opportunities for entrepreneurship in the field of pet health care and grooming. Based on the performance within 3 years, the analysis of the business was ROI of 36%, BEP 2146 services and RC of 1.52

## Keywords

IbIKK, animal health, grooming, health care

## 1. INTRODUCTION

Public awareness regarding the importance of healthy living has become of major concern in recent year. This affect pet owners to be very concerned about animal health. Consequently, the field of animal health business become an important issue and has a good opportunities and prospects. Pet care may bring a lot of positive impact to the owner including value of responsibility, compassion, comfort and give companionship. Some considerations, however, have to be taken into account especially conditions associated with cleanliness, hygienic and health care because the pets can be a source of disease transmission [3].

Some pathogenic agents causing diseases to pet animals such as Parvo virus, whip worms, hook worms, round worms, Giargia, Coccidia can be found in pet feces [4]. This will cause disease and lead to infection in pet animals that will impact the health of the pet owner. Therefore it is necessary to take into consideration the health-related risks of owning and caring for animals due to public health concern [5]. In addition to the spread of disease pets provide many benefits to humans, including comfort and friendship. Having a pet can be a wonderful and useful for the owner and family. Moreover, it is believed that pets can help their owners, which are psychologically and even physically give life more colorful and feel better. For many people, pets more than just animals, they are like family members.

One attempt to resolve the issue of preventing diseases transmission from the animals is implementing pet grooming. Pet Grooming is an activity related to the hygienic care and clening of the pets. Pet grooming involves techniques on brushing, excerpting nails, eyes and ears care, hair trimming, and hair brush. All these activities should be done perfectly [1]. Groomers work in a variety of locations and environments, including veterinary offices, animal shelters, pet supply stores and even a salon specifically designed for pets [2]. Grooming can strengthen the bond between owner and pet if it is done according to the standard. Therefore the IbIKK program offers pet owners to get closer to animals without the risk of disease transmission.

In order to improve the quality of pet grooming service, it beneficial to provide mobile grooming unit using grooming van. The van equipped with grooming table and storage shelves and a layout inside the van is established that allows for easy access to needed supplies during the grooming process. IbIKK program is the unique and professionally managed program that provide mobile grooming van for health care, disease prevention programs (immunization) and animal hygiene programs under supervision of veterinarian, the grooming van always standby and ready some remedial action even in the case of an acute illness. The pet owner can just order to get a house call services and this program provide quality services in the owner front door. In Malang, especially, there is only few mobile car grooming provided. Therefore, this mobile grooming car is needed and can be of benefit for Malang where are many pet lovers.

## 2. METHODS

Material in this IBIKK project is pet health care and mobile grooming van. This program is executed in three years consecutively. At the first year, the program preparing car for grooming van and promote the program. Year two transform the car into van that is equipped with table, selves and appliances for pet health care, beauty and hygiene services. In this year, the program has a considerable amount of klients and provide services not only for grooming but also for sick animals. Generally the grooming needs depend on the breed and hair types. Basic grooming include hair brushing, nail trimming, ear care and hair cutting. If the pet has fleas, special care should be given usually bathing with a special shampoo for fleas and Tick, and medication.

## 3. RESULTS AND DISCUSSION

The children may be most at risk of developing the disease that transmitted from pet animals, because they play very close to the pets and they just do not understand about the disease that pets may have. Maintaining the health of pet animals become very important in order to prevent transmission of the diseases to family members. Animal Hospital could help provide health services for the animals and reduce spreading of the diseases especially the diseases associated with skin diseases, such as ringworm, scabies and internal parasites. Ringworm (ringworm) is a fungal infection of the skin, hair or nails. These infections can cause hair loss, with or without lesions under the skin. This infectious agent can survive in the environment as spores for long periods of time. People infected with this fungi will show signs of red and circular lesion in the skin.

Ibikk activity program provide health care and grooming services using mobile grooming van equipped with table, shelves, water heater and all appliances needed. Grooming is one of basic needs for pet animals and an important part of pets ownership. All pet animals, just like people, need physical maintenance to look and feel their best. Eventhough pets do not need to bathe as often as people, but it do need to learn how much grooming the pets actually needs and keep it on a schedule. Generally, pets grooming needs depend on the breed and hair type. In some cases of skin, ear or nail condition, it requires veterinarian's instructions regarding grooming the pets. It is also important to use the appropriate grooming tools.

In the third year of this program, the grooming van has been equipped for health care services and pet grooming including standard and basic health care equipment, the examination table, disposable injection, stethoscope, microscope and cage. Equipments for grooming including pet bath sprayer, bath towels, furminator deshedding tool, mat removing tools, nail trimmer, a set of clippers for pet grooming, hair dryer, comb and gloves.

Target market of the program are pet owners who stay at elite estates. Promotions and marketing techniques were done by direct approaching to the consumer, visiting door to door using the mobile grooming car. Social level of the target consumers are from the middle to upper class who have a pet. Product selling prices for health care services is Rp 100,000, -, while for vaccination is Rp 150.000, -. Mobile health care provides vaccine according to the consumers needs, with high standard quality and suitable price. Grooming services based on hair types. Long-haired pet usually require daily brushing to prevent matting and tangling of hair. Medium-haired may be prone to matting and tangles and should be brushed at least weekly. Short-haired can typically go up to a month in-between brushing. The rate for grooming short hair pet is Rp 35,000 and Rp 50,000, - for long hair pets. This include services for bathing, drying and nail trimming. If the klient require additional services the price range from Rp 60,000 to Rp 75,000, -. Based on the performance in the second year, the number of klient obtained both for dog and cat range from 15-20 per month at a rate of Rp 30,000, - per service. From the analysis of the business, it is known that the value of an ROI of 17.38%, BEP is 2.146 and RC of 1.2.

These services also involve students in doing health care and grooming in order to provide benefits and support the teaching and learning process for students of Veterinary Medicine School UB (PKH UB). Services and promotional activities further enhanced by supporting community service work which also involve students and take an active role in the of pet contest organized by PKH UB and the pet lovers. IBIKK activity is perceived outcome mainly by pet owners who have obstacles to bring the ptes to the clinic and for those who have not been accustomed to pet's grooming. To further expand this project, the marketing network has been carried out by doing socialization to elementary school students in collaboration with several elementary schools in Malang. It is expected, this project could improve the understanding and knowledge of the community regarding the importance of animal health care and animal welfare at the early stage of pets. Socialization is accomplished by an active role in the activities of cat shows and dog show organized by a pet lover dogs and cats. In this activity, the group IBIKK assisted by students to do grooming, while health care is assisted by several young veterinarians who are members of PKH UB. Thus, this mobile animal health care program that has been initiated through IBIKK program can be sustained after the project ends.

Some IBIKK program activities :



Fig 1: Car before renovate



Fig 2: Interior renovation



Fig 3: Car's interior for health care and grooming



Fig 4: Grooming activities

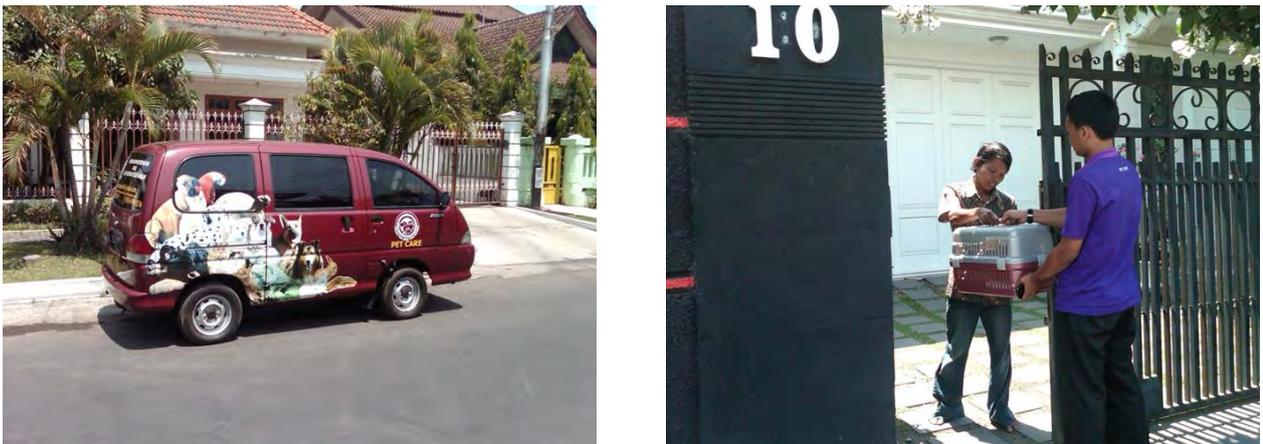


Fig 5: House call for pet health care



Fig 6: Promotion activities

#### 4. CONCLUSION

1. IBIKK for Health Care and Grooming car facilitated with mobile grooming van equipped with standard appliances allowing to give qualified and confident services for pet health care and grooming.
2. IBIKK program has opened a new opportunities for entrepreneurship in the field of pet health care and grooming.
3. Based on the performance in three years program, the analysis of the business was ROI of 36%, BEP 2146 services and RC of 1.52

It is suggested to the pet owners for maintaining the health and hygienic condition of the pets in order to prevent diseases transmission from the pets to the family member especially children.

## **ACKNOWLEDGMENTS**

Thank you to DIKTI for providing funding to IbIKK program for 3 years from 2010 to 2012.

## **REFERENCES**

- [1]. Anonim. 2005. Mobil Salon Keliling. <http://www.anjinkita.com/wmview.php?ArtID=824>. Tanggal Akses 14 November 2011.
- [2]Anonim. 2011. Pet Grooming Is usually a Responsibility. <http://www.iuiu-mbale.com/pet-grooming-i-usually-a-responsibility/>. Tanggal Akses 14 November 2011.
- [3].Caesar, R. 2009. Hewan Peliharaan dan Kesehatan Manusia. [http://www.medicalera.com/info\\_answer.php?thread=9906](http://www.medicalera.com/info_answer.php?thread=9906). Tanggal Akses 14 November 2011.
- [4].Moore, J. 2011. A Beginner's Guide to Pet Grooming. <http://www.northorion.com/careers/trade/petgrooming-great-career-0736/>. Tanggal akses 14 November 2011
- [5].Soeharsono. 2005. Penyakit Menular dari hewan ke Manusia Volume 2. Penerbit Kanisius:Yogyakarta

# Training of Standard Operating Procedures on Semi Material Recovery Facilities/UPS to increasing its efficiency for officers of Depok Cleanliness Department/DKP-Depok

**Djoko M. Hartono, Irma Gusniani, Gabriel Andari Kristanto**

*Environmental Engineering Study Program, Civil Engineering Departement, Faculty of Engineering, Universitas Indonesia.-Depok.  
Email: djokomh@eng.ui.ac.id*

## ABSTRACT

*The implementation of semi material recovery facilities (named UPS/Unit Pengolahan Sampah) has greatly assisted Depok Cleanliness Department in managing solid waste. During the past five years, capacity of Cipayung landfill has become very limited due to the high amount of waste generated and disposed directly. It is critical that the UPS with their 3R-P Program (Reduce, Recover, Reuse and Community Partnership) will not only minimizing the waste transporting to the landfill but also supporting Depok in managing solid waste in more sustainable way. The objective of this community development is to implement standard operating procedure for Unit Pengolah Sampah in Depok. This standard operating procedure will consists of operational management function, building structure, layout arrangement, equipment, and environmental protection equipment. Standard Operation Procedure of the UPS has been introduced to the UPS workers in 4 (four) separate training sessions. During these activities, around 160 UPS workers and participants were actively involved. These training were not only conducted inside the classroom, but also in UPS University of Indonesia. Several approaches were developed to transfer the knowledge including study group, one day workshop, real experience, and discussions.*

## Keywords

*Community Development, Training, Material Recovery Facility, Standard Operating Procedure, Depok Cleanliness Department*

## 1. INTRODUCTION

Based on Ministry of Public Work Decree Number 21/PRT/2006 on National Policy [1] and Development on solid Waste Management and Indonesia Law Number 18/2008 on Solid Waste management [2], it was stated that the new paradigm on solid waste management has shifted from old paradigm to new paradigm. The old paradigm consists of collect, transport and dispose which was all solid waste collected from the sources of solid waste will bring them to solid waste disposal site as the result solid waste disposal site with the short periode has full their capacity. The new paradigm introduce 3 R, reduce, reuse and recycle in the source of solid waste before collect to the disposal site and as the result the generation of solid waste will be reduced in the solid waste disposal site. City of Depok with population in 1982 was 240,000 population, in the year of 2010 became 1,736,565 and almost 90% of solid waste are in old paradigm. As a result solid waste disposal site in Cipayung Disposal Site will no more longer can handle solid waste generation from the city of Depok. To over come that situation, Mayor of City Depok through Cleanliness Department has build 31 Small Material Recovery Facilities [4] so call Unit Pengolahan Sampah (UPS) in several Sub District (Kecamatan) as well as several housing locations. The main objectives of UPS is separating and sorting organic waste to produce compost and inorganic solid waste by reuse and recycle to become valuable things. Mayor City of Depok has planned to built 12 UPS per year until 2018. However, among 31 UPS that has been constructed, only 18 UPS are still in operation. The rest are not in operation due to the in proper standard operation procedure. One UPS has been built in Campus Universitas Indonesia in cooperation with the City of Depok. Universitas Indonesia allocated space and city of Depok sharing UPS building, see Figure 1., and using as pilot project in implementing the SOP of UPS [3].



Figure 1: UPS in Universitas Indonesia

## 2. METHOD.

The method to conduct this community development is divided into 2 parts, (i) material preparation and (ii) training.

(i). Material preparation.

Material preparation is collecting since 2010, the first grant received from Directorate Research and Community Development Universitas Indonesia.

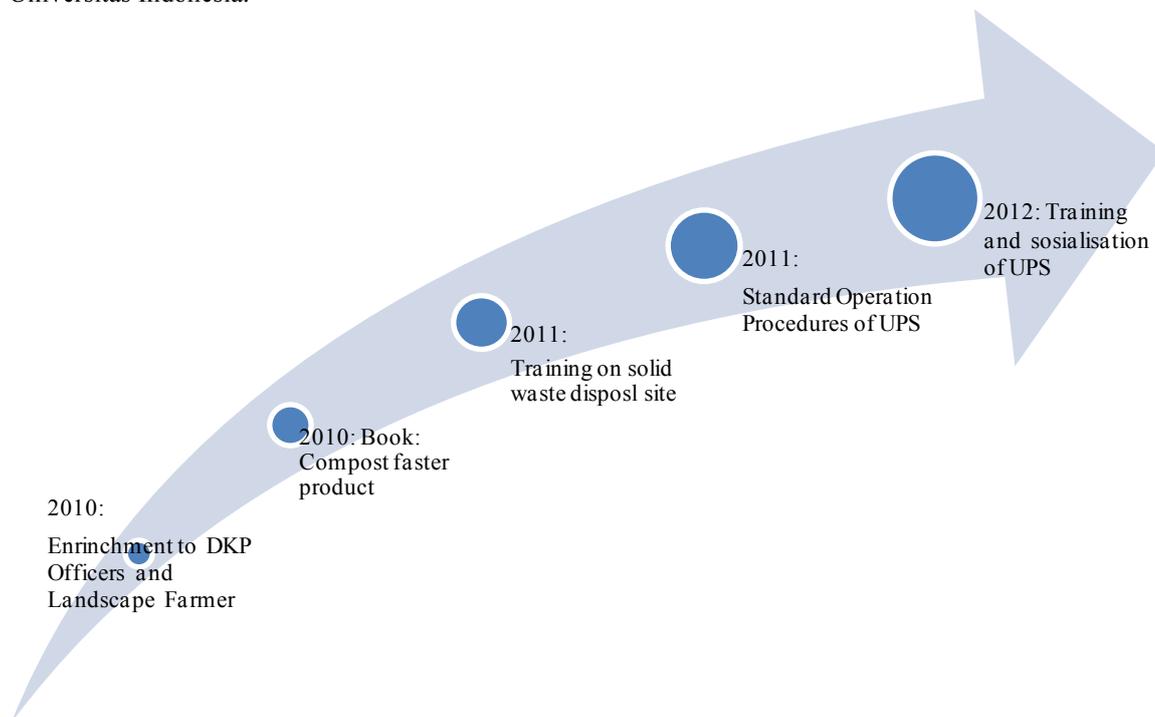


Figure 2: The processes in setting up SOP

As can be seen in Figure 1., the processes in setting up of standard operation procedure was begun in the year 2010 which trained small farmer and solid waste officers and followed by making a handbook on composting method. In the year 2011, received grant on training of solid waste final disposal. Finally by studying almost all 31 UPS in the City of Depok, succeeded in producing guidebook for standard operation procedures. This standard operating procedure will consist of operational management function, building structure, layout arrangement, equipment, and environmental protection equipment [3].

(ii). Training.

There are 4 stages in conducting training which were held continuously, 1<sup>st</sup> stage from 11-18 July 2012, 2<sup>nd</sup> stage on September 18, 2012, 3<sup>rd</sup> stage on October 30, 2012 and November 7, 2012. Several approaches were developed to transfer the knowledge including study group, one day workshop, real experience, and discussions.

### 3. RESULT

On the 1<sup>st</sup> stage training which was held in UPS Universitas Indonesia from 11-18 July 2012, were follows by around 150 participant during the training period. Every day training, the participants consists of staffs of Cleanliness Department, Universitas Indonesia staffs, teacher and student from Faculty of Engineering and other guest from other UPS management.



Figure 3: Participants on the 1<sup>st</sup> Taining

On the 2<sup>nd</sup> stage training on September 18, which was held in Chevron Room Dekanat Building of Faculty of Engineering. This one day workshop carried out with Technische Universitat Darmstadt, Germany with Master Program Environmental Engineering, Civil Engineering Department, Faculty of Engineering Universitas Indonesia, with 110 list of attendants from various discipline.



Figure 4: Speaker in One Day Workshop on the 2<sup>nd</sup> Training

On the 3<sup>rd</sup> stage training on October 30, 2012, which was held in Chevron Room Dekanat Building of Faculty of Engineering, Universitas Indonesia. The participants are consisting of UPS officer, Cleanliness Department, lecturers and students



Figure 5: Facilitators in the 3<sup>rd</sup> Stage Training

On the 4<sup>th</sup> stage training November 7, 2012, which was held in UPS Universitas Indonesia, was implementing standard operation procedure for UPS and as the result some correction to be done to improve SOP



Figure 6: Implementing Standard Operation Procedures in UPS UI

#### 4. CONCLUSION

The volume of solid waste to be processed in the UPS should be limited to maximum of 12 m<sup>3</sup> so that the objective of UPS clean and aesthetics will be accomplished. The officers of UPS should be completed with uniform, masker, hat, worker shoes and other equipment for environmental protection such as fire extinguisher and other. Compost should also be analyzed regularly to get the best quality. Although UPS construction is template with other UPS in Depok, the lay out of UPS UI should be redesign so that can cope with efficiency and effectively of UPS as can be seen on Figure 6. The residu of composting process should also be disposed to solid waste disposal site in TPA Cipayung.

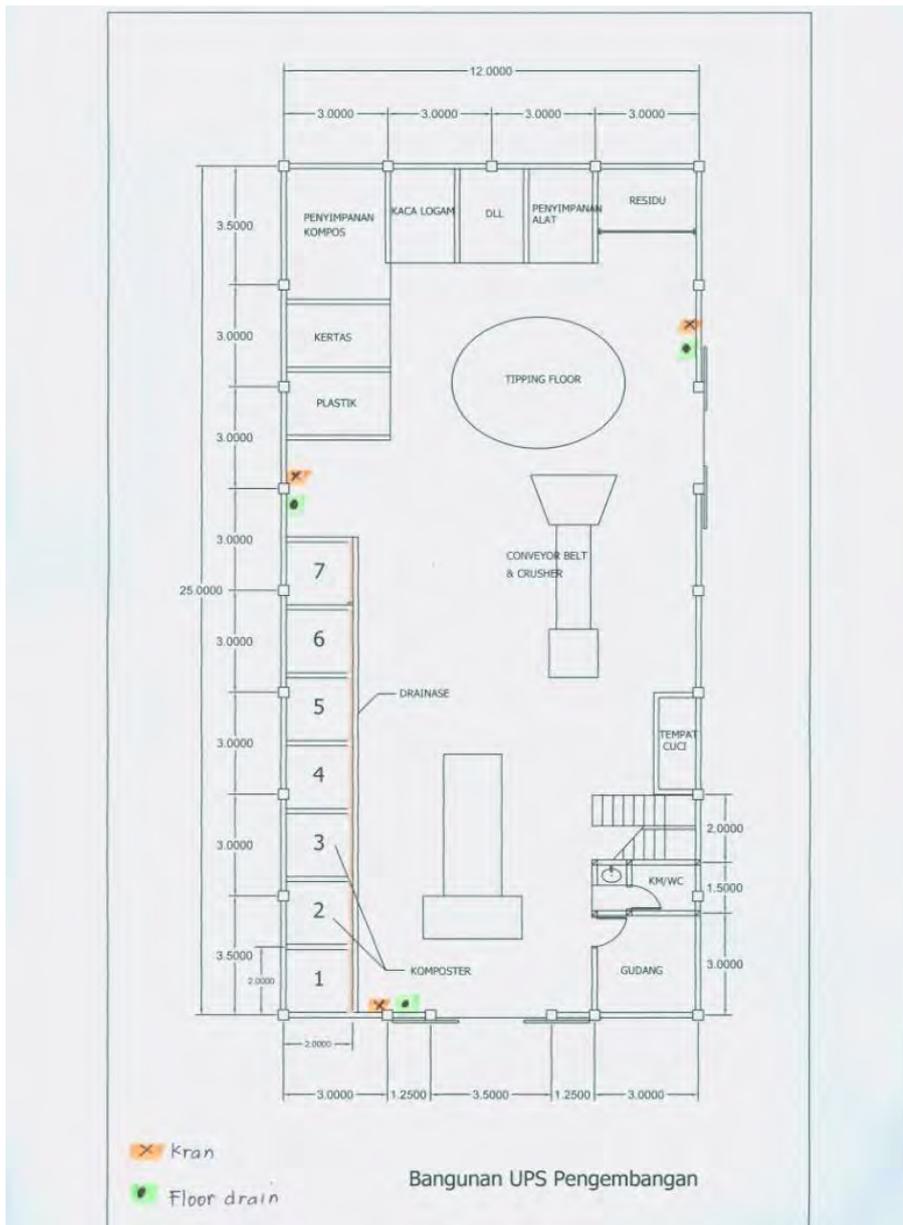


Figure 7: Proposed Lay out UPS UI

## REFERENCES

- [1].Peraturan Menteri Pekerjaan Umum Nomor: 21/PRT/M/2006, tentang Kebijakan dan Strategi Nasional Pengembangan Sistem Pengelolaan Persampahan (KSNP-SPP), 2006.
- [2]. Undang-Undang Republik Indonesia Nomor 18 Tahun 2008 tentang Pengelolaan Sampah
- [3].Laporan Akhir Program IPTEK bagi Wilayah (i<sub>b</sub>w) Pelatihan Tatalaksana Pengoperasian Unit Pengolahan sampah (UPS) bagi pegawai Dinas Kebersihan dan Pertamanan Kota Depok untuk meningkatkan efisiensi UPS (Kerjasama antara Universitas Indonesia dan Dinas Kebersihan dan Pertamanan Kotamadya Depok.
- [4]. Tchobanoglous, G., Thiesen & Vigil, S. A., 1993. *Integrated Solid Waste Management: Engineering Principles and Management Issues*. McGraw- Hill, Inc. Singapore

# Future Welfare of Neglected Children: Empowerment or Community Development

**Chairun Nasirin**

College of Health Sciences (STIKES) Mataram  
 E-mail : chairun\_nasirin@yahoo.com

## ABSTRACT

*This paper explores the quality of social policy that implication to the neglected children welfare. The neglected phenomenon is real social problem in Mataram nowadays due economic and urbanization. The neglected happens for a child who has no capability to empower themselves and welfare condition as economic is one of important variable in policy formulating process. Despite this problems, social problem of neglected children seen not only in Indonesia, but also happens in all part of the world. Data from statistic bureau (2012) in figures shows that the number of social issues in West Nusa Tenggara (301.153) and 2 % from the total numbers of neglected children needs special attention from the government and community. The phenomenology analysis appropriate to remark the issues of neglected children's in the city of Mataram as they are related to the setting of social phenomena. From this study can be concluded that core message of existing program for neglected children in Mataram should be evaluated the quality of social services and government need to create the regulation to implement the legalizing program for neglected children in the future. This study found that the social welfare policies, needs to be developed continuously to create the conductive situation and condition to the children development, which a constitution mandate to educate the life of the nation can build a better future.*

## Keywords

*Empowerment, Community Development, Neglected Children*

## 1. INTRODUCTION

The problem of neglected children is a main phenomenon that faced by social department in nowadays. The phenomenon is not only happens in Indonesia, but it also in the other part of the world. The social phenomenon of neglected children is a real faces in Mataram, that can't be avoid in the society life, especially to people who lives in the urban area due the poverty. Those phenomenon is an offspring of the modern urban environment, represents one of humanity's most complex and serious challenges. The problem of these neglected due they don't have a settled home to live, homeless family and their parents can't afford to buy a house for their family. This is may also happened in country which has wide region like Indonesia that needs an effective social government system. This system is not just as a mean to execute all kinds of government's programs for all local area but it is also for local community to develop their own area. On the other hands, the strengthen of local social institution is the way of social development to carried out the root problem in local community that increasing the capability of local social institutions.

Data shows in 2010 there are 78.96 million children, ages between 7-18 years old (35,5 %) lives in urban area and need attention to government to achieve the goals in overcoming social problem as neglected children and able to create programs to developed children in the future. The neglected children occur due to the family can't support to increase the family welfare as low paying jobs or no settled job. According to the Crittenden (1992), says that A neglected child is a social phenomenon in part of the world which effect children's life in their growing period and also the neglected children problem occurs due a manifestation from a deep anxiety during child's growth, therefore family's social relation is an important part to a children's life. The establishment of family's social policy it was usually emerged from politics and government intervention dealing with social problem. Therefore, Roditti (2005) suggest that the approaches to overcome the children's problem, as: (a) emotional support (b) informational support and (c) concrete services.

The social issue of social protection as neglected children was highly effective of local government to improve the social welfare for the population in the region through the services, empowerment and public participation as well as government efforts in addressing social problems. This strategy is an effort that directly point to the root of problem that is by increasing the capability of all kinds of local social institutions. Dasgupta & Serageldin (1999) stated that as social progress from a group of society, that can be a strengthen factor in supporting the success of social welfare development in an area.

In accordance with the social policy of neglected children in Indonesia, as outlined in the law number 12/2008, the local government has authorities to self-organize and self-manage their government in aiming to accelerate the realization of public welfare through the improvement, services, empowerment and public participation as well as government efforts in

addressing of social problems. The processes of social governance in Indonesia social welfare development were considered three main components. First, private sector which establishing a working relationship with government. Second, the civil society that interaction in local community in various forms of social life in the society and the local government itself to protect the social life the neglected children. From the point of view of social welfare, Martinussen (1997) considered that the government official should implement the correct economic policies. The change from traditional local government to a more complex network of agencies involves in 'local government' is no longer theory (Goss, 2001). This means that the policy of local government appropriate critical consideration to achieving the social problems as neglected children phenomena. This also approach provides a theoretical justification including neglected child problem, unemployment, to improve health and to reduce crime and to build communities in society. For Ryan, 1999, social action determined the goals (often politicians) were often deemed dependent on technically competent (generally bureaucrats) to flesh of neglected problems. Essentially, Williams (1989) looks at social welfare that the mainstream concept was in economy crisis, whether it had lost legitimacy not simply amongst social policy but amongst the public in large. Thus, the decentralization adds importance of local government institutions to hold government in autonomous regions. Beyond the classical definition of Smith (1985), decentralization is widely regarded as a necessary condition for social, economic and political development.

## 2. METHODOLOGY

This descriptive study uses phenomenology to illustrate the local governments to improve the pattern of relation between local government with community empowered and stakeholders in running the government functions. Details of the design the governments need to create regulation in form of local regulation to legalizing the neglected children, therefore the local government functions can running optimally. To understand how the local government functions of social welfare for neglected children empowerment in the of Mataram, as they are related setting of social fenomena requiring comprehensive study. Figure 1 shows the system model to empowered the neglected children model in Mataram.

The issues related to local government of social welfare regarding the neglected children in Mataram is very complex. In so doing, the study stressed at on to three specific issues of each case. This study analyzed by qualitative inquire and employs several method of data collection to explore the data sources. To gain the information regarding the empowerment of neglected children in the city of Mataram, depth interview is conducted. Yet it is acknowledged data analysis used Miles and Huberman (1994) character. Basically, to understand local government function of neglected children in Mataram, three main substances that related to this study as: [1] neglected phenomenon, [2] local government policy in the empowerment of neglected children and [3] the function of government of neglected children involving the private area and public sectors.

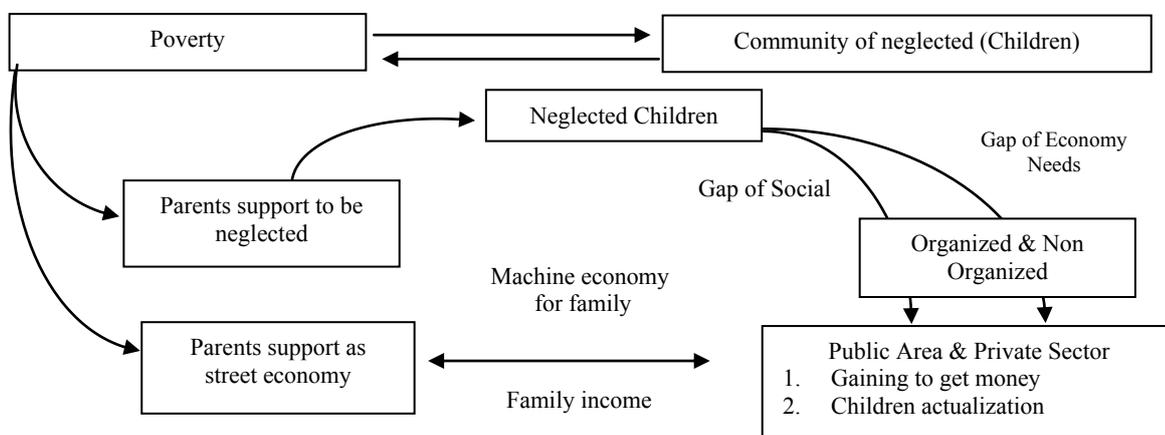


Figure 1: System model to empowered the neglected children model in Mataram.

## 3. DATA

To collect further information on the formulation, data were collected from Mataram statistic bureau between 2009 and 2011 that the number of issues in this province as 262,159 number of neglected children throughout both regency and municipalities. To ascertain views on the neglected child, the researcher conducted investigations and depth interview regarding the children phenomenon. Neglected children interviewed were audio-taped and transcribed. The data shows that the large number of children living without their parents for various reasons and indeed need special attention from the government and society.

Data were analyzed with a focus on describing the essence of neglected child life experiences and factors related to be neglected.

The majority of neglected children interviewed, both male or female which reflected in the participating. The ages ranged between 8-15 years old with the majority of the child interviewed is street worker participants in different places or locations in the city of Mataram. The interviewees were provided with an open-ended questions asking them to identify any areas where they doing their activities or who organized the neglected child community. Internal validity on the other hand, by having third party check decision made throughout the analysis process to bias minimized.

#### **4. DISCUSSION**

A neglected child is real phenomenon of social problem in the world. Although it is difficult for government to overcome that social problems, this study were based on neglected children's real life experiences of how they managed and struggle their life even as street working children that mostly living on the street.

The Research findings describe and underlying proportions from this study were based on these neglected children's real life experiences of how they managed their life economy. These description not only provide a clear and substantial concept of neglected children as a real social problem, but also provide the local government regulation for social department conceptual both regency and municipalities in West Nusa Tenggara Province. Indeed, the implementation of local government functions in administrating the government social welfare affairs, including the empowerment of neglected children in general [1]. Adherence to the rule, the principle of participation, optimizing the local government authority along with the implementation of decentralization, competence and professionalism of planners, the compliance toward the real problems of society, reducing its dependence on the budget from central government and the success to adjust the budget with the burden that must be resolved through specific programs, [2]. Clarity of policy design, support and coordination between inter-regional bureaucracies' instruments, institutional capacity enhancement, public or community neglected children participation and partnership with various stakeholders.

#### **5. CONCLUSION**

The main contribution of this paper is that present a new approach to overcome the social phenomena problem due neglected. Yet the finding of this study suggest necessary information might be sufficient for the local government to overcome the social phenomenon. The existing implementation and I believed that the concept can be applied to develop the policy of social problem as neglected children.

Neglected children is a root problem that can be underlying the actor occuring in the city of Mataram. Interestingly, how the policy implementation and pcesses can be overcome due the social problem. The paper can be highlight that the neglected and the empowerment of children in Mataram become the priority of social department agenda. The implementation of local government functions in the administration of government social welfare affairs sector, largely determined by the rules, optimization of government authority and the budget from central government.

The conclusion suggests that a neglected child is typified child inadequate care from their parents, less attention from their family, poor family, failure to provide a child with an adequate education in form of enrolling in school, away from home and failure provide needed.

Finally, this study recommendations constructive professional practice in order providing optimal care and solution for neglected children based on these essential research findings. These recommendations may be able to help the local government find formulated and solution regarding the social problem and neglected children social phenomenon. Clearly, as evidenced in this study, social problem of neglected can be formulated as follows: (1) the social department should be redesign of the implementation of local government functions, (2) the need of certain legal instruments supports so that a program should have optimal power, both at the time of planning and implementation; (3) a specific legislation related to the real problems of society is to be formulated; (4) a culture change in local bureaucracy in order not only to adhere to the ethics and morals that have been established in the personnel regulations and central regions, but have also strengthened with the creation and implementation of reward and punishment system, so can encourage the creation of high performance in carrying out the local government functions; (5) the civil community organizations, such as NGOs should conduct institutional reform so as to make active and critical participation and avoid dependence on the Regional Government funding alone.

## REFERENCES

- [1] Blau, Joel & Abramovitz, Max. 2003. *The Dynamics of Welfare Policy*. New York: Oxford University Press.
- [2] Chang, Janet. (2008). Child Abuse and Neglect in Cambodian Refugee Families: Characteristics and Implications for Practice. *Journal of Child Welfare*, 87 (141).
- [3] Cheema, G. Shabbir & Rondinelli, Dennis A. 1983. *Decentralization and Development: Policy Implementation in Developing Countries*. Beverly Hills, California: Sage Publications.
- [4] Chapple, Constance L. 2005. Child Neglect and Adolescent Violence: Examining the Effects of Self-Control and Peer rejection. *Journal of Violence and Victims*. 20 (1).
- [5] Dasgupta, Partha & Serageldin, Ismail. (1999). *Social Capital: A Multifaceted Perspective*. Washington DC: The World Bank.
- [6] Friedmann, John. 1992. *Empowerment: The Politics of Alternative Development*. Cambridge, Massachusetts: Blackwell Publishers.
- [7] Gwardz, Marya Viorst. 2008. The Initiation of Homeless Youth into the Street Economy. *Journal of Adolescence*. xx (1-21)
- [8] Goss, Sue. (2001). *Making Local Governance Work: Networks, Relationships and the Management of Change*. Great Britain: Palgrave
- [9] Kooiman, J. 2003. *Governing as Governance*. London: Sage Publication.
- [10] Le Roux, Johan & Smith, Cheryl Sylvia. (1998). Causes and Characteristics of the Street Child Phenomenon: A Global Perspective. *Journal: Adolescence*, 33 (131).
- [11] Mangold, Susan Vivian. 2007. Poor Enough To Be Eligible? Child Abuse, Neglect, and The Poverty Requirement. *Journal of John's law*. 81 (3), 131-138
- [12] Martinussen, John. 1997. *State, Society and Market: a guide to competing theories of development*. Canada: Fern wood Books Ltd.
- [13] Narayan, Deepa, Raj Patel, Kai Schafft, Anne Rademacher, and Sarah Koch- Schulte. 2000. *Can Anyone Hear Us?: Voices of the Poor*. Washington, DC: Oxford Univ. Press.
- [14] Raper, Michael. 2006. *Social Security & Social Protection in Australia and Indonesia*. Jakarta: TURC.
- [15] Roditti, Martha G. 2008. Understanding Communities of Neglectful Parents: Child Care Giving Networks and Child Neglect. *Journal of Child Welfare*. 82 (2)
- [16] Rukmana, Deden. 2008. Where the Homeless Children and Youth Come From: A Study of the Residential Origins of the Homeless in Miami-Dade County, Florida. *Journal of Children and Youth Services*. 30 (3) 1009-1021.
- [17] Smith, Brian C. (1985). *Decentralization: The Territorial Dimension of the State*. Australia: George Allen & Unwin (Publisher) Ltd.
- [18] Williams, Fiona. (1989). *Social Policy: A Critical Introduction: Issue of Race, Gender and Class*. Great Britain: Polity Press
- [29] Wilson, Dee & Horner, William. 2005. Chronic Child Neglect: Needed Developments in Theory and Practice. *Journal of Families in Society*. 86 (4).
- [20] Zell, Maristela C. 2006. Child Welfare Workers: Who They Are and How They View the Child Welfare System. *Journal of Child Welfare*. 85 (1).

# The Pre-specific City: A Theoretical Narrative in the Post-Generic Age

Diana Alvarez-Marin

FCL Future Cities Laboratory – Simulation Platform  
 ETH Zürich – CAAD Computer Aided Architectural Design Department  
 alvarez@arch.ethz.ch

## ABSTRACT

During the 20th century, the interest and preoccupation over subjects such as global crisis, scarcities, urbanization or population growth, ended up in a series of statistics and simplifications of reality, which in the urge for efficiency, control and optimized unilateral solutions, didn't take into account their interconnectedness to many other factors. This 100% optimized scenario, ultimately manifested itself in a Taylorisation of the city and by the same tokens into generic space, as the imprint of market economy and globalisation. However, the emergence of networked communication technologies has extended our interaction with the city towards an invisible and complex network of relations and data, embodied through growing interactive platforms such as social media. For the first time in history, we are not only aware of such a degree of complexity surrounding us but also likely to grasp it through a real-time flow of data. Hence, we are no longer constrained to see the city as a limited set of logical assumptions on reality, but as a data platform able to preserve any potential relations. The Pre-specific City is the upgraded space of the any-relations. The Pre-specific City is not exactly definable in geometric terms. In order to locate it, one must consider  $n$ -dimensions, out of which none is correct or false. In fact, all of them coexist simultaneously into one single space-time. Therefore, the Pre-specific City is not a point in space, but rather a point and all its possible trajectories. This non-Euclidian condition, have induced some of its inhabitants into some kind of painful sensation, like the one that persists in an amputated phantom limb. Seemingly, the definition of the city has been stretched towards inconceivable limits, in a desperate try to fit to it what has become the contemporary urban condition. But why does uncertainty seem always so painful, when change is the only certainty we have? This theoretical narrative embeds a double purpose. Firstly, it celebrates the generic condition, inherited from the 20<sup>th</sup> century, through an exploration of its possibilities, and considers its empowerment within the rise of information technologies, through new social phenomena such as the democratization of knowledge, the diversification of identity, the rise of an economy of information and the extension of public space towards more virtual grounds. Secondly, it challenges modern science generalizations and rule-based models, suggesting a shift towards non-linear data driven approaches likely to go beyond mere representation and to provide insight on the rising complexity of the city.

## Keywords

*Pre-specific, city, identity, data, media*

*"If there is to be a "new urbanism" it will not be based on the twin fantasies of order and omnipotence; it will be the staging of uncertainty; it will no longer be concerned with the arrangement of more or less permanent objects but with the irrigation of territories with potential; it will no longer aim for stable configurations but for the creation of enabling fields that accommodate processes that refuse to be crystallized into definitive form; it will no longer be about meticulous definition, the imposition of limits, but about expanding notions, denying boundaries, not about separating and identifying entities, but about discovering unnameable hybrids; it will no longer be obsessed with the city but with the manipulation of infrastructure for endless intensifications and diversifications, shortcuts and redistributions – the reinvention of psychological space. Since the urban is now pervasive, Urbanism will never again be about the new only about the "more" and the "modified." It will not be about the civilized, but about underdevelopment."*

Rem Koolhaas. *What Ever Happened to Urbanism?* (1994)

## 1. IDENTITY DOPES THE GENERIC

### 1.1 Decoupling

Here, is where people live. Yet *here*, is not exactly definable in geometric terms. In order to locate us, one must consider  $n$ -dimensions, out of which none is correct or false. In fact, all of them coexist simultaneously into one single space-time. Hence *here*, is not a point in space, but rather a point and all its possible trajectories. This non-Euclidian condition, have induced some of us into some kind of permanent and painful sensation, like the one that persists in an amputated phantom limb. Seemingly, our definition of the city has been stretched towards inconceivable limits, in a desperate try to fit to it, what has

become our contemporary urban condition. But why does uncertainty always seem so painful, when change is the only certainty we have?

## 1.2 Post-Generic

The curtain goes up. A voice-over opens up the scene: 'I am everywhere and I am no one, therefore, I can contain you all. I potentially could become anything and still be no one'. In the background, a city defined by numbers, functions and performances strictly classified by some general features. A mirage of objectivity. A theoretical scenario for scientific scrutinisation. The Generic is our scenario. Instead of despising it, we celebrated it. We learned how to blend with its motion and –merit goes to its massiveness- redirect the force of its occurrence. The operation, if performed with the dexterity of an aikido master, requires little effort. Grasping the leading of its momentum relies on cultivating the essential elasticity embedded in infrastructures. Infrastructures, the subtract of globalisation, populated the territory with a schematic logic of interconnected elements, providing the framework for an entire structure of developments such as a double life span, literacy levels enhanced by factor 60 and an increasingly global population manifested in global urbanisation, accounting today 7 billion inhabitants out of which more than a half are already urban.

We populated infrastructures beyond their physical configuration, learned to abstract their own logistics by turning things into facts and facts into symbols, crafting the conditions for ubiquitous and mobile computing. The emergence of networked communication technologies has extended our interaction with the city towards an invisible and complex network of relations and data, embodied through growing interactive platforms such as social media, urban computing and crowd sourcing. For the first time in history, we are not only aware of such a degree of complexity surrounding us but also likely to grasp it through a real-time flow of data. Hence, we are no longer constrained to see the city as a limited set of generalizations, but as a data platform able to preserve any potential relations: this is the new surface of our world.

This pre-specific surface can be ossified, fossilized, territorialized, deterritorialized; it can turn stale and rigid, but can never be given nor can be lost. Our universality is not defined by the adaptation of a generalization to any context, but rather by the articulation of any identity in a space of possibilities. Hence, the generic is now occupied, doped, induced into a long term 'cohabitation' of multiple identities. 722000 parodies of Gangnam style. 1 billion combinations of tastes and experiences on Facebook. As many definitions of theory as languages on Wikipedia. Identity is an amalgam of secretly borrowed lives and one's own. No longer surrendered to physics and history, its virtual makeup decouples from geometry or locality, replaces one point by a cloud, explodes one centre into *too many centres*. Social media has opened up a wide space of unexpected encounters, where the combinatorial possibilities between cultural indexes are unaccountable. Identity is paradoxically sameness and oneness, simultaneously what integrates and differentiates. You and I are no longer twofold commuters through this city, but *n-dimensional* identities navigating through as many social spheres as traits we are made of.

## 1.3 Memory

Perceptions of time in the Pre-specific City, and prominently the present, are always too full. Since time has taken the role of space, space is just another index and our presence is continuous, always on. One fraction of our (non-linear) time is compressed and concurrently populated by a myriad of events. 1 minute, 694.445 Google queries, +6.600 pictures on Flickr, 600 videos on YouTube; 695.000 status updates, 79.364 wall posts and 510.040 comments on Facebook; +168.000.000 emails, 320 new accounts in Twitter and 98.000 tweets, 20.000 new posts on Tumblr, +50 downloads of WordPress, 100 new accounts on LinkedIn, +1.600 reads on Scribd. Social media has become an indefinite extension of the manifold social memory. The imminence of this real-time construction has merged past, present and future into an approximation of a single point. Memory is now an ambiguous amalgamation of externalized knowledge and lived experiences. "To write a single line of verse... One must have... Many... Memories... And having memories is still not enough... For the memories are not what is essential. It is only when they become blood within us, become our nameless looks and signs that are no longer distinguishable from ourselves - not until then does it happen that... The first word of a verse rises..." [1]. We extended our memory through incorporation, overlapped the privacy of the diary to a network of real-time chronicles. Even before you go to Paris, an Eiffel Tower already erects in your mind, within the experience of others distributed over a trillion of indexes.

## 2. NOTHING AND EVERYTHING

### 2.1 Information

The Pre-specific City has been the scenario of diverse inversions. Once, we revolted against the absolutism of form because its specificity was incarcerating. Ultimately, form is just one of the too many representations the data embedded in things can be mediated into. Since then, our questions are no longer exclusively about the pure geometrical manifestations of the city (the roman *urbs*?) but thrive on the interactions with subjacent levels of *cityness*. In the Pre-specific City, every fact carries a latent

existence in data, the lowest level of abstraction from which information can be derived, and because of this its abundance is incontestable. Strikingly, our more cherished resource is embedded in *everything*, yet outlandishly close to *nothing*, almost inexistent. This incongruous circumstance only allows it to be described by negation. Information is neither matter, nor energy, has no weight, no body, no meaning. Paradoxically, and unlike *things*, its abundance does not lead to its own devaluation, but rather to a striking condition of discernment. Pedestrians sprawling in the streets, sudden crowd gatherings, Twitter geographies, checking-in at favourite restaurants, multiple daily taxis journeys, or even *likes* on friends' status, are no longer isolated events but clusters of insight. Every second, urban life is being engendered, mediated and interpreted within the very banality of social media.

## 2.2 Articulation

Dealing with the informational make-up of facts has prepared us to the restlessness of the unsettled and the primacy of the exception. For instance, the emblematic image of the Pre-specific City is the wasteland. A heap of meaningless indexes appears in seductive nuances on touristic brochures, which reading is notably demanding for newcomers. The plasticity of the metaphor allows to contain previous slogans of the city: Perfect City, Model City, Machine City, System City, Non-stop City, Generic City. The visitor is hence required to build her/his own story-city, for only when articulated, the indexes are likely to evoke a meaning. This one scenario will be an incomplete, but not untruthful, image of a possible city. We've become rhetoric craftsmen, frivolous storytellers aware of the influence our statements can have the development of events. Sometimes, we imagine we had already accomplished something in order to impose upon ourselves a future out of many others. Once Borges depicted the Pre-specific City: "*This network of times which approached one another, forked, broke off, or were unaware of one another for centuries, embraces all possibilities of time. We do not exist in the majority of these times; in some you exist, and not I; in others I, and not you; in others, both of us. In the present one, which a favourable fate has granted me, you have arrived at my house; in another, while crossing the garden, you found me dead; in still another, I utter these same words, but I am a mistake, a ghost*" [3]

## 2.3 Pre-specific

The Pre-specific City has the encapsulating properties of a Matryoshka doll. On these symbolic grounds, an apple is not just an apple. It is rather an x number of possible declinations of it, spanning from apple pie, raw cider, apple juice, to compote or even the apple tree that is present in it, in its seeds. Something like, the possibility of an apple. Similarly, the territory, the city, the quarter, can no longer be described through the narrow and objectifying supremacy of one single map. Instead, *civitas* and *urbs* are rendered concurrently, by a symbolic surface of indexes, elucidating the world through pictures, tweets, feeds, signals, *likes*. We don't look at things anymore, but things look at us, they surround us. We never talk *about* something but always *around* it.

## 3. FROM DATA TO KNOWLEDGE

### 3.1 New Symbolism

Last information revolutions in the Pre-specific City, one after the other, strengthened the articulation between the virtual and the actual, deepening the mark of its operability over the territory. But please, don't get us wrong, we are no technocrats here. Technology itself gave us the means to see it coming, provided us with a wide sense of self-awareness to think to whom and how it should be useful. We managed to learn from previous revolutions, understand the real stakes of the time. Our efforts were both technical and symbolic: writing, printing, computing, just to name a few, not only changed our relation to technology from syllogistic to logic to logistics but also towards increasingly abstract levels of literacy, from ideography to digitality. Certainly, we still have struggles to think about, but they are based on the terms of our century. We built on the leftovers of preceding times with cheerful opportunism and rediscovered in information technology, not just a means for narcissistic self-promotion and inquisitive morbidity, but also a fabulous tool for the transformation of the world, the struggle against ignorance and the extension of democratic space.

Whereas Industrial revolution produced tools to provide extensions of the body, such as the steam machine or the automobile, information revolution engendered mediums to prolong the intellect. Nevertheless, regardless of their level of abstractions, progress in symbolic coding has been the catalyser of all information revolutions. Computers have been the compelling force of globalisation and market economy: their performance allowed us to access and deal with the growing amount of information. In the Pre-specific City, *computers (...) are not just fast machines of the same kind, as we know them. Computers are abstract machines*[4]. Their abstract logistics form a continuity of transformability through mediation: the conversion of our social memory into different kinds of extensions, images, animations, texts, sounds, music. "*Today we're beginning to realize that the new media aren't just mechanical gimmicks for creating worlds of illusion, but new languages with new and unique forms of expression*"[5]. We see the world symbolically, and this is the sheer essence of our upgraded literacy. Since an early age, we

have developed an awoken interest in diverse modes of translation, an ability to read and write processes. This polyglotism of signification regimes has deeply penetrated our popular culture. Grasping the real significance of the formal is an exercise of backwards gymnastics: it cares about engendering forces rather than crystallized outcomes. Bottom-up or Top-down discussions seem now irrelevant: our literacy is orthogonal to them.

### 3.2 Resilience

Since access to information has been declared an inalienable citizen right --as well as disconnection--information is *res publica*. But you must wonder, how do we approach something, which can be taken by anyone? Education systems have been short-circuited by a reciprocal apprenticeship. What genuinely matters is not what you can learn or its amount, but how resilient your intellect can be: everything you learn becomes already useless by the time you think you are done with learning. Learning is an extended process of learning, unlearning and relearning, over and over. Actually, the only thing we can learn is how much we don't know: once we take a look at how much information we can get, we can't help but considering how much of it we need to ignore. Our capacity to generate knowledge relies on our ability deal with things we are not familiar with, to link information in patterns, find relations and give it meaning into a context. This interference is a desired attribute, at least as much as schizophrenia. Whilst content is obvious, changes are subtle. Information without connective thinking is like a labyrinth with no walls, you can stand in the middle of a vast open space and still not be able to find your way out.

## 4. POLITICS

### 4.1 Spect-actors

Media defined and spread the common sense to come in a clearly unidirectional mode, outlining agendas and frames, the which and the how of stories to be told. Namely, in the Pre-specific City it is not this fundamental role that has changed, but rather the ways in which we relate to it. Trader politicians and political corporations embraced in grotesque family portraits carefully framed by media. A remarkable drama distributed profusely through a single centralized stage to isolated quiet spectators. In the Pre-specific City, an inversion takes place from one central point towards a constellation of information foyers. You cannot say 'it', but you have to get people saying 'it' for you, because we trust more and more friends and networks rather than experts. Social media has reached in no time deeper levels of infiltration into social practices than any other prior physical channels. Evolution in social media mechanisms allowed us to do a proper shift from supply to interaction, from being spectators to become spect-actors. Publishers, producers, distributors or any kind of intermediaries are no longer main actors in the process of dissemination of intellect in the Pre-specific City. Intermediaries are now obsolete because social media provide nodes of power with increased capacity for direct control and mobilization of resources, skills and markets, wherever they happen to be. Collaborative culture is a market outside the market.

### 4.2 Sense of Critique

Millions of mobile phones in the streets at this very moment take pictures, make videos, blog, and post on social networks every single event surrounding them. Nevertheless, the same tools we praise as emancipators have the embedded potential of efficient and massive monopolization weapons, and even more, the potentiality of power and knowledge to control doesn't no longer concern merely the state but also market and even our peers (the multitude!). Hence, what is the use of an independent press, blogs or social networks when there is more data than our memory can store, and more images than our eyes can take in? Just another source of information to choose from, think over, or become indignant about? Yet, the distance we can keep from it is like a lifesaver when drifting away in the ocean, it keeps one's head out and breathing. Indignation, appraisal, elucidation (a new level of critical consciousness!) are the very conditions of a smart abundance. The only thing more painful than a lost sense of critique is the quiet brain's mediocre feeling of contempt.

### 4.3 Critical Mass

Domestic dramas, international crisis, existential speculations, and increasingly diverse points of view, simultaneously populate our social sphere. We have learnt new forms of solidarity, not in order to enforce dogmatic views but to make a bold use of our differences. Either you build models out of matches or have an extremely high sense of justice, your experience will be potentially compelling to someone, or even reach a group of people large enough as to become a critical mass and promote change. Taking over power or replacing one political party for another is just another form of perpetuation. Politics in the Pre-specific City do not revolve around parties or ideologies but are rather based on non-ideological community interests or even on smaller scales. New aspects of direct democracy, such as evaluation of public policies transparency, elaboration of urban questions by citizens and self-organization of local communities, have replaced traditional political structures inherited from the French Revolution, based on delegation and representation.

#### 4.4 Peer-to-peer

The generic emerged as the *phantasmagoria* [6] of a centralized production system: the purely physical translation of its purposely hidden production processes. The measure of its success has only been defined in superlative terms. Higher, bigger, greater, mightier. The scale of the Pre-specific City is universal and tends towards the tremendously small because it manifests within peer-to-peer relations. Non-hierarchical and contingent, their rules are not derived from an external authority but are generated within. “*Last night 40,000 people rented accommodation from a service that offers 250,000 rooms in 30,000 cities in 192 countries. They chose their rooms and paid for everything online. But their beds were provided by private individuals, rather than a hotel chain*” [7]. The pre-specific City is the city released from *laissez-faire* capitalism or centralized economy; it is not defined by a centralized managerial command but by out-numbered social relations.

### 5. CITYNESS

#### 5.1 Hybrid

The Pre-specific City is *the city of the too many centres*. The multiplicity of our identities and their eased diffusion has led us into a state of desired schizophrenia that depicts itself effectively into geographical space. Our practices are no longer exclusively shaped by physical context, but by the different mediations information can go through. Public space is more than a *communal world full of differences* [8]: it not only embraces diversity but decouples through a range of dimensionalities spanning between actual and virtual. This *n-dimensional* space is appropriately describable through oxymoron: manifestly virtual, fundamentally actual, specifically global, comprehensively local, peripatetically static, inertly mobile. Admittedly, social media have provided us with a relational space, open to the active self-mapping of the real and vivid scenario of the spatial practice of contemporary urban life. The Pre-specific City has increasingly extended towards new public and virtual grounds, not through a derealisation of the world but rather through an extension of human abilities. These new territories cannot be described geometrically nor calculated physically because their limits are elastic, flexible, negotiable, constituted by the conduct of its occupants or, rather, by certain minimum elements of their behaviour. In this new urban plane, distinctions between subject and object are blurred in a reciprocal way: every writer is a reader, and every reading is a potential writing.

#### 5.2 Landscape

The Pre-specific City mimics a landscape, any attempt to define it through urbanism is reductive. Urbanisation depicted a transmutation of the city from an agrarian to an industrial setup, unfolding its translation into commodities, production into space and growth into settlements, a *city of stones* where territories have been exclusively defined by the proximity granted by the power of infrastructures. This celebration of urban physicality provides a reductive account of what the Pre-specific City is about. Notably, the Pre-specific City does not have an explicit form, because it embodies something more than what it apparently represents: its level is operational, not representative. Skyscrapers, houses, bus stops, streets, highways, bricks do not look radically different from what they used to be, though they are unquestionably transformed entities. Through *Cityness*, we have been empowered to look above the infrastructural level of things (*Urbs*) and enabled to describe the city as a set of collective narrations, the imaginary of the *city of people (Civitas)*<sup>1</sup>. Information technology decouples from familiar categories or pre-defined conceptions of what urbanity, public space, and private space were meant to be<sup>2</sup>. Westernised formalisations of public space such as the plaza, the square, the park or the street, have been enlarged towards physically decoupled and pervasive cohabitations. There is here a radical inversion: Whereas public space, has been largely seen as a static setup populated by mobile subjects, later on updated as a productive commodity, social media engenders hybrid spatialities where the scenario is never officially defined, and the pre-specific citizen becomes the permanent element navigating through these pervasive centres.

<sup>1</sup> Pier Vittorio Aureli and Martino Tattara define in their essay “The City as Political Form”: *Civitas is the political institution that signifies the collective will of a community to inhabit and coexist in one place. Urbs is the infrastructure that ultimately materially supports this choice* [9].

<sup>2</sup> Robert Venturi describes already in 1966, in *Complexity and Contradiction in Architecture*, the relation American have to public and private space: *The piazza, in fact, is ‘un-American’. Americans feel uncomfortable sitting in a square: they should be working at the office or home with the family looking at television* [10].

### 5.3 Poiesis

The Pre-specific City aspires to the East and to the South, or any other latitude that challenges institutionalisation of use. While centralized urban planning imitates the sense of contingency existent in the multitude, in just a few seconds railways become open-air markets in Lagos and whole domestic realms extends into the streets of Jakarta. The distinction between public access and public space is here blatant: the first one is purely bureaucratic whereas the second, built in the making, entangles poetic and poetic processes. Hence, the Pre-specific City, like a doping platform, exacerbates this engendering condition on a levels decoupled from spatiality and physical proximity.

### 5.4 Population(s)

The Pre-specific City is universal although not totalisable: it cannot grow since all the indexes were already there. Its urban environment enlarges in the same degree that relation and articulations are empowered. In order to gather 50 million of spectators it took to radio 38 years, 14 years to TV, 4 years to Internet while Facebook gathered 200 million members in only 12 months. While you read these lines, the social media community is already the largest country in the world. The nexus of place, blood and identity is no longer relevant: we have found a concept of universality that integrates all the individualities. Are you ready? The Pre-specific City is now, and now, and now.

### REFERENCES

- [1] Rilke, Rainer Maria. *The Notebooks of Malte Laurids Brigge*. Translated by M. Hulse. Penguin Classics, 2009.
- [2] Wittgenstein, Ludwig. *Tractatus Logico-Philosophicus*. CreateSpace Independent Publishing Platform, 2013.
- [3] Borges, Jorge Luis. *Collected Fictions*. Translated by Andrew Hurley. Penguin Books, 1999.
- [4] "Unpublished". Hovestadt, Ludger. *What is the Chair of Computer Aided Architectural Design (CAAD) contributing to FCL Singapore?* 2013.
- [5] Edmund Snow Carpenter and Marshall McLuhan, *Explorations in Communication: An anthology* (Boston, MA: Beacon Press, 1960), 2.
- [6] Benjamin, Walter. *Arcades Project*. Harvard University Press, 1999.
- [7] "The Rise of the Sharing Economy." *The Economist*. Mar 9<sup>th</sup>, 2013.
- [8] <http://www.economist.com/news/leaders/21573104-internet-everything-hire-rise-sharing-economy>.
- [9] Arendt, Hannah. *The Human Condition*. 2nd Revised edition. University of Chicago Press, 1999.
- [10] Cauter, Lieven de, Michiel Dehaene, and Saskia Sassen. *Power: Producing the Contemporary City*. Edited by Berlage Institute. NAI Publishers, 2007.
- [11] Venturi, Robert. *Complexity and Contradiction in Architecture*. 2nd ed. The Museum of Modern Art, New York, 1977.

## Unconventional and Original *Anecdote*: Textual Space Construction in The Dictionary of Obscure Sorrows, a Tumblr Blog

Ratna Erika M. Suwarno

Faculty of Humanities, University of Indonesia, Depok 16424  
 E-mails: erika.suwarno@gmail.com, ratna.erika@ui.ac.id

### ABSTRACT

Within a social media platform tumblr, The Dictionary of Obscure Sorrows (DoOS) stands as a unique blog variety of personal space, offering unconventional textual treats in form of dictionary entries. Textual features and signs within navigable space and within electronic space thus are viewed as textual strategies and construction and exploration of one niche representation of modern identity. Textual construction of electronic text then relates to construction of navigable space within the medium, as it provides more scope compared to printed text. Materiality is re-conceptualized as the interplay between a text's physical characteristics and its signifying strategies, a move that entwines instantiation and signification at the outset. This definition opens the possibility of considering texts as embodied entities while still maintaining a central focus on interpretation. Thus within the culture of global internet, DoOS then offers more than just wild sorrows of textual treats; it creates and presents a valid and accessible free textual space, challenging the conventional ways of producing text and meaning.

### Keywords

*Textual space, social media, production of meaning, dictionary, electronic text.*

### 1. INTRODUCTION

As a medium for social blogging Tumblr was first introduced in 2007 and has experienced a significant growth in popularity among Internet users. Taking the specialty of micro blogging, Tumblr[1] service offers minimalist looks with maximum posting abilities ranging from text, pictures, links, short videos, or other media. These services then become norm in Tumblr, giving the outlook of disseminated pieces of digital content throughout the platform; be it in forms of short quotes, personal picture, screen captures of popular video or even any customized content. Yet, among its the busy hive, Dictionary of Obscure Sorrows (DoOS)[2] stands as a unique variety of forms offering a different treat. Dictionary format adapted by DoOS also plays significant role in this discussion as format to build not only textual form but also imagery and meaning. The format then should be considered as an attempt to provide, in opposite, what is not featured in a conventional dictionary. With self-declared mission "to harpoon, bag and tag wild sorrows", through DoOS John Koenig offers unconventional textual treats in form and layout of dictionary entries. With a background as freelance graphic designer, he has been composing entries in his Tumblr blog for over two years with each of the entries completely made up, both the original words and the lengthy and poignant definitions.

Using Figure 1 below as an example, I aim to show all the features for the specific entries of DoOS that will be discussed in this paper. While the linguistic specifics of entry content will be discussed further in other part of this paper, I would like to draw the attention to the visual information first. Reading the entries in its entirety, starting from the first page of the blog, has given the same impression of reading dictionary entries, albeit not alphabetical.

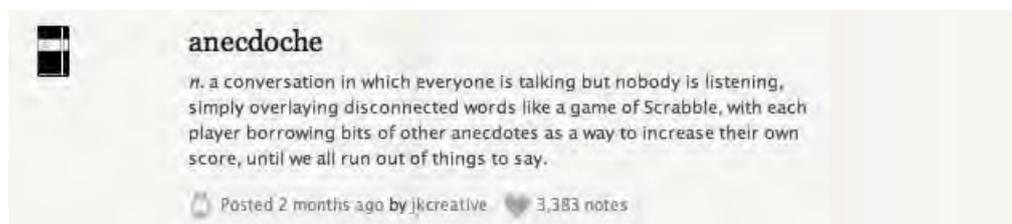


Figure 1: *anecdote* [3]

Lined up in neat rows and entry slots, each word is put forward at the top of the slot in bigger font size, followed by definition of related parts of speech in italics, and the elaborate and relevant meanings last in smaller font size.

Just as any blog entry, located below it, there are also information of metadata providing information of time, date and author of the entry posted. As shown by the wristwatch icon, the entry was posted two months before the time of retrieval and authored by jkcreative, as abbreviation of John Koenig and as one of Tumblr features, a heart mark functioning as link for #notes is displayed at the end of each entry. If you hover your cursor upon it, you can click the link and are led to a list of Tumblr users that has both 'like'-d or 'reblog'-ed the entry to be posted on their own blog. These sets of visual information enable us to obtain information on 1) basic time and date of posting to limit the range of this discussion; I only consider a selection of entries within the last two years for this discussion and, most importantly, 2) since I believe re-blogging feature promote authorship by retaining the author's metadata, we can see how many #notes, and by extension, how popular each of the entries is.

I will fully dissect five of the most popular entries, categorized by the number of #notes received by respective entries retrieved at the same span of time. This decision was made as an attempt to effectively show the flexibility of spatiality, a quality of electronic texts of the original DoOS text for discussion—instead of temporal category of most recent entries if we follow the order of posting time or another temporal category based on timeline archives. Then I will briefly analyze the meaning and how the word origin is linguistically constructed before proceeding to a detailed exposition of how then meaning is encoded and decoded by the author for the readers [4] to show process of shaping meaning as “a much more public and collaborative act.”[5] Readers that went through the act of consuming and constructing meaning consciously are then relating themselves toward the meaning provided and being aware and conscious of their own constructive participations they will have been actively participating in the process of reproduction of meaning. The notion of reproduction then is linked with Gumbrecht's idea of production of presence (2003), the idea of “specific moment of intensity, the specific appeal that such moments hold for us and what...it [is] that fascinates us in the objects of aesthetic experience” [6].

## 2. INTENSE PRODUCTION OF MEANING

Thus how the experience of reading DoOS, of consuming meanings and words, of connecting (obscure) sorrows relates to production of meaning and textual space? After the attempt to show how verbal content and dictionary format in form of electronic text are employed to construct the form of the blog, how it then form a base of materiality within the realm of electronic text and how readers formulate response toward the textual treats, the new meanings—all the visual and textual signifiers—are taken as free re-assembled meanings within familiar code of given quotidian referential. Code familiarity, as dominating result of encoding/decoding process, is perceived as a sign of both production *and* consumption of words, of “language” that “gives a value to things (in this case, words), acquir[ing] a social existence when they are named, denoted and systematized”[7]; a *conversation*.

### 2.1 Inexplicable *Mauerbauertraurigkeit*

English language based readers would find it difficult to directly relate themselves with the word *mauerbauertraurigkeit*; which is partially the reason of I wanted to start with this entry (and another, and more compelling this being the fifth entry with the most #notes). With the unfamiliar word as code, how then process of encoding/decoding works? This entry in particular provides what I believe a display of dominant process of decoding—a process when the readers took more effort on breaking the code of communication yet grasping the meaning at the end. Definition comes purely from the entry, setting the platform of referential on an “inexplicable urge”.



Figure 2: *Mauerbauertraurigkeit* [8]

Without reference to any other image, the *mauerbauertraurigkeit* is attempting to define itself with another set of quotidian referential, directly taking stance of communicating with “you”. The explanatory clauses added explication to what starts as unfamiliar by delivering some codes of familiarity, defining the word in moments “as if all **your** social tastebuds suddenly went numb, leaving **you** unable to distinguish cheap politeness from the taste of genuine affection. (bold represents my emphasis).” All the referential then are referred to “you”, enabling “us” (as plural form of “you” as addressed in the entry and

“us” readers in general) to define the abstract “urge” as indeed “inexplicable”, unable to be explained, just as the urge *mauerbauertraurigkeit* tried to embody.

In this paper #notes are taken as a general representation of how many times this entry received nods from the reader. Over the choices readers have for every entry, they could merely read the entry without contributing anything, giving their simple acknowledgement and ‘like’ the entry or ‘reblog’ the entry entirely with or without additional comments, as seen in example of screen capture below:



Figure 3: Mauerbauertraurigkeit [9]

Figure 3 shows variety of notes accumulated by the entry of *mauerbauertraurigkeit*. A tumblr user, for example *pretentiouslimericks*, and *Iwayout*, can ‘like’ the entry without adding anything else. Other options would be to ‘reblog’ the entry with comment, tumblr user *nakedpineapple* shown in figure above, as an expression toward the entry, or simply without, tumblr user *usernamesbugme* shown in figure above. Tumblr user *usernamesbugme* also perform an act of ‘reblog’ not directly from DoOs, but from another user who has previously ‘reblog’-ed the entry.

These number of #notes accumulates all the ‘like’ and ‘reblog’ action each entry gain and, in my opinion, express sense of decoding the reader has performed upon the entry. Readers then grasped the meaning at the end of the code mapping; putting the quantity of readers in numbers, there are 15,156 #notes and counting for this entry. With *mauerbauertraurigkeit*, the moment of intensity, the inexplicable urge the entry pointed out, is then somehow recognized through the quotidian referential that was presented. At the end, the original word *mauerbauertraurigkeit* holds what I see as explicable number of #notes, showing participation and by extension also the level of decoding. Readers then has collaboratively participated in mapping the urge by acknowledging the “inexplicable” as related, eliminating the sense of conditional in “as if—”, and, by extension, explicating an urge, “the inexplicable urge”.

## 2.2 Spatial Kenopsia

*Kenopsia* also starts with an unfamiliar code even if it has vague relations toward a blur image we have on the back of our mind and in particular provides another dominant process of decoding. The platform of definition as “the atmosphere of a place” is thoroughly modified and described by the adjectives “eerie” and “forlorn”. Unlike the previous word, *mauerbauertraurigkeit*, and the rest of the entry I am going to discuss, definition of *kenopsia* operates in slightly different manner. Not only that it provides quotidian referential, its main subordinate clause is describing spatial quotidian referential, of specific places, of “a school hallway in the evening”, of “an unlit office on a weekend”, of “vacant fairgrounds”.

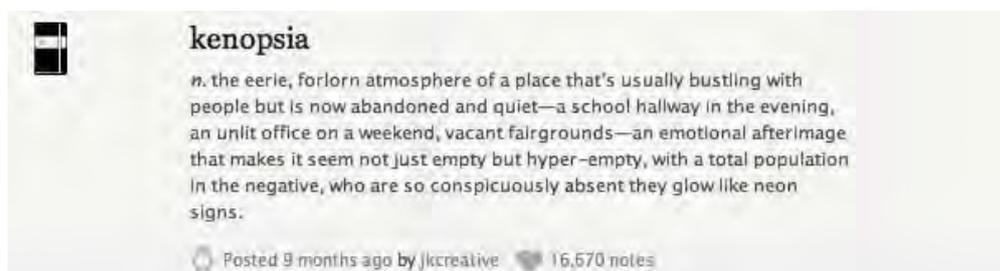


Figure 4: kenopsia [10]

Readers can easily relate to “school” as the symbol of our first stage of our life, “office” as the symbol of our adult life, and “fairground” as the vague symbol of in-between stages—as you generally went to a fairground either when you were a child or when you are already an adult as parents. I consider this attempt of providing spatial concrete referential, instead of emotion/feeling’s abstract ones.

Most of readers also decoded *kenopsia*’s definition through juxtaposing it with references of places they are familiar with.

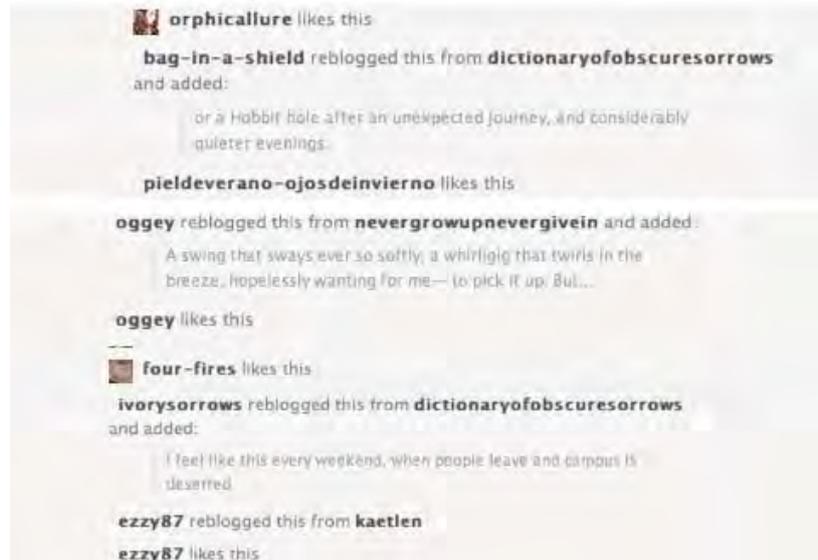


Figure 5: kenopsia [11]

I consider such decoding act as the easiest act among all other acts for definitions on the blog. Naming and identifying specific physical places provide specific connecting tools and at the end simplifying the act of decoding. Readers are guided kindly into embracing the definition by bringing more established and relatable, in terms of intensity, spatial relations. In result the code of *kenopsia* is the most specifically decoded because instead of explicating the “*atmosphere* of a place”, the code operates along with “a place”, a range of places, a range of *specific* physical places.

### 2.3 *Xeno* Connection

Opposite to the previous two, the word *xeno* does strike a sense of familiarity and we immediately connect both the similarity of spelling and pronunciation to a combining form of *xeno-*. Originated from Greek word *xenos*, the (partial) word was usually combined with other words to give referential meaning of “relating to a foreigner or foreigners”.



Figure 6: xeno [12]

Few readers have voiced their arguments noting that *xeno* has already attached to a certain definition, as mentioned above being a combination form. Yet, DoOS then took the definition into more than combination form but word with attachment. Starting in the platform of solitary moment, of where you only pass strangers, *xeno*, as an independent word in this entry, tries to explain the meaning of a single noun that is parallel with, for a start, "the smallest measurable unit of human connection".

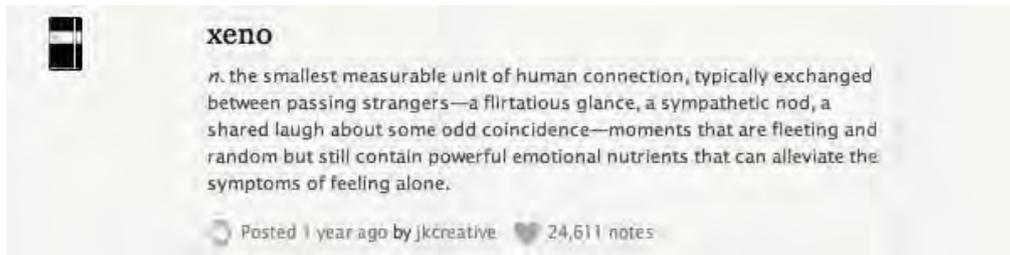


Figure 7: xeno [13]

By not giving any other possible interpretation, the definition was locked on the specific "unit" of meaning that is "the smallest measurable". The definition then was sharpened and detailed in two subordinate clauses "typically exchanged between passing strangers" and the "moments" signifying that there were two detailed definitions given to further explaining "the smallest measurable unit of human connection". Dealing with the "symptoms of feeling alone", *xeno* then mapped several exchanges of people that are "fleeting and random". Connection played as an important signified part of the definition. By explaining the detailed definition of "connection", this entry itself also "alleviate the symptom of being alone".

Reminders that those exchanges with "passing strangers" in forms of glance, nod or laugh (all which are mere and simple contacts with other "human" even if s/he is only "passing stranger") serve as what Stuart Hall [14] referred as stage of "recogniz[ing] that the discursive form of the message has a privileged position in the communicative exchange". I then consider this stage of recognition as important since it then summed the moments of "encoding" and smoothly bridged the discussion to the "relatively autonomous decoding" process within the communicative process as a whole; emphasizing the moments—be it both *xeno*'s "fleeting and random" moment and *determinate* moments of communication process, as a production of meaning.

#### 2.4 Specific *Kairosclerosis*

Meanwhile, dealing with none other than "the moment" itself, *kairosclerosis*' definition process began with employing several of methods that I have discussed above; 1) directly taking stance of communicating with "you" and attaching "the moment" into "you"'s experience by focusing on the moment of realization that belongs to "you" instead of anybody's; and 2) like *xeno*, striking a sense of familiarity with the word *kairos*, again from Greek origin, to give referential literal meaning of "opportunity" and the word *cleriosis* with association of "abnormality" and "excessive".

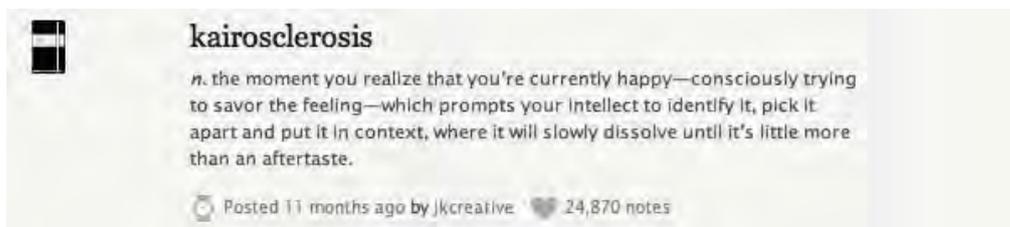


Figure 8: kairosclerosis [15]

But even if it starts within the platform of solitary moment, *kairosclerosis* mapped its definition in further details of mere realization of being "currently happy". There are acts of identification of, "put[ting] in context", and "pick[ing] apart" of feeling. There is also sense of uncontainable from last clause, when feeling "will [eventually] dissolve," turning into *uncontainable* liquid. All these signified that *kairosclerosis* tried to map moments of intensity involved in relating oneself with the specific feelings. This act then is not only taken as "relatively autonomous decoding" process within the communicative process as a whole but also a calculated act of encoding, bringing a specific "appeal that such moments hold for us" [16], for the readers.

#### 2.5 Epic Story of *Sonder*

*Sonder* is the most popular, and one of the entry with the most of number of words within the whole realm of DoOS; open praises, questions of origin and many other compliments have been addressed regarding this particular word through 30,852 #notes and counting for this entry and other avenues. These number of #notes accumulates all the 'like' and 'reblog' action each entry gain and, in my opinion, express sense of decoding the reader has performed upon the entry. I believe dominant

process of encoding is played impressively on this particular code, since *mauerbauertraurigkeit*, *sonder* stands at first as an unfamiliar code. In this particular entry, the author has displayed a great effort in encoding as many details and quotidian referential as possible, so that readers could relate themselves almost seamlessly to the meaning.

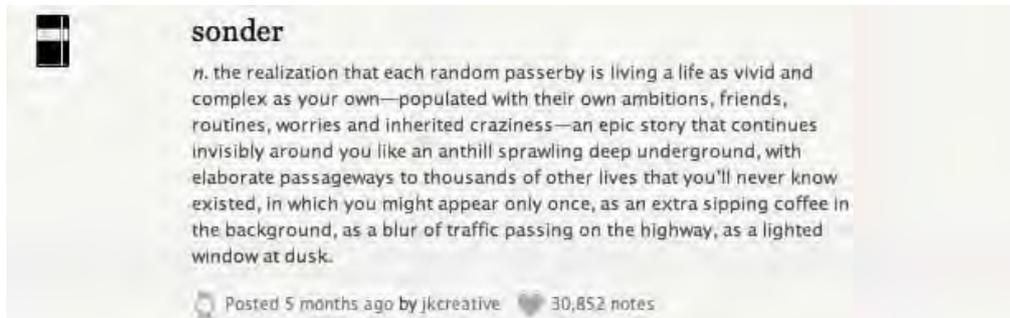


Figure 8: sonder [17]

Not only directing the stance to a possessive adjective for “you”, *sonder* went as detailed as attaching the referential “[own] life” to the definition. It also did not provide any other possible referential relation between “you” and again stranger, like *xeno*, in form of not only one, or two, but “each random passerby.” That being so, considering that both the subordinate clause for attribute for “living” as parallel, *sonder* dealt with the definition of “the realization that each random passerby is living a life” and “is [living] an epic story”. To avoid confusion, I will discuss the first subordinate clause (*sonder* as the realization that each random passerby is living a life) first then the second (*sonder* as the realization that each random passerby is living an epic story) before at the end merging the discussion to map the overall production of meaning.

The first subordinate clause dealt mostly with definition of “life” for both “you” and “each random passerby” being “vivid and complex”. Additional acts of defining “life” are conducted by attaching firm explanations of populating objects for a life to be vivid and complex; i.e. “ambitions, friends, routines, worries and inherited craziness”. The acts signified that first clause of *sonder* tried to map moments of intensity involved in relating oneself with the specific objects and by bringing specific “appeal[s] that such moments [of possessing objects] hold for us” [18], another calculated act of encoding has been accomplished.

To complement the encoding act of the first clause, the second clause was even more encoded in the most explicating manner, employing not only operating codes along with specific places but also specific quotidian referential. Starting with a sense of continuation parallel of “life” operating invisibly, two points of quotidian referential are offered for “anthill” as an object related to life that “[is] sprawling deep underground” and “[has] elaborate passageways”. The quotidian referential then carried the sense of a range of *specific* physical places, a spatial concrete referential.

To further complement the act, extra quotidian referential points were added to “other lives that you’ll never know existed”; at one point further locking the definition on specific “life” while at the other giving the another notch of intensity to the solitary sense of “life”. “You” then is defined as “might appear only one”, “as as an extra”, “as a blur of traffic” or as “a lighted window”, while at the same time just “sipping coffee” and “passing” within, again, a spatial concrete referential of “in the background” and “on the highway”.

With *mauerbauertraurigkeit*, the moment of intensity, the inexplicable urge the entry pointed out, is then somehow recognized through the quotidian referential that was presented. At the end, the original word *mauerbauertraurigkeit* holds what I see as explicable number of #notes, showing participation and by extension also the level of decoding. Readers then has collaboratively participated in mapping the urge by acknowledging the “inexplicable” as related, eliminating the sense of conditional in “as if—”, and, by extension, explicating an urge, “the inexplicable urge”.

*Sonder* had not only attempt to provide abundant spatial concrete referential but also played with detailed emotion/feeling’s abstract ones, forming itself as an epitome of textual treats as it works on almost all identified encoding acts, resulting in “enforce[ing], win[nin]g the most plausibility for and command[ing]...decoding within the limit of dominant definitions in which it has been...signified” [19]; an *epic* textual treat.

### 3. CONCLUSION

As Hayles argues, materiality is re-conceptualized as the interplay between a text’s physical characteristics and its signifying strategies, a move that entwines instantiation and signification at the outset. [20] This definition opens the possibility of

considering texts as embodied entities while still maintaining a central focus on interpretation. Yet debate on considering whether a textual treat from a public blog could be classified as literary text is still a heated argument nowadays. In spite of that the fact that dictionary has become a firm format of DoOS blog I find the exploitation of its medium specificity is important.

I suggest that DoOS should be understood as interplay of content, an attempt to describe the indescribable sorrows of everyday life into words through its materiality as a blog and through interactions with readers signified by the readers' #notes. Such interplay signifies, in my opinion, a distinctive dynamic quality, enabling readers to relate to conceptual content and share collaborative interpretive activities. Textual features and signs within navigable space within electronic space thus are viewed as textual strategies and construction and exploration of one niche representation of modern identity.

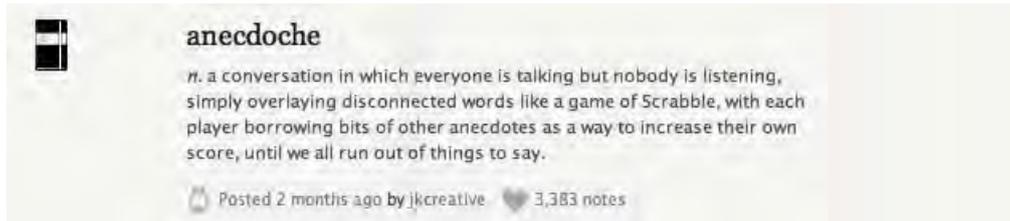


Figure 9: *anecdote* [21]

Thus within the culture of global internet, DoOS then offered more than just wild sorrows of textual treats; it creates and presents a valid and accessible free textual space, challenging the conventional ways of producing text and meaning. Readers were presented with textual treats within their convenient spaces, allowing themselves to connect with specific moments of their choosing, specific appeal to the words and definitions provided. As result, DoOS becomes a navigable space that did not only feature a static temporal text (in form of dictionary) but also dynamic conversations with its readers. Putting aside originality notion, the unconventional space holds important conversation in which everyone (the author and the readers) was "talking, overlaying disconnected words." However even if either the author or the readers are "running out things to say", DoOS will stay as a space where once words, signs, and collaborative interpreting acts hold a conversation; a valid and accessible free textual space produced to defer the temporal meaning of disconnected conversations of a shared collective obscure sorrow.

## ACKNOWLEDGMENT

This paper could not have taken shape without the initial support of Vauriz Bestika, as she has encouraged me to compose the original ideas for this paper, all the way throughout the completion of this draft, and Manneke Budiman who had generously offered his time and support, which I, unfortunately, could not meet due to personal circumstances. I also extend a special thank you to Teti Sumarni for her lightning grammatical proofread. The remaining mistake is mine. Last but not least I would want express my deepest gratitude for John Koenig, the dictionary artist, for his permission to use his blog as research object and to reproduce all the necessary materials; to be able to write this paper on your beautiful literary work has been an honor for me.

## REFERENCES

- [1] In this paper, the term "Tumblr" is duly used generally as adjectives and specifically as nouns only when I refer to the services and company, in accordance with Tumblr trademark policy (see: <http://www.tumblr.com/policy/en/trademark>).
- [2] See <http://www.dictionaryofobscuresorrows.com/>.
- [3] Screen capture of *anecdote* entry [Image]. Retrieved April 21, 2013 from <http://www.dictionaryofobscuresorrows.com/post/42961208848/anecdote/>.
- [4] *Readers* are used in this paper as a general term to include many kinds of parties performing the act of reading, among other the Tumblr users who only accessed the DoOS and read the entry, other Tumblr users who read the entry on other users' page and liked the entry, other Tumblr users who read and liked and re-blogged the entry, or any other way of reading the entries through other social media vehicles, which unfortunately is not discussed in this paper.
- [5] A. Van Der Weel, "New Mediums: New Perspectives in Knowledge Production in *Text Comparison and Digital Creativity: The Production of Presence and Meaning in Digital Text Scholarship*, W. Van Peursen, E. D. Thoutenhoofd, A. Van Der Weel, Eds. Leiden: Koninklijke Brill NV, p. 261, 2010.
- [6] H. U. Gumbrecht, *Production of Presence: What Meaning Cannot Convey*, Stanford: Stanford University Press, ch. 6, p. 97-104, 2003
- [7] H. Lefebvre, *Everyday Life in the Modern World*, (Trans. S. Rabinovitch), New Jersey: Transaction Publishers, ch. 3, p. 120, 1994.

- [8] Screen capture of *mauerbauertraurigkeit* entry [Image]. Retrieved April 21, 2013 from <http://www.dictionaryofobscuresorrows.com/post/25422386446/mauerbauertraurigkeit/>
- [9] Screen capture of *mauerbauertraurigkeit* entry [Image]. Retrieved April 21, 2013 from <http://www.dictionaryofobscuresorrows.com/post/25422386446/mauerbauertraurigkeit/>
- [10] Screen capture of *kenopsia* entry [Image]. Retrieved April 21, 2013 from <http://www.dictionaryofobscuresorrows.com/post/27720773573/kenopsia/>.
- [11] Screen capture of *kenopsia* entry [Image]. Retrieved April 21, 2013 from <http://www.dictionaryofobscuresorrows.com/post/27720773573/kenopsia/>.
- [12] Screen capture of *xeno* entry [Image]. Retrieved April 21, 2013 from <http://www.dictionaryofobscuresorrows.com/post/16571284794/xeno>.
- [13] Screen capture of *xeno* entry [Image]. Retrieved April 21, 2013 from <http://www.dictionaryofobscuresorrows.com/post/16571284794/xeno>.
- [14] S. Hall, "Encoding/decoding" in *Culture, Media, Language. Working Papers in Cultural Studies, 1972-79*, S. Hall, D. Hobson, A. Lowe, and P. Willis, Eds. London: Routledge in association with the Centre for Contemporary Cultural Studies University of Birmingham, pp. 118, 2005.
- [15] Screen capture of *kairosclerosis* entry [Image]. Retrieved April 21, 2013 from <http://www.dictionaryofobscuresorrows.com/post/22019547629/kairosclerosis/>.
- [16] H. U. Gumbrecht, *Production of Presence: What Meaning Cannot Convey*, Stanford: Stanford University Press, ch. 6, p. 99, 2003
- [17] Screen capture of *sonder* entry [Image]. Retrieved April 21, 2013 from <http://www.dictionaryofobscuresorrows.com/post/23536922667/sonder/>.
- [18] See note. 12.
- [19] See note. 10.
- [20] N. K. Hayles, "Print Is Flat, Code Is Deep: The Importance of Media-Specific Analysis" in *Poetics Today* 25.1, pp. 72, 2004.
- [21] See note. 2.

# The Changing of Play Culture and Electronic Game: It's Meaning on Children Emotional Ties and the Loss of Children's Sense of Place in Outdoor Space

SusinetyPrakoso

Postgraduate student, Department of Architecture, Faculty of Engineering, University of Indonesia, Depok 16424  
 E-mail : susinety@gmail.com

## ABSTRACT

This paper investigate the changing of play culture affected by the present of electronic game, have impacts on children's emotions as well as their sense of outdoor place. The study focuses on the voices of small group school-age children and their parents who live in a gated residential community in an urban setting located in Jakarta. The findings reveal that the additional member of family (since the birth of their brother/sister); parental fears and concerns on children independent ability to play outdoors, and electronic game as parent's solution; have caused electronic game shifted the play culture before. This study also reveals that children place two different meanings toward electronic game. First, electronic games are represented as a joyful experience with high sense of positive emotional feeling attached to them. Second, as an unpleasant experience when parental controls toward electronic game take effect. In sum, children connote electronic games as an attachment figure that repetitively lures children inward. Consequently, their environmental range remains within familial space or microsystem. The outdoor space is represented as a fearful and frightening place. Their sense of place is low. There is hardly any outdoor place in them.

## Keywords

*Changing of play culture, children, electronic game, emotion and sense of place*

## 1. INTRODUCTION

Today, children's use of technology has been a common public phenomenon. Research by Jessen [1] confirmed that children's play culture had changed for the last 20 years due to the influence of electronic games and digital media. She [1] distinguished that children's play culture previously were: 1) playing with group; 2) there was good contact between young and older children; 3) young children learned a wealth of games from older children; 4) play was done outdoor; 5) many games involving motion; 6) and playmates are close, well-defined social relationships. Today, children's play culture are: 1) play with fewer groups of children; 2) more organized activities, more school and academic activities; 3) less contact between children of different ages; 4) tend to play only with the same age groups; 5) indoor oriented; 6) and playmates farther afield [1].

One of the causes of the shifting play culture is electronic games. Why? Verenikina & Herrington [2] asserted that electronic games such as computer games allow and gave opportunities for engagement with make-believe play. Product of technology and media provide an unlimited playground for children without have to rely on space and play equipments. In a virtual reality world, children has the opportunities to play and interact with other children without the restriction of space and time [1]. Olson [3] revealed that children's motivations for playing electronic games are various, e.g. for social interaction, joy of competition, opportunities to lead, making friends, young teaching each other, challenge and mastery, experimentation with different identity, expressing creativity, curiosity, discovery and learning.

Researches done mostly in Western society show both negative and positive influences of children playing electronic games. McCarrick's [4] showed positive influences of electronic games on pre-school's social, cognitive, language development and motivation, while Subrahmanyam et.al [5] showed positive influences in the increasing of ability to read, ability in visualize images in three-dimensional space, ability to tract simultaneous images and even contribute to better academic performance. The use of wireless and mobile technology can contribute to the increase of children's awareness towards their environment. On the other hand, there are also negative influences, such as Subrahmanyam et.al [5] indicated the risk of obesity due to lack of physical activities, loneliness, depression, aggressiveness, unable to distinguish real life and virtual reality, while The Henry J. Kaiser Family Foundation [6] reported on violence, addiction, interfering academic performance, and Olson [3] revealed fear of mature content as the negative influences of electronic games.

On the other side, there is a phenomenon called 'shrinking world of child' [7], where children independent access to outdoor environment are limited due to parental fears and social traps [8], children's negative perception on their environment [9], unaffordance environmental factors of children's neighborhood [7, 10] and children's dependency on TV and digital media [11]. These all cause children spatial ability in outdoor environment [12] and the loss of children's sense of place in outdoor

environment [13]. Several researches revealed that factors influenced children's use of outdoor spaces are: family, community and social factors [7, 10], physical factors [10], availability of parks [14] and its amenities [15], including infrastructure [16].

Those reviewed research emphasize on the present of children *in* the city, by investigating how and why they use outdoor places. How the inevitable present of electronic game have impacts on children's emotions as well as their sense of place are still open for investigation. Therefore, my prime interest has been to let the voice of children and parents tell what the meaning of electronic games to them and how it will impact the developing of their sense of place presented by the present of place *in* children. This investigation is essential and significant, because freedom to move and to explore the surrounding are very important for children's physical and mental development [7, 17-19]. Accordingly, a city has to provide amenities and infrastructure that are child friendly [8, 17, 20, 21].

## 2. WHAT IS ELECTRONIC GAME?

Electronic game is a play activity in a virtual setting that can stimulates environment, is implemented by the use of instrumentations like computer, laptop, tablet, mobile phone, game console, TV, etc. Richard Bartle (2004) cited in Walz [22] defined that play has three modalities. They are physical (players, spaces, and objects that are material), imaginary (which is not material), virtual (that which is not material but had the form or effect of that which is material). Walz [22] cited Bartle (2004, p.1) defined "Virtual worlds are places where the imaginary meets the real and Virtual worlds are implemented by a computer – ora network of computers – that simulates an environment" (p.28). According to Walz [22], this notion of virtuality propose a new modality which he called "hybrid: that which is not material but has the form or effect of that which is material mixed with that which is material to the extent that one can no longer be separated from the other without losing its form or intended or emerging effect" (p.28).

In order to understand the experience while playing electronic games, one has to be able to distinguish the difference between game and play. Huizinga [23] defined play as 1) a free or voluntary activity, not a serious activity but a joy and make-believe activities involved with imagination process; 2) not ordinary or real life; 3) its secluded, its limitedness. It is "played out" within certain limits of time and place (p.9) – all play moves and has its being within a playground marked off beforehand either materially or ideally deliberately or as a matter of course (p.10); 4) it creates order and tendency to be beautiful, enchanting, captivating (p.10); 5) all play has its rules (p.11); 6) as a contest for something or a representation of something (p.13). Huizinga [23] perceived play community as an emotional ties which would take player away from reality. He [23] defined formal characteristic of play as "a free activity standing quite consciously outside 'ordinary' life as being 'not serious', but at the same time absorbing the player intensely and utterly" (p.13).

According to Roger Caillois (1961) in *Man, Play and Games* cited in Masters [24], game is a social part of play. Caillois cited in Masters [24] categorized the game as *agon* (competitive play engaged individuals and groups in tests of skill and ingenuity), *alea* (games of chance or luck), *mimicry* (pretense and illusion), *ilinx* (games when individuals pursued vertigo). Huizinga [23] and Caillois cited in Masters [24] definitions of play certainly imply that "part of play's enchantment rests in the pleasure that it provides" (p.860). On the other hand, Mihaly Csikszentmihalyi (1990) in Master [24] asserted that what game players felt are positive experiences. According to Csikszentmihalyi (1990, p.49) cited in Masters [24], this positive experiences occur when the individual acts with "a deep and effortless involvement that removes from awareness of the worries and frustrations of everyday life" (p.860).

In sum, electronic games can be as joy and make-believe activities, not ordinary or real life, attractive and captivating, competitive, has aspect of luck, giving the player an experience and positive emotion which absorb the player intensely and utterly from fear, frustration and daily life problems.

## 3. RESEARCH OBJECTIVES AND METHODOLOGY

The major interest of this research is to investigate whether the outdoor place is *in* children. How the *voices* of children and parents tell what the meaning of electronic games to them and how it will impact the developing of their sense of place presented by the present of place *in* children. The methodology is partial ethnography conducted for about three months (September-November 2012). Ethnography is "the art and science of describing a group or culture" [25]. Ethnography emphasizes on everyday engagement and immersion between ethnographer and "native" for a long period of time, richly contextually, situated in a certain location, in order to grasp in rich and thick description of certain culture [26, 27]. Data was collected through participant observation, in-depth interview with both parents and children. The children and parents were interviewed individually. Participant observation was conducted in a setting accompanied by their parents. To record children's understanding of outdoor place, children were asked to participate in a drawing. Fieldworks were done at four different locations.

The study focuses on the voices of small group of school-age children and their parents who live in a gated residential estate in an urban setting located in Jakarta. There are four children participated in this research. They are Dewi (girl, 11 years old), Dimas (boy, 11 years old), Martin (boy, 9 years old) and Evan (boy, 7 years old). All names used in this paper are pseudonymous. The selected school age children had been intensively used electronic game for 5-6 years. They do not have any academic problem at school and come from middle income family. Their parents are aged between 30-40 years and well-educated. All of the children's fathers are working fathers. Dewi and Martin's mother are career women. Evan and Dimas' mother are house wives. Figure 1 shows the housing estate where the children live, has adequate amenities. There are pathways for pedestrian, open playground, open spaces for activities in various sizes. The environments is also relatively clean, safe and have various environment richness to encourage senses, e.g. smell, sight, touch and feel. Children mobilization to and from school and other activities are carried out by private cars.



Figure 1: Images of children's housing environment

## 4. RESEARCH FINDINGS

### 4.1 The Changing of Play Culture

Children's interaction with electronic games are introduced by their own parents. Electronic games, such as Nintendo DS, Play station, PSP, Ipad, PS3, and Nintendo Wii, are bought as gifts and as a sense of sympathy from parents to children. All children have been interacted with electronic games since they were 4 or 5 years old till now. Hence, they have been playing electronic games for about three to six years long. Since then, their play culture have changed. The observed children come from a small family (with 1 or 2 children) and are the eldest in the family. As in the case of Dimas, before he knew about electronic games, he would spend his time with various extracurricular activities, e.g. piano, drawing, singing and cycling. Moreover, according to his mother, Dimas has no impediment problem like today. For the case of Martin, Evan and Dewi, they used to play outdoor with peers, nannies, parents or play individually and they frequently play outdoors, e.g. cycling, soccer, or playing with their neighbor (under their nannies supervision). It means that their play culture before are more varieties, from physical outdoor activity into sedentary indoor activity together with peers, nannies and parents.

The additions of a new member in a family are obviously affecting children's play culture. Their parents have been occupied with the new born sister or brother, caused most children are not having the same attention from their parents as before. Mostly, they are let playing alone with their electronic games and watching TV while their mothers take care of the new born. While for the case of Martin, the attention and the focus of his mother is more towards his young brother who has ADHD syndrome. According to Jessen [1], media and electronic games become important for children because they stimulate the impulse to play (p.8). When parents are occupied with the arrival of new sister or brother in the family, there is also reluctance from parents to allow their children play independently outdoor without supervision. These cause media and electronic games move in and fill in the gaps in greater or lesser extent. Media and digital toys are also becoming good play tools that inspire children to interact socially and play together [1]. The electronic games become a means of social interaction between children, as experienced by Evan's mother, where the electronic games become the fun conversation topic amongst the children.

### 4.2 Electronic Game as Parents' Solutions & Control

Referring to children's daily schedule, it is revealed that parents and children are not too often involve in play activities together. This is because parents are busy with the household chores, their career and occupation. Parents' involvement in

children's activities take place only when helping children with their homework or studying for exams (if necessary) and during Sunday morning (cycling with father while mother busy with household chores). For example, in the case of Martin, he plays his own game, unaccompanied. No maternal involvement during Martin's free time. Moreover, during my observation at Dimas' house, his parents only sat and looked at their children playing and there was no involvement from the parent in engaging play with their children.

Career building, caring for younger sibling(s), caring for school age child, caring for husband and households have been impacting every mother in exhaustion. Based on these reasons, most parents use game as the solution for their child to not overburden their parents. Mrs. Dewi and Mrs. Martin also let their children play games so that they will not 'bother' them. All mothers even suggesting and letting their children play games during their spare time such as waiting time in the restaurant, in the car and before entering the cinema. Although all mothers perceive game as the parent's solution, but all mothers show a firm stand on when their children need to play; to go school; to go for extra lesson outside school; to study; to worship, and others. This was reflected in the daily schedule written by the children's mother. Of the daily schedule, it can be seen that the duration of playing game is relatively long hours (approximately 6-12 hours per week), even longer during school holiday season. Every mother has a strategy in dealing with the emotions and behavior of their children, e.g. in the form of playing time restrictions, reward and punishment's method, control over time spent playing games.

### 4.3 Emotional Ties and Electronic Game

During participant observation, there were emotional and behavioral expressions in the form of pleasure or excitement, skills in using the electronic games and the desire to always touch or play with the electronic games. Emotions and behavior observed are from the face, verbal words, and actions/behaviors. During my participant observation with Dimas, he shouted "... *there is a dragon vale!*" (an Ipad's game) when he saw my son's ipad during a visit to his home. He also seemed very enthusiastic and immediately took the ipad without the permission of my son and immediately played some games (for example 'stickman', 'plant vs zombies', etc.). Similarly, during my participant observation with Dewi, she was very excited in playing games. She laughed and her eyes lit up saying "*yes ... now I can play ipad*", after 2 weeks of being grounded without an Ipad /game. However, during my 2.5-hours observations with Martin and Evan, showed that they had spent intensive time in playing games. They stopped playing games only during the mealtime. Before and after the mealtime both Martin and Evan spent their time in playing games. Martin stopped playing game only when the battery depleted. I observed Martin when the battery was depleted, he just sat sideways, quietly, and looking very confused on what to do next. He obviously bored and did not know what to do. Their eyes and attention of all the children were deeply focused on the game. They did not hear me when I called them because they 'sunk-in' with their electronic game.

The observation revealed that the children have a fun positive experience during their time in playing game. They are very focused and deeply immerse in their electronic game. Children interpret the game as something fun, enjoyment, challenging, exciting, and competitive. Some positive affirmations are delivered from the children such as: "*karena game lebihseru... lebihasikaja. Game itu endless. Pakeotakjuga..bikindulu..challenging...mestimikir...*", explained Dimas. "*simulation..kitamainnyaenakgitu...*" continued Dimas. "*lebih seru aja*" said Martin. "*because it is fun, like super jumping Fin, talking Tom. It's challenging, like PVZ, home sheep home, angry birds...and it's competitive, like racing game...I feel fun...the game is fun...*", said Dewi. In sum, while playing, they become unaware of time, deeply immersed into the games, recognize and familiar with all the characters in the game. Clearly, they are capable of expressing in details which are to be their favorite games. The games are truly *in* them.

The phenomenon of positive emotions and experiences of children in playing reveal that the children are not only feel an emotional ties or absorbing themselves into a condition that was far from reality [23] and positive play experience as asserted by Mihaly Csikszentmihalyi [24]. However, during the participant observation and in-depth interviews with the children's mothers revealed, that there are emotional attachments that arise in children towards their games. This emotional attachment is not shown in the form of a positive experience but rather in a form of a negative experience, such as sadness, anger, jealousy, anxiety, arguments. Dimas and Martin gave sullen expression when they prohibited during game play and refused to download new games. Dimas also separated himself from the crowds of children who were playing games when he wanted to play certain games but were not approved by the other children. At the time when Dewi was suspended for two weeks without a game, Dewi looked envious and jealous with her lucky brother who could play the games. Dewi was in nervous conditions (uncertain with her direction, lying in bed for a while and then get up again), especially when her little brother (5 years old) are playing games (Ipad). She was caught a few times when sitting next to her brother and began to intervene in the game. During the observation, Dimas seen several time intensively argued with his mother. Dimas' argument was about his resentment at her mother, because her mother forbade him to play, limiting what should be played and limiting the playing time.

To understand about what the children thought and felt, then I asked them about what happened if the game was banned by the parents? "*Keselajasamamami...samapapi...ah..tapiudahbiasa*" said Dimas. "*sedih, marasih..*" answered Evan.

“pernahsihdilarang main sama mama, tapilupakarenaapa....kayaknyaseminggudeh, eh...tapi kayaknyangkunginselamaitudeh” said Martin. In addition to the negative emotions and behaviors arise, there are also behavioral desires to be close to the electronic games at any time, especially at a time when the children have already done all the school work and daily activities programmed by parents. According to Dimas’ mother, every day Dimas is always whining to her mother “Can I play Ipad?” Dimas’ whining is done every day after school and after he has done the school’s homework. Martin’s mother also experiences the same thing. According to Martin’s mother, Martin asked the same thing like “PR udahselesai, boleh main game, ya, ma.....” everyday.

The phenomenon of negative emotions when children have been kept away from the game shows some characteristics similar to the characteristics of the phenomenon of human attachment (which is studied by Bowlby [28] and Ainsworth [29] in infants). Characteristics of human attachment by Bowlby and Ainsworth in Giuliani [30], are: 1) relatively long and continuous emotional and affectional bonding; 2) unique characteristics of attachment figure; 3) desire to seek and maintain proximity as well as contact with the attachment figure as a secure base; 4) attempts to get security and comfort with attachment figure. This research revealed that the meaning of electronic games for the children is as an interesting and attractive attachment figure, which lure children to always come closer to the game. Negative emotional attachments that arise when children are separated from game, indicate an emotional tie due to the children have been permitted and allowed to interact with the game for over the years. Although the game itself does not provide real-world realities (e.g. texture, odor, etc.), but the game remains an attachment figure for the child. Since the game can become a “friend”, as a place for self-actualization (providing the ability to act could not be done in the real world) and as a comfortable place, especially during stressful time after doing homework, school & extra curriculum activities that are so pack as well as good academic performances expected by parents.

#### 4.4 The loss of Children’s Sense of Place in Outdoor Space

The changing of play culture from outdoor to indoor, from physical motoric activities to sedentary activities give influence on the crisis of children’s spatial relations in outdoor space [12]. According to Ainsworth [29], since pre-school age (4-6 years), children experience cognitive development, language development, memory, social interaction which oriented in partnership and peers, as well as motoric abilities to run and walk significantly. Then, primary school age children (6-12 years) have the ability to think logically and concretely [31]. Children are capable to thinking inductively than deductively and understand reciprocal relationship. These abilities lead the children to move away from the secure-base area (home) to explore their world widely and interact with others (including strangers and peers). School-age children are independent enough to move around and explore their environment. Their environmental range should be at mesosystem [32] or neighborhood space [33-35]. However, this research found that areas explored independently by the children are remain only at microsystem or familial space (as indicated by Erikson, Porteus, Bronfenbrenner as space explored by children below 6 years old). Children’s environmental range in this case is only inside the house and on the street just in front of their house. Social relations with peers are also showed a strong influence in the emotional ties between children and games. Peers are also becoming the only reason children willingness to explore the neighborhood and playing outside.

Everyone has emotional experience with a place; it can be a pleasant or unpleasant experience. According to Canter [36], place is strongly associated with perception and cognitive knowledge. Children emotional experience in open space show a negative emotional experience, not a positive emotional experience. During my fieldwork with the children, I tried to explore what open space meant for children. Fear to something (e.g. fear of animals, fear to older and bigger children, fear hit by a car on the street, fear of fatigue, fear of pain, fear of falling, fear of heat, fear of sweating) are all negative expression expressed by children. “panas, keringetan...” said Dimas. “Outside is hot...” said Dewi. “Tidak boleh sama mama, main di luar... karena diluar ada jalan raya”, replied Martin, “kejauhan lapangannya” replied Martin and Evan. “Karena dilapangan ada anak-anak yg gede-gede... dantakut digigit binatang... trusngakseru.. dankalaujatosakit...” explained Evan.

Place attachment development depends on positive cognitive responses received by the children, and generally positive responses occur in places that are considered important or special by children [7, 37, 38]. However, the positive response of children on the environment is not revealed in this study. Repeated experience and direct as well as the social meanings attached to the children and other people (such as parents, teachers and peers) have a tendency to influence the development place attachment [7]. The Children also do not connoted the open space as a place of social interaction, except for Evan who connoted the street in front of his house as a place for social interaction and play with his peers. To find out if outdoor place is in children, I asked the children to participate in drawing a map of their neighborhood. Of 4 children interviewed, only Martin who refused to participate. The drawings appeared on figure 2 show that their knowledge about the environments is limited. Their body movement in place either individually or collectively with peers are also very limited. Therefore, their knowledge about their outdoor places is higher formed by their abstract knowledge than emplaced knowledge [39].

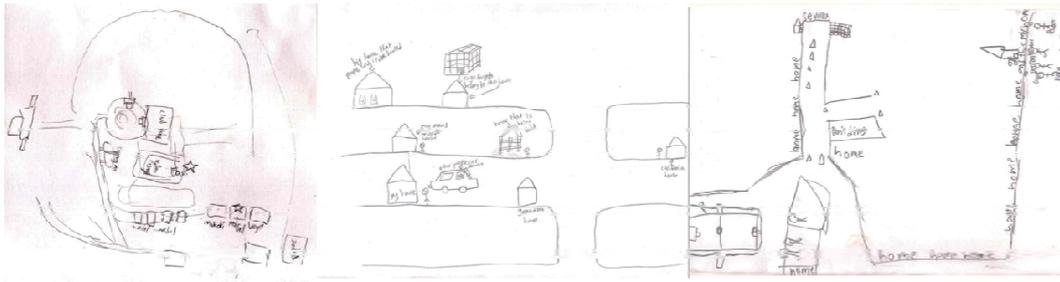


Figure 2: Children's environmental cognition by Dimas, Dewi & Evan (left to Right)

This study revealed the lack of children movement in place, resulted in the low level of children's sense of place of their neighborhood and the low knowledge of outdoor place in children. Sense of place is a specific experience that people experienced [40]. Referring to Shamai's seven levels of sense of place [41], observed children show second level of sense of place, i.e. awareness of their presence in the outdoor space, could identify several places located in the outdoor space, but they do not show any emotional feelings associated with open space. The outdoor space is represented as a fearful and frightened place. The low level of children's sense of place in outdoor space is also caused by parent's social traps that affect children's freedom to move [8] and these several unsupportive environmental factors [7, 10].

The study also shows that there are two different parental perspectives regarding to their neighborhood. Dimas and Evan's mothers explicitly stated that they always encourage and not worry about the safety of their children playing outside. While Martin and Dewi's mothers severely restricted outdoor play activities for their children. All parent's view are relevant when placed in the context of their neighborhood. Evan's and Dimas' home environment are more closed, less crowded and more secured with security guard. According to Martin's mother, her neighborhood was not safe due to direct frontage with major roads. Due to these conditions, Martin's mother was never allowed her children to play outside. Meanwhile, according to Dewi's mother, the neighborhood was quite busy with passing vehicles and parking, especially on the main road. There is a playground nearby, but not too appealing. Playground is generally used by toddlers and their nannies in the afternoon. To reach the playground they need to walk across the main road.

In sum, negative meaning towards the outdoor space by the children and parents result in lesser movement of children in outdoor space. Their environmental range remains within familial space or microsystem. The Negative meaning contributed to the low level of children's sense of place in outdoor space. Consequently, their emplaced knowledge of place in them is very low (limited). There is hardly any outdoor place in them.

## 5. CONCLUSION

This research finds that the addition of a family member (the presence of a new brother/sister), parental fear and concerns on children's independent ability to play outside, have caused electronic games move in and fill in the gap and shift the play culture before. Electronic games become a tool that inspires children to socially interact and play together. Parents perceive electronic games as parenting solution (not be bothered by their children). However, parents also make an effort to control when to play and when to study, limiting the playing time and impose a system of reward and punishment.

This study also reveals that children place two different meanings toward electronic game. First, electronic games are represented as a joyful experience with high sense of positive emotional feeling attached to them. It makes the children become very focused and deeply immersed in the game and keep them away from reality [23, 24]. Second, as an unpleasant experience such as sadness, anger, jealousy, and arguments, when parental controls toward electronic game take effect. In sum, children connote electronic games as an attachment figure that repetitively lures children inward. These negative emotional indicate an emotional ties caused by children attachment to electronic games over the years. There is also observed behavior of the children having desire to maintain closeness to electronic games at any time, especially at a time when the children were already doing all the school work and daily activities programmed by parents. The phenomenon of negative emotional experiences shows similarity to the characteristics in human attachment. Electronic games become a safe and secure attachment figure that repetitively lures children inward. These emotional feelings towards electronic games are not revealed in outdoor places. Shouldn't outdoor places also become a safe and secure attachment figure for children that will also repetitively lures children toward them?

Consequently, the electronic game also affects the low level of children's sense of place in outdoor space, i.e. awareness of their presence outdoor environment, can identify a few places, but they do not show significant positive emotion associated

with the outdoor space. The outdoor space is represented as a fearful and frightening place. Their environmental range remains within familial space or microsystem. Peers are also the only reason children willingnessto explore their neighborhood and playing outside. The low level of children's sense of place is also caused by parental social traps and different parent's views of security and comfort of an outdoor space environmentthat affect children's independent to move and explore their neighborhood [8]. At the end, there is hardly any outdoor place in them.

The findings of this study suggest that the design of children's environment especially home's environment, should take serious considerations on how the outdoor place can be a safe and secure attachment figure for them and their parents. Although their neighborhood is considered as a well-designed gated community, nevertheless their outdoor environment is still not served as an attachment figure for the children. The inevitably impacts of electronic games clearly confine the children into just familial space. They have almost never moved beyond their secure familial space. Policy makers and developers should consider outdoor place for children is not only playground. But how outdoor space should be designed as attractive and fun place as electronic games, so it will lure the children repetitively to move, to explore and to play for the benefit of their physical and mental development.

## ACKNOWLEDGMENT

This research was conducted as part of ethnography research coursesupervised by Ms. SurayaAffif, Ph.D. I would like to express my appreciation to all children and parents who give consent for me to do this research; and to my advisor Ms. ParamitaAtmodiWirjo, Ph.D. for her encouragement for me to revise this paper for the conference.

## REFERENCES

- [1] C. N. Jessen, C. B. , "The changing face of children's play culture: Children's play, learning and communication in a technology driven world," Lego Learning Institute 2003.
- [2] I. Verenikina and J. Herrington, "The affordances of computer play in young children: A preliminary study," in *Emerging Technologies Conference*, Australia, 2008.
- [3] C. K. Olson, "Children's motivations for video game play in the context of normal development," *Review of General Psychology*, vol. 14, pp. 180-187, 2010.
- [4] K. X. McCarrick, "Buried Treasure: The impact of computer use on young children's social, cognitive, language development and motivation," *AACE Journal*, vol. 15, pp. 73-95, 2007.
- [5] K. Subrahmanyam, R. E. Kraut, P. M. Greenfield, and E. F. Gross, "The impact of home computer use on children's activities and development," *The Future of Children*, vol. 10, pp. 123-144, 2000.
- [6] T. H. J. K. F. Foundation, "Key facts: Children and video games," The Henry J. Kaiser Family Foundation, Washington, DC2002.
- [7] G. Jack, "Place matters: The significance of place attachments for children's well-being," *British Journal of Social Work*, vol. 40, pp. 755-771, 2008.
- [8] P. Tranter, "Overcoming social traps: A key to creating Child Friendly Cities," in *Creating Child Friendly Cities: Reinstating Kids in the City*, B. S. Gileeson, N., Ed., ed New York: Routledge, 2006, pp. 121-135.
- [9] L. Chawla and K. Malone, Eds., *Neighborhood quality in children eye* (Children in the City: Home, Neighborhood and Community. Routledge, 2003, p.^pp. Pages.
- [10] N. F. Aziz and I. Said, "The trends and influential factors of children's use of outdoor environments: A review," *Procedia - Social and Behavioral Sciences*, vol. 38, pp. 204-212, 2012.
- [11] R. Clements, "An investigation of the status of outdoor play," *Contemporary Issues in Early Childhood*, vol. 5, pp. 68-80, 2004.
- [12] M. Williams, O. Jones, C. Fleuriot, and L. Wood, "Children and Emerging Wireless Technologies: Investigating the Potential for Spatial Practice," in *SIGCHI Conference on human factors in computing systems*, Oregon, 2005, pp. 819-828.
- [13] V. Derr, "Children's sense of place in Northern New Mexico," *Journal of Environmental Psychology*, vol. 22, pp. 125-137, 2002.
- [14] A. Loukaitou-Sideris and A. Sideris, "What brings children to the park? Analysis and measurement of the variables affecting children's use of parks," *Journal of the American Planning Association*, vol. 76, pp. 89-107, 2009.
- [15] J. Veitch, J. Salmon, and K. Ball, "Children's perceptions of the use of public open spaces for active free-play," *Children's Geographies*, vol. 5, pp. 409-422, 2007.
- [16] K. K. L. Davison, C. T., "Do attributes in the physical environment influence children's physical activity? A review of the literature," *International Journal of Behavioral Nutrition and Physical Activity*, vol. 3, 2006.
- [17] N. Sipe, Buchanan, N. & Dodson, J., "Children in the urban environment: A review of research," in *Creating Child Friendly Cities: Reinstating Kids in the City*, B. S. Gileeson, N., Ed., ed New York: Routledge, 2006, pp. 86-102.
- [18] C. Spencer and M. Blades, "Children's understanding of place: The world at hand," *Geography*, vol. 78, pp. 367-373, 1993.
- [19] C. Spencer, Ed., *Place attachment, place identity and the development of the child's self-identity: Searching the literature to develop and hypothesis* (Researching Primary Geography. 2004, p.^pp. Pages.
- [20] K. Malone, "United Nations: A key player in global movement for Child Friendly Cities," in *Creating Child Friendly Cities: Reinstating Kids in the City*, B. S. Gileeson, N., Ed., ed New York: Routledge, 2006, pp. 13-31.
- [21] S. Chatterjee, "Children's friendship with place: An exploration of environmental child friendliness of children's environments in cities," Doctor of Philosophy Dissertation, Design, North Carolina State University, Raleigh, 2006.
- [22] S. P. Walz, *Toward a ludic architecture: the space of play and games*. Zurich: ETC Press, 2010.
- [23] J. Huizinga, *Homo Ludens: A study of the play elements in culture*. Boston: Beacon Press, 1950.
- [24] P. A. Masters, "Play theory, playing and culture," *Sociology Compas*, vol. 2, pp. 856-869, 2008.

- [25] D. M. Fetterman, *Ethnography: Step by Step* vol. 17. Newbury Park, California: Sage Publications, Inc., 1989.
- [26] P. T. Have, *Understanding qualitative research and ethnomethodology*. Thousand Oaks, London and New Delhi: Sage Publication, 2004.
- [27] V. Jupp, *The Sage Dictionary of Social Research Methods*. London: Sage Publications Ltd., 2006.
- [28] J. Bowlby, *A secure base: parent-child attachment and healthy human development*. Great Britain: Routledge, 1988.
- [29] M. D. S. Ainsworth, "Attachments and other affectional bonds across the life cycle," in *Attachment Across the Life Cycle*, C. M. Parkes, Stevenson-Hinde, J. and Marris, P., Ed., ed, 1991, pp. 33-51.
- [30] M. V. Giuliani, "Theory of attachment and place attachment," in *Psychological Theories for Environmental Issues*, M. Bonnes, Lee, T. and Bonaiuto, M., Ed., ed England Ashgate Publishing Limited, 2003.
- [31] J. I. Piaget, B., *The psychology of the child*. New York: Basic Books, Inc., 1969, 2000.
- [32] U. Bronfenbrenner, *The ecology of human development: Experiments by nature and design*. USA: Harvard University Press, 1979.
- [33] D. J. Porteous, *Environment & behavior: Planning and everyday urban life*. Menlo Park, California: Addison-Wesley Publishing Company, 1977.
- [34] E. H. Erikson, *Childhood and Society*. New York: W.W. Norton Company, Inc., 1950, 1963.
- [35] E. H. Erikson, *The life cycle completed: Extended version* New York: W.W. Norton & Company, Inc. , 1982, 1997.
- [36] D. Canter, *The psychology of place*. London: Architectural Press, 1977.
- [37] K. Korpela, "Children's environment," in *Hanbook of Environmental Psychology*, R. B. C. Betchtel, A., Ed., ed New York: John Wiley & Sons, Inc., 2002, pp. 363-373.
- [38] C. L. Benson, "Changing places: Children's experience of place during middle childhood," Master of Arts Social Science, Environment & Community, The Faculty of Humboldt State University, 2009.
- [39] P. Chistensen, "Place, space and knowledge: Children in the village and the city," in *Children in the City: Home, neighborhood and community*, P. Chistensen and M. O'Brien, Eds., ed London & New York: Routledge, 2003, pp. 1-12.
- [40] M. S. Najafi, M. Kamal B. M., "The concept of place and sense of place in architectural studies," *International Journal of Human and Social Sciences*, vol. 6, pp. 187-193, 2011.
- [41] S. Shamai, "Sense of place: An empirical measurement," *Geoforum*, vol. 22, pp. 347-348, 1991.

# From Bricks to Bytes: Digitizing Green Cities

Diane Valerie Wildsmith<sup>a</sup> and Phil Smith<sup>b</sup>

Department of Architecture, Faculty of Engineering, University of Indonesia, Depok 16424  
E-mail: [idx2003@cbn.net.id](mailto:idx2003@cbn.net.id)

Managing Director: Hoshin, Data Hoshin, Studio Hoshin, 32 Wilmslow Road, Manchester, M14 6HQ, UK;  
Consultant Director: PT Multi-Interdana, Jl. Gonseng Raya No. 43, Jakarta 13770, Indonesia  
Visiting Scholar: VEPR, Vietnam National University, Hanoi, Vietnam E-mail: [phil@hoshin.co.uk](mailto:phil@hoshin.co.uk)

## ABSTRACT

The research is focused on green cities and how the digital media has formed the basis for the development of corporate sponsorship of high tech green cities currently under construction like Masdar in Abu Dhabi, Songdo in South Korea and PlanIT Valley in Portugal. The urban imaginary of virtual green cities is directly linked to an ecological cyberspace which promotes futuristic images of green cities such as Vincent Callebaut's Hydrogenase (2010), which is a transport hub for an algae farm and biohydrogen airships. These images of sustainable green cities pose a challenge to define ecological civic space and green architecture in order to allow for the transformation of Jakarta into an eco-architectural hub that balances social, economic and environmental issues. The role of Google Earth and digital maps are not be underestimated in digitizing the 'bytes' and realizing design scenarios of the 'bricks' for green cities, including those options related to traffic planning simulations, water catchment scenarios, disaster planning and flooding as well as social media simulation for crowd control and governance issues.

### Keywords

*Civic space, glocal, green architecture*

## 1. INTRODUCTION

The phenomena of social media are focused on the Hotel Indonesia Roundabout (*Bundaran HI*) as an urban accupressure point for the promotion of civic space. Worldwide social media has promoted spontaneous flash mob dancing inspired by the South Korean singer PSY with his Gangnam style in an almost Elvis Presley or for the current generation Michael Jackson craze for public street galloping and dancing in a *glocal* celebration of globalization and localization in civic spaces from New York City to Jakarta. Besides being a media hub for cultural expression (Gangnam Style Flash Mob 9 Sept. 2012), the Hotel Indonesia Roundabout is also a contested political territory whose various designs have celebrated the emergent nation state of Indonesia with the Welcome Statue (*Tugu Selamat Datang*, 1961), built during the Sukarno era as one of the national monuments and a landmark to herald the ASEAN Games IV. (Kusumawardhani & Kurniawan, 2013) After the Reformation Era, (1997-present) the Welcome Statue at the Hotel Indonesia Roundabout was modernized in 2002 with a fountain as a way to reclaim security and police control over what had become a contested site for various political and social demonstrations during the emergence of democracy after the handover of the Suharto government. As a civic proponent for the vitality of the democratic process Jokowi's (Joko Widodo) successful election campaign for Governor of the DKI Jakarta (October 2012) included the massing of supporters wearing checkered shirts. Yet, even such a powerful national and international symbol of the central business district of Jakarta as a global megacity is not immune to the effects of climate change, flooding, and natural disasters, as witnessed by the January floods in 2013 that inundated the Hotel Indonesia Roundabout and shut down the main corporate and commercial boulevards of Thamrin and Jalan Sudirman.

Recent plans for the new Mass Rapid Station (MRT, 2013) suggest that the positive civic space will become instead an urban void leading to the new underground mass rapid station and commercial mall, further underscoring the need for additional green space in the urban streetscape. In its most recent permutation the civic space at the Hotel Indonesia Roundabout will be celebrated as part of a modern mass transit hub connecting the city of Jakarta with the suburbs of the megacity in South Jakarta, thus expanding the access for social media penetration and mass gatherings. Whether the realities of mass transport planning are able to accommodate the infrastructure required for the MRT, possible relocation of the main traffic arterials, additional drainage infrastructure, plus an allowance for an expansion of 30% open space and the provision of civic space to allow for festivities, street markets, and New Year's celebrations remains as a challenge for Jakarta's architects, planners, politicians, and citizens. One example of how 'bytes' or information technology can improve the physical structure or the 'bricks' of a city is the Boston Transport system (2010) that used real time data simulation to synchronize its bus lanes. The necessity of 'bricks' as well as 'bytes' to solve Jakarta's transport infrastructure and civic space will undoubtedly converge at the Hotel Indonesia Roundabout as Jakarta becomes one of the megacity hubs for ecological green architecture.

The paper follow a tripartite sequence: first, realizing the imaginary of green cities and the metaphors of bricks and bytes are analyzed in the context of three case studies of green cities under construction with high technology components, namely Masdar in Abu Dhabi, Songdo in South Korea and PlanIT in Portugal. Second, the role of the social media in relation to local and global phenomena is considered relative to the balance between eco-social and eco-technological issues in urban planning and green architecture, specifically at the Hotel Indonesia Roundabout as a contested civic place in central Jakarta. Third, in comparing the virtual reality of green cities with the actual realities of civic space, traffic congestion and climate change, the Hotel Indonesia Roundabout and plans for the MRT are analyzed in the context of realizing a mandatory increase of 30% in open space, providing civic space, and implementing a mass rapid transport system. In conclusion, a visionary design competition entitled “Architecture Triennale 2012: Architects For People - Towards Jakarta 2045,” sponsored by the Indonesian Institute of Architects (IAI), shortlisted ‘Jakarta Xcavated’ in the professional category. The design allows for the addition of green parks above and underground commercial and transport facilities below the city as one alternative to realize the connection between bricks and bytes.

## 2. REALIZING THE IMAGINARY OF VIRTUAL GREEN CITIES

Generally speaking, computer-generated virtual realities are based on bytes that are units of digital information in computing and telecommunications composed of 8 bits, a term coined by Werner Buchholz, a German computer scientist in 1956 for the design of the IBM 701, a defence calculator introduced in 1952 as IBM’s first commercial scientific computer and IBM 7030 Stretch computer, (Wikipedia, 2013). A byte is used to encode a singular character of text and in that sense is comparable to a brick in tectonic architecture as being the major component of a wall. The catch phrase ‘bricks and mortar’, is a metonym, a figure of speech associated with two concepts, related to traditional building materials. In banking terms ‘bricks and mortar’ are related to investments in buildings as securities. In e-commerce ‘bricks and mortar’ refers to a business with a physical presence and face-to-face communication as opposed to online shops with electronic communication such as Amazon, etc. The computer language metaphors overlap between computer architecture and building architecture, resulting in the dissemination of virtual realities.

Social media web sites like YouTube and specific websites on green cities promulgate the idea of virtual green cities. Hydrogenase by Vincent Callebaut (2010), (Figure 1), is a virtual reality project based on hydrogen powered airships. This fantastic idea literally fuels the imagination and provides the precedent for green cities based on alternative energy from algae farms coupled with high technology. To paraphrase M. Christine Boyer (1996), what the machine was to modernism, the computer was to postmodernism and what the social media is to hypermodernism, YouTube is to spontaneous hyperconnectivity. The computer or the information age involved Boolean logics, a series of logics denoted as true or false, 0 or 1 as a series of binary syntaxes to organize data into worlds of artificial intelligence and cyberspace. The metaspaces or the hyperspace often imposes a bird’s eye view, a level of reality that allows for a collective imaginary about cybercities that combines globalization and localization into a *glocal* experience. Boyer (1996) defines CyberCities as:

“This unwieldy mixture of urban dystopia and cyberspace – here called CyberCities – turns the reality of time and place into an imaginary matrix of computer nets electronically linking together distant places around the globe and communicating multilinearly and non-sequentially with vast assemblages of information stored as electronic codes.”



Figure 1: Vincent Callebaut, Hydrogenase, (2010), Permission Pending <http://www.inhabit.com>

With their philosophical and intellectual roots in cybercities, technological variants of green cities like Masdar in Abu Dhabi, Songdo in South Korea and PlanIT in Portugal rely on technological sponsorship and linkages with computer companies and high technology as tangible evidence of the realization of cybercities into sustainable ecocities. Indeed the city itself is managed and controlled by sophisticated computer programmes consuming terabytes of data, providing smart grids, smart traffic and transport and smart waste and water management, a genuflection to the fact that reducing our consumption of resources is as much about management as it is about the technology. The sponsors are keen to promote connected smart communities and their particular management solutions to achieving them, as smart cities are seen as the drivers of the next

technological revolution underpinning future revenue streams; whilst cyberspace focuses more on technology to realise utopian visions.

Masdar, as a global hub for emergent technologies, is a sustainable city under construction, (Figure 2). It is scheduled for completion in 2025. Designed by Foster + Partners, Mott MacDonald, and Sheppard Robson International, Masdar is estimated to cost US\$18-19 Billion for 40,000 residents and 50,000 commuters on a 6 km<sup>2</sup> site. Masdar is based on a pedestrian city with a modular transportation system of Personal Rapid Transport (PRT) and Freight Rapid Transport (FRT) as well as electric cars. Technology and development partners include Siemens, Mitsubishi Heavy Industries, GE, Schneider Electric, BASF, and Bayer MaterialScience among others.



Figure 2: Masdar City Master Plan, Foster + Partners (2007), Permission Pending, <http://www.bustler.net>

Designed by Kohn, Pedersen and Fox, Songdo International Business District (IBD) at Incheon in South Korea is under construction with a completion date of 2016 for 65,000 residents and 300,000 commuters at a construction cost of US\$35 Billion on a 1,500 acre (6.07 km<sup>2</sup>) site, (Figure 3). The buildings are expected to receive LEED ratings and there will be 40% green space in the city with sustainability designed into the master plan. In partnership with Cisco, the city includes state-of-the-art communications, broadband connectivity and smart meters in each home to monitor electricity and water consumption. The model of an instant city is applicable to meet urban infrastructure needs. The instant city has a potential market beyond Songdo. "According to a study by an investment bank CIBC World Markets, governments are expected to spend US\$35 Trillion and public works projects in the next 20 years," (Johnson, 2010). In terms of the 'City of the Future,' Cisco cites ABI Research with estimates that US\$39.5 Billion will be spent on smart city technologies in 2016, (ABI Research, 2013). The technologies include smart transportation pricing, Internet connectivity to all homes and schools, demand alert response for energy consumption, medical facilities, and patient coordination as well as electronic offices.



Figure 3: Songdo Master Plan, Kohn, Pederson and Fox (2009), Permission Pending <http://www.archleague.org>

PlanIT is a model city and sustainable community being developed by the Municipality of Paredes near Porto in Northern Portugal for a population of 225,000 people on a 1,700 hectare (17 km<sup>2</sup> or 4,000 acre) site for €10 Billion (US\$14.1 Billion) with a targeted completion date of 2015, (Figures 4 and 5). The co-founder, Steve Lewis of PlanIT in Portugal, was formerly the General Manager of Market Development at Microsoft. According to Quintain, a London based property developer, they are joining "...Microsoft, Buro Happold, Cisco and Formula One suppliers McLaren as partners in the Living PlanIT concept to develop a "smart" city, where built-in sensors measure occupancy, temperature, humidity and energy production and use." The intention to incorporate technology and computer systems is apparent in the 'Introduction to Future City Technology' as follows:

“Living PlanIT’s Urban Operating System (UOS™) provides essential middleware – built on Cisco infrastructure and Microsoft Cloud platforms – that enables networked sensors and actuators to be deployed at scale, coordinated through a unified and secure real-time control layer which also shares and collects data across the entire urban landscape.”

Based on an UOS (Urban Operating System) and PlaceApps, urban data and monitoring systems form the core of intellectual property. Construction is to be based on mass production principles of automotive and aircraft manufacturing. Besides portraying an image of a digital green city, PlanIT Valley will involve partnerships with Portugal’s national government, universities, and companies in a living technology laboratory.



Figures 4 and 5: PlanIT, Portugal, Buro Happold, Engineers (2010), Permission Pending, <http://jornal.publico.pt/noticia/06-03-2011/planit-valley-quer-ser-a-montra-do-urbanismo-sustentavel-21474643.html> and <http://cdn.controlinveste.pt/storage/ng1153995.jpg?type=big&pos=0>

Each of these green city developments share a strong economic vision and how this integrates with the wider global economy (globally interconnected through bytes). Masdar is branded as a global centre of excellence for renewable and clean technologies and has already recruited the International Renewable Energy Association and Siemens to its hub; however, Masdar has modified its targets as a zero carbon city. Songdo International Business District is co-ordinated by Gale International, United Technologies Corporation and the Hanjin Group; it aims to attract multi-national companies who will make it their regional office for Northeast Asia. PlanIT is marketing itself as a base for companies developing products and services for other cities seeking to develop their green credentials. Neither Masdar nor PlanIT have given serious consideration as to why environmental companies would want to move to either the UAE or to Portugal, save the important agglomeration effects popularised by Richard Florida in his Ideopolis thesis, but which are dependent on a significant mass being achieved (Alusi, A. Eccles, R., Edmondson, A., Zuzul, T., 2011).

Despite all of the green cities expressing a desire to be replicable and replicated, it is likely that only the property-driven Songdo economic model (more bricks than bytes) could be replicated by other aspiring green cities, and presumably only those strategically placed, as Songdo is, between major economic powerhouses (in Songdo’s case between Beijing and Tokyo). The connectivity of their communities seems to suggest a desire that from it will cultivate an Ideopolis-inspired creative class at the forefront of the knowledge economy (more bytes than bricks). Nevertheless, even those cities that could claim the title of knowledge cities have done so in response to global economic forces, more so than through the sort of planning and control that is being integrated within these green cities, (Yigitcanlar, T., Velibeyoglu, K. and Martinez-Fernandez, C., 2008). Indeed, the failure to attract high technology tenants to Serpong’s Science Parks, provide a warning of what happens when well-intentioned plans fail to coincide with global market forces.

In conclusion, digitized images of cybercities and YouTube broadcasts have formed the basis for the imaginary of digitized green cities and the development of corporate sponsorship of high tech green cities currently under construction like Masdar in Abu Dhabi, Songdo in South Korea and PlanIT Valley in Portugal. Their technological solutions are far more than the ‘green wash’ Jakarta’s newer commercial developments have cloaked themselves with, although the application of these technologies outside these ‘experimental’ cities may prove little more than a tool for managing our increasing consumption of scarcer resources (crowding even more cars into Jakarta’s crowded streets).

### 3. SOCIAL MEDIA: CHALLENGING THE REALITY OF CIVIC SPACE

The impact of technology on urban development and the allocation of civic space are related to the provision of data from Geographic Information Systems (GIS). In 1972 NASA dedicated its Landsat satellite to mapping natural and cultural resources on land and ocean surfaces in order to classify land use, monitor urban growth and to act as an aid in regional

planning for mapping and transportation networking. The information was and is being used to facilitate transport and power transmission routes. The satellite data analysis is able to predict various urban growth scenarios so that planners can evaluate the spread of urban growth in the context of megacities and their imposition in peri-urban areas on forestry and agricultural lands, (Salkin, 2008).



Figure 6: “The Welcome Statue” at the Hotel Indonesia Roundabout, Permission Pending

<http://www.eazytraveler.com/2011/08/jakarta-jaunt.html>

This grouping together of databases and cartography plus the increased power and usability of computers led to the ability of storing large amounts of data as visual representations with access to websites such as Google and Google Earth. With access to visual mapping, the land use review process is streamlined with the ability to produce accurate maps and three-dimensional views of the city, thus further materializing the city in a virtual way through the Internet and social media access. The ability to manage transport, water, and sewage infrastructure is enhanced as well as the ability to calculate green space areas. Salkin reports that GIS, as a web based, interactive tool is used by local governments for the proposed location of parks.

Besides providing mapping data with access to Google Earth, Internet websites such as Facebook and YouTube provide a social media platform for organizing and communicating with individuals and socio-political groups to arrange for events and demonstrations, thus underscoring the importance of social media and its impact on civic space. One new phenomenon, related more to entertainment than politics (although in Southeast Asia’s case it is sometimes difficult to accurately differentiate, reminiscent of 1960’s youth movements in the west), is the *glocal* phenomena of South Korean Gangnam-styled dancing. However, the occupation of public space by illegal flash mobs also involves the state and security systems to safeguard the peace and security of the city and provide the means for crowd control, specifically in relation to the Hotel Indonesia Roundabout in Jakarta, (Figure 6).

According to Lai Chee Kien at the First Conference on Civic Space in 2010, (Universitas Indonesia and the University of British Columbia), “At the monument at the Hotel Indonesia, demonstrations take over the state space. The people who want to have a say in the civic culture will want to occupy that place. The police also occupy the same space. We have to look at galactic poles with centrally contained power.” This analysis illustrates that space is a contested social process as much shaped by, as shaping, social interaction and power relations as indicated at the WWF-sponsored Panda and Car-Free Day in 2012, (Figure 7).

Gangnam styled dancing derived from songs by South Korean rapper PSY and an illegal flash mob advertised through the social media by the Happy Holiday Indonesia team (a group of video artists inspired by JackAss and Running Man, Korea), resulted in 1,000 people converging at the Hotel Indonesia Roundabout on 9 September 2012 ostensibly to jump in the fountain. Afterwards a 4-minute video broadcast on YouTube generated 336,000 views and 1.4 million comments amongst Indonesian netizens after it was posted on 13 September, (Figure 8). More recently they organized a Harlem Shake (another *glocal* phenomena) on one of Jakarta’s rapid transport buses TransJakarta Busway (BRT), itself a precursor to the MRT.

#### 4. HOTEL INDONESIA ROUNDABOUT: FACING THE REALITY OF GREEN CITIES

“Under a 2007 national law, the city is supposed to dedicate at least 30 percent of its total land area to open green space, but Jakarta has never been able to meet the requirement because of complications in freeing up occupied land and past administrations’ preference for developing open areas into commercial and retail zones rather than parks,” (Tambun, 2012). At the first stage, Jakarta DKI Governor, has targeted an increase in green space from current levels of 9.8% to 20%. Whatever the overall planning target, the fact is that unless there is a radical departure from the use of cars and trucks around the Hotel Indonesia Roundabout or to an extreme measure of road closure, requiring 30% green space would reduce the number of

traffic lanes, (Figure 9). Additionally, the void also presents weather problems during the monsoon season, let alone during disastrous flooding occurrences related to the failure of the canal infrastructure as happened in January 2013 and the potential impact of climate change and urban development on urban water catchment areas (especially around Jakarta's iconic shopping malls, the current substitute for civic space), (Figure 10).



Figure 7: Flash mob at the Hotel Indonesia Roundabout during a WWF sponsored Panda and car-free day illustrating the contested space between City of Jakarta and the public. (2012), Permission Pending, <http://www.hersmagz.com/spotlight/2012/12/flashmob-panda-di-car-free-day-wwf-indonesia-2>



Figure 8: Flash mob and South Korean Gangnam dancing, Hotel Indonesia Roundabout, 2012, Permission Pending, <http://indoboom.com>

Even if the fountain was considered as 'blue-green' open space, the MRT proposal for a void open to the mass transit station and underground shopping concourse and mall produces a negative space, rather than a civic space at ground level, (Figure 11). The potential for use of the urban space for civic events, including festivities, giant digital TV screens, and peaceful political protests would be reduced significantly with the proposed expansion of green space and the MRT void. In fact glass paving blocks, may meet the requirements for the fountain, a skylight atrium and fulfil its symbolic use as public space to be enjoyed by all Jakartans and visitors as a new symbol for an eco-architectural transit hub at the Hotel Indonesia Roundabout.

## 5. CONCLUSION

To a large extent Jakarta epitomises the challenges that most cities will face in attempting to develop their green credentials. Whilst, the conceptual framework, provided by Jabareen, (2008) highlights the enormous task confronting the new Mayor and his administration. These issues include the ethical paradox of balancing sustainability with economic development, the limits to greening and eco-repairing this high-density city (as an extension of its natural capital) and the need for greater equity (political and economic), following a period of spectacularly uneven development, the need for a green architectural forms suited to Jakarta's climate (incorporating passive solar design) and the need to integrate city management (in the ways that the green cities have with their smart grids, transport and traffic). Governor Jokowi's final two challenges of utopianism and global urban political leadership, only serve to highlight the inappropriateness for Jakarta to borrow from distant examples, inspiring Jakartans to devise a unique solution for their tropical megacity. Despite the challenge of new green architectural forms (bricks) and the integration of city management (bytes), these are arguably the easiest of the challenges. Borrowing from David Satterthwaite's (1997) definition of a healthy city, as one which provides a healthy living and work environment, safe water, sanitation, refuge collection and disposal, drains and paved roads, we immediately understand what needs to be prioritised, but the reality of converting bytes to bricks remains the challenge of our times.



Figure 9: Hotel Indonesia Roundabout, Traditional commercial development leaves little room for civic space, Permission Pending, <http://4.bp.blogspot.com/->



Figure 10: Hotel Indonesia Roundabout: January 2013 with 1-meter high flooding Permission pending, <http://www.bing.com/images/search?q=Flood+Thamrin+Jakarta+2013&view=detail&id=4ABE67DCE3A2270FADA39DC3D8D99A9FBB361C3C&FORM=IDFRIR>



Figure 11: Proposed Jakarta MRT with transport system and shopping mall below grade, leaving the main boulevards of Jalan Thamrin and Jalan Sudirman above functioning as commercial traffic corridors with landscaping strips for trees along the perimeter. <http://www.indoboom.com/2012/stories/jakarta-plans-to-build-most-advanced-mrt-system-in-the-world.html>

Although the aspirations for green cities are based on the balance of green space and civic space, the realities of the built-up metropolitan infrastructure require the imbrications of the materiality of the city with its digital management of human, spatial and natural resources. The IAI Architecture Triennale 2012: Architects For People - Towards Jakarta 2045 design competition proposed various alternatives including canals and parks in Jakarta's main throughfares and squares to accept the seasonal inundation caused by flooding and to provide parks and open space with underground facilities, (Figure 12). Besides the vertical expansion of high-rise buildings the potential for green roofs and green architecture with urban agriculture inspires the convergence of the virtual realities with the future reality of green architecture as a *glocal* response in Jakarta, bearing in mind the multiple layers of eco-social, economic, political and social media priorities.



Figure 12: Jakarta Xcavated Project: Shortlisted Finalist Professional Category IAI Visioning Jakarta 2045, December 2012 (Margaret Jo, Sylvia Mei, Silvia Adityavarna, Khattiya Hendarta, Albertus Prawata), Permission Pending, <http://volumefactory.wordpress.com/2012/12/20/jakarta-xcavated-project/>

## REFERENCES

- [1] Alusi, A., Eccles, R., Edmondson, A., Zuzul, T., (2011), "Sustainable Cities: Oxymoron or the Shape of the Future," Harvard Business School, Working Paper.
- [2] Boyer, M. C., (1996), *Cybercities*, New York: Princeton Architectural Press, p. 14.
- [3] Callebaut, V. (2010), "Hydrogenase Algae Farm to Recycle CO<sub>2</sub> for Biohydrogen Airships, Shanghai, 2010," downloaded from: <http://vincent.callebaut.org/page1-img-hydrogenase.html>
- [4] "Cities in the Cloud: A Living PlanIT Introduction to Future City Technologies," (2011), p 3. White paper pdf edition, downloaded from <http://living-planit.com/planit>
- [5] Citronot, Luc, (2013), "Jakarta Hit Again by Flooding," 7 February, downloaded from <http://www.bing.com/images/search?q=Flood+Thamrin+Jakarta+2013&view=detail&id=4ABE67DCE3A2270FADA39DC3D8D99A9FBB361C3C&FORM=IDFRIR>
- [6] Gangnam Style Flash Mob, an illegal mob Happy Holiday Indonesia, 9 September 2012, 1000-person flash mob dancing and singing Gangnam style, downloaded from <http://www.youtube.com/watch?v=lh1edaOa514>
- [7] Institute for Transportation and Development Policy (ITDP), (2007), "Making TransJakarta Busway a world class BRT system" downloaded from [http://www.itdp.org/documents/Presentation\\_to\\_Gov\\_6Nov07.pdf](http://www.itdp.org/documents/Presentation_to_Gov_6Nov07.pdf) and "Implementing Low Carbon Public Transport in Jakarta Project, March 2012, downloaded from <http://www.itdp-indonesia.org/images/stories/Publication/Report/recep%20%20-%20optimized%20transjakarta%20network.pdf>
- [8] Jabareen, Y., (2008), 'A new conceptual framework for Sustainable, Environment, Development and Sustainability, 10, pp. 179-192.
- [9] Kien, L. C., (2010), National University of Singapore, "States and States: colonial and national governances of civic space in Southeast Asia" presented at UI International Conference on Civic Space (1), A Joint Conference of University of British Columbia and University of Indonesia: "Space, Culture and Power: Identity and Civility in the Post-Authoritarian Urban Asia," 3 - 5 August 2010, Department of Literary Studies and Department of Architecture, Universitas Indonesia, Depok, DW notes.
- [10] Kusumawardhani, Ratu Arum; Kurniawan, K.R., (2013), "Space and Symbols: The History of the Hotel Indonesia Roundabout," Working Paper, Seminar on Architectural History, Buffalo, New York, USA.
- [11] Salkin, P.E., (2011), The Touro Law Center, "From Bricks and Mortar to Mega-Bytes and Mega-Pixels: the Changing Landscape of the Impact of Technology and Innovation on Urban Development," in *The Urban Lawyer*, Fall 42-4/43-1, downloaded from: [http://works.bepress.com/patricia\\_salkin](http://works.bepress.com/patricia_salkin)
- [12] Satterthwaite, D., (1997), 'Sustainable Cities or Cities that Contribute to Sustainable Development', *Urban Studies* 34, 10, 1997, pp. 1,667-1,691.
- [13] Shatkin, G., (2008), "The Modern City: State, Space, and Citizenship in Urban Asia," in *The Journal of the International Institute, The University of Michigan*, Ann Arbor, Michigan, Fall, Vol. 16, No. 1., downloaded from <http://quod.lib.umich.edu/cgi/p/pod/dod-idx/state-space-citizenship.pdf?c=jii;idno=4750978.0016.101>
- [14] Stev, (2012), 'Gangnam Style' Flash Mob Hits Jakarta Bundaran HI Landmark," 13 September, downloaded from <http://indoboomb.com>
- [15] Sweet, R. editor, (2010), "Wembley City developer Quintain now on board for PlanIT Valley, Portugal's futuristic eco-city," in *Construction Research & Innovation*, 25 November, downloaded from <http://www.ciob.org.uk/news/wembley-city-developer-quintain-now-board-planit-valley-portugal%E2%80%99s-futuristic-eco-city>
- [16] See also <http://www.ciob.org.uk/planitvalley>
- [17] Tambun, L.T., (2012), "Jokowi Plans to Boost Green Space in Jakarta," December 10, <http://beritajakarta.com/2008/en/newsview.aspx?idwil=0&id=26374>
- [18] Thompson, B., (2010), "The rise of the instant city," in *Asia Infrastructure*, Issue 1, 10 December, p. 41, downloaded from <http://www.asianinfrastructure.com/article/The-rise-of-the-instant-city/>
- [19] Wright, T.K., (2010), "From Bricks to Bytes, Cities and Innovation," in *Regional Plan Association*, NY, NJ, CT, 27 April, downloaded from <http://www.rpa.org>
- [20] [www.masdar.ae/](http://www.masdar.ae/) and [www.openmint.net](http://www.openmint.net)
- [21] Yigitcanlar, T., Velibeyoglu, K. and Martinez-Fernandez, C., (2008), 'Rising knowledge cities: the role of urban knowledge precincts,' in *the Journal of Knowledge Management*, 12, 5, pp. 8-20.

## Video Games Modification in Indonesia As Players Creative Contribution In Producer-Consumer Model of Popular Culture.

Yudi Amboro<sup>a</sup>, Yasraf Amir Piliang<sup>b</sup>, IntanRizkyMutiaz<sup>c</sup>

*Faculty of Art and Design, Institut Teknologi Bandung, 40132  
amboro@gmail.com*

*Faculty of Art and Design, Institut Teknologi Bandung, 40132  
yasraf2000@yahoo.com, ya-piliang@bdg.centrin.id*

*Faculty of Art and Design, Institut Teknologi Bandung, 40132  
intanrm@yahoo.com*

### ABSTRACT

Many believe that video games are part of a popular culture and were created for consumption purposes only. These video games were seen only as a means of entertainment; thus creativity is not usually considered as a quality that can be gained from playing video games. Negative views towards video games came as a result of how people think that the video game player's unable to produce or create new expression from consuming video games. However, there are some users who believe otherwise. These users do not stop at the consumption stage but they venture further. They creatively modify the games for various personal reasons and thus make themselves as the Producer-Consumer. The transition of video game players from Consumer only into Producer-Consumer stage, also happen in Indonesia. Along with the creativity root deep inside cultural traditions, video game player in Indonesia also create their video game modification community. This study tries to identify the relation between creativity and video game modification in Indonesia, and also the purpose of this modification.

### Keywords

*Video Games, User, Modification, Producer-Consumer, Popular Cultures, Creative Contribution*

### 1. INTRODUCTION

The common notion of most people nowadays though see video games as popular media are still thinking that video game created for consumption purposes only. This common perception toward video games comes from negative judgments of the video game players. People tend to look the players as those who are passive and have excessive times. Those judgments lead to conclusion that the players are non-productive people who spend most of their time doing nothing but playing video games. These negative perception often neglecting the other side of playing video games, which also stimulating creativity. In fact, it takes extensive and tremendous talents to make and to play video games, and labeling video games as a non-creative media is simply a simplified misconception since two of the basic elements of video games are creativity and interactivity. In order to play or consume video games, player cannot do it by sit and passively watch thing that happen in screen. Player musttake action and follow the rule, use tactics and logic. It requires the player to interact with the content of video game. Playing video games mean engaging in these creativity and interactivity.

Thanks to the Hacking Subculture, these creativity and interactivity have offered the players some possibility to be a creator as well. There are insatiable players who are not satisfied with the content of the games he/she plays. They would not hesitate to hack or alter the content of the games to optimize their own consuming experience and thus extending the media usage, this activity is known as Modifying or commonly called Modding. For Indonesian players, the modification seen as a way to add local content into popular video game title since the localization of game content is still low. But how exactly video game modification functions as the players' creative contribution in the Producer - Consumer Model of Popular Culture? This is where the research begins.

### 2. PROSUMERMODEL, MODIFICATION, AND VIDEO GAME

Prosumeror Consumer as Producer is a term coined by Dovey and Kennedy in their book Game Cultures: Game as New Media. With theProsumer terminology Dovey and Kennedy try to explain the phenomena of participatory culture where consumer try to accessing, altering, and disseminating symbolic text for further consumption. What happen next is the collapse of distinction between the dominant culture and the subculture [1]. Participatory culture itself is not a new phenomenon in history of media consumption. Long before the digital media emergence people already try to challenge the establish media content producer by making their own content, and distributing it through their own network. The advent of digital media with all its facility accelerate the participatory culture into phenomena that now being accepted as part of modern creativity process.

What people need right now is an idea, time and basic skill to create content, everything else can be provided within the digital media it self. For example a music video that being upload to youtube by prominent musician and being watched by world wide audience, in turn inspiring one of the audience to create his or her own music video. He or she create the video using some of the material from original video, edited it and adding additional material using his or her own laptop. Upload it to youtube have feedback and can have worldwide audience like the video of prominent musician. This may lead to his or her stardom in music industry. The example is just one of many example how the prosumer model in digital media and popular culture context being accepted as modern creativity process.

Prosumer or Consumer as Producer is a term coined by Dovey and Kennedy in their book *Game Cultures: Game as New Media*. With this terminology, Dovey and Kennedy try to explain the phenomena of participatory culture, which is a culture where consumers try to assess, alter, and disseminate symbolic text for further consumption. What happen next is the collapse of distinction between the dominant culture and subculture [1]. Participatory culture itself is not a new phenomenon in the history of media consumption. Long before the digital media emerged, people had already challenged the established media content producers by making their own contents and distributed them through their own networks. The arrival of digital media, and all its facilities, had accelerated the participatory culture into a social phenomenon, which is now being accepted as a part of modern creativity process. Currently, people only need an idea, time and basic skill to create content and everything else can be provided within the digital media world. For example, a worldwide audience is watching a music video, which is uploaded to YouTube by a prominent musician; one of the audiences is inspired to create his or her own music video. He or she creates the video using some of the materials from the original video, edits, and adds their own materials using his or her own laptop. Then, he or she uploads it to YouTube to gain some feedbacks from the worldwide audience, through the same process and the same channel as the video of the prominent musician. This action can lead him or her to his or her stardom in music industry and become a YouTube celebrity. This example is only one of the many examples of how the prosumer model in digital media and popular culture context can be accepted as modern creativity process.

The act of modifying or modding video games at first was seen as an act of altering the content for humorous or parody purposes. Dovey and Kennedy gave the example of people replacing the Nazi enemies in the video game *Castle Wolfenstein* with Smurf character from TV cartoon [2]. As the time goes by, the modification serves different and more complex purposes. If we look at the current video games modifications, we can see at least four types or models of modification, according to Newman [3]:

1. Modding to help finish the game being played.

This model alters the game data or programming codes in order to make the players finish the game easily. For example: editing player's life, or bullet, or time from limited to infinity.

2. Modding to spread or communicate the issue.

This modification alters the data or programming codes by injecting a message, then spread the edited version back to the community. For example: changing the villain character into hero character or vice versa.

3. Modding to convert or extending original material.

This modification alters the data or programming codes in order to extend the playability or converting the original content of the video game into different looks. For example: adding more levels that originally did not exist.

4. Modding to achieve economy benefit.

This modification alters the data or programming code in order to achieve economic benefits by adding new features or services over the previous version. For example: by offering patching or selling downloadable content released by developer.

Few examples of famous modification case are: *Half Life* modding that spawn the *Counter Strike* video game and *Warcraft* modding that create the *Defense of the Ancient* video game, or more known by their abbreviation: *DotA*. Both were modifications, which created new games over the original material, and have became as famous as the original game. At first, video game developers were reluctant and objected the modifications, which were done by the players, due to the nature of video games as software that are licensed to users. But some more independent developers, like ID Software and Valve, encourage players to modify their game contents by providing the players tools for editing. Some of these modding could help developers by providing features that previously not included in the original release. It produces cooperation between the producers and the players, and lately it is being seen as a standard business practice for some developers [4]. In most cases, a modder with adequate technical background could find a way to alter, even if they are not given the tools. The modder often uses this act of modification to gain some experiences in developing a video game before actually involved in video game industry.

### 3. METHOD

This research gathers primary data, taken from visual artworks, records, and online interviews with players from modding communities. These data are analyzed qualitatively using the guidance of the Dovey and Newman's descriptive interpretation approach for Production - Consumer Model. There are some difficulties in gathering data from modding communities, one of it come from the nature of modification activities that sometimes considered as hobby or personal activity. As a result most modification process have unorganized documentation. However, the data gathered from interview and visual artworks captured from the modification video game are adequate to give some information on the creativity process and reasons beneath modification.

### 4. DISCUSSION

Although modding is still in its infancy stage of Indonesia's video games development, there are cases of video game modding that can be used as research objects. One of them is the "Battle of Soerabaja 1945". It is a modification from Close Combat: Invasion Normandy video game that was produced by Atomic Combat. It is a war strategy game which placing the player as the general who lead and command the soldiers to achieve victory in war. [5] Like most war strategy games, Close Combat: Invasion Normandy uses historical event as the background. Thus some elements in the game were created using historical data. The modder uses the same approach for the Battle of Soerabaja 1945. The modder alter the original game data especially the visual artwork of Close Combat game; in order to create visual that closely resemble Battle of Surabaya 1945.

This research uses online interviews, In the interviews the modders being asked about the creative processes they went through and their motives for the modifications of the Battle of Soerabaja 1945. The result shows that the motives behind the modification are to spread and communicate nationalism amongst Indonesian youth through video game. This is a very interesting finding because the modders are independent individuals, not being supported financially or mentally by any government agency. They propagandate nationalism on their own will, which match with model number 2 of modification motive. The game also match with another model of modification, model number 3, where the motive of that model is to convert or to extend the original game that was based on Allied versus Axis on World War II in Normandy France into the Battle of Soerabaja 1945, because it is one of the important battles in the history of Indonesian Independence War. The modders: Dicky Octavia, Gregorius Satia Budhi, and Yusuf T, gathered some historical data from the real event of Battle of Soerabaja for the game [6]. These data consist of: the regiment from the both side, Indonesia and Allied (British Occupation Army) that were involved in the war, their whereabouts during battle, and other relevant data. These data were translated into visual artworks in forms of: uniform, insignia, weaponry, voice, sound, leader, and so on. Some of the contents were fictional, since there were difficulties in finding documented historical data. Some were taken from a movie on the Battle of Soerabaja that was produced in 1990, such as the voice and the sound. The motive for using the voice and sound from the movie for the modification was to enhance the dramatic effects on the players being in the war. Other data, such as regiment insignia and uniform colors, were elaborated from partial historical data. The modders had to recreate them because the original photographs and movie footages from the war period were black and white, and they did not have high quality details. For these efforts, the modders and their modification had gained national media coverage in some news paper and magazine [7].



Figure 1 : Screen Shot of Battle of Soerabaja 1945 video game

Other example of video game modification can also be seen in Indonesia Driving Simulator (IDS). IDS is a video game that modded from the United Kingdom Truck Simulator video game, produced by SCS software. The original game places the player as a driver of big vehicle who have to transport cargo from one city to another city within United Kingdom. A group of Indonesian modders modified this game into the Indonesia Driving Simulator. Similar to the Battle of Surabaya 1945, Indonesia Driving Simulator modification also uses alteration of the data inside the video game. The vehicles were altered into various big local vehicles that were common in Indonesia traffics, such as a truck from national oil company or a bus from local bus company. The modder also alter the environment and map inside the game.

Using similar method like being done for Battle of Surabaya 1945 interviews, the finding for this modification is taken from online interviews and records from the IDS modder community. The community using Indonesian largest forum: Kaskus (kaskus.co.id), for communicating and publish their newest modding. Through these data, it is found that the motives to modify also match modification model 3, which is to convert or extend the original material. The modders want the content of the video game to have local visual look. The modders in this model admit their reasons for doing this alteration are to gain some experiences before they go to the full game development industry as well extend the usability of original game. The most interesting part is that the company for the vehicle and the restaurant that are being used in the alteration and were actually contacted the modder and offered them sponsorship as long as the modder add the 3D model of the vehicle or company building inside the game.



Figure 2 : Screen Shot of Indonesia Driving Simulator video game

## 5. CONCLUSION

From discussion above we can see that the modification content of video game already accepted in video game community as a creative way of producer and consumer model involvement to add value to the content of video game. Although the producer may not provide modification tool to facilitate the user for altering game data, if the user have enough technical skill they still can do the modification. Most modification that has big impact on video game community usually has significant alteration of its content. Either by altering the visual look or extending the level or map so the player can have new experience of playing previous version of the video game title. The video game modifications in Indonesia happen because player-who later become modder-need to add local content that previously not exist in original version of video game. The modification also serve the need to exercise programming skill (hacking) that later could be applied in the real game development business. The popularity of modification also not necessarily depend on the quality of visual artwork, even when the modification can not keep up with current standard of visual technology the game it self can still have wide acceptance. Of course not all of modification of content bring positive side effect there are also negative side effect. One of the example can be seen in the message of nationalism in Battle of Surabaya that being spread, it lacks historical accuracies and fall into cheap propaganda where Indonesia nationalism can only be achieved through war effort. There are also the consequences that the game being modified bring generic visual look in the perception of gamer due to the minimal effort of modder who are not willing to start from scratch when modifying the content. Other problem that can be add into this conclusion related with copyright issue not all of developer allowed user to modifying their game but usually this problem arise when there is a clear copyright violation or the game mods got popular without original developer involvement.

The discussion above shows that the modification of the content of the video games has been accepted in the video game community as a creative way from the players' part to add value to the content of the game; this is seen as the producer and consumer model of involvement. Even though the producer did not provide any modification tool, the modders can alter the games nevertheless, provided they have enough technical skills. Most modifications alter the game's content and this gives big impacts on the video game communities and the game popularity as well. The alteration can be done by either altering the visual look or extending the level or map so that the players renew their experiences. In Indonesia, the modders serve the need to add local contents that did not exist in the original version. They also use modification as exercise of programming skill by hacking the games. Later on, the modders may use their experiences to enter the actual game development industry. Modification of video games does not necessarily relying on high quality visual artwork. A modification can still be widely accepted even if the modification doesn't meet the standard of visual technology. There are some weaknesses, flaws or problems in a modification. In the Battle of Soerabaja 1945, the message of nationalism can be seen as cheap propaganda, due to the lack of historical accuracies. In other modifications, the altered version were so similar to the original ones because the modders only put minimal efforts and did not want to start from basic when modifying the content.

## REFERENCES

- [1] Dovey, Jon, Helen W Kennedy, *Game Cultures, Computer Games As New Media*, Berkshire: Open University Press, 2006, ch.1, pp 14 - 15.
- [2] Dovey, Jon, Helen W Kennedy, *Game Cultures, Computer Games As New Media*, Berkshire: Open University Press, 2006, ch.7, pp 131.
- [3] Newman, James, *Playing With Video Games*, New York: Routledge, 2008, ch.7, pp 151-178
- [4] Dovey, Jon, Helen W Kennedy, *Game Cultures, Computer Games As New Media*, Berkshire: Open University Press, 2006, ch.7, pp 133.
- [5] Amboro, Yudi, *Representasi Nasionalisme Dalam Propaganda Di Media Video Game, Kajian Semiotika Visual Close Combat – Battle of Soerabaja 1945*, 2010, pp 39 unpublished
- [6] Amboro, Yudi, *Representasi Nasionalisme Dalam Propaganda Di Media Video Game, Kajian Semiotika Visual Close Combat – Battle of Soerabaja 1945*, 2010, pp 40 unpublished
- [7] Amboro, Yudi, *Representasi Nasionalisme Dalam Propaganda Di Media Video Game, Kajian Semiotika Visual Close Combat – Battle of Soerabaja 1945*, 2010, pp 41 unpublished