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PREFACE

The Regional Symposium on Chemical Engineering (RSCE) has become an important annual forum for academicians, researchers and professionals from both public and private organizations in the South East Asia and the Asia-Pacific regions. It is organized to serve as venue to exchange knowledge and information of relevance to the chemical engineering.

The committee received 282 abstracts and accepted around 230 papers in which around 170 papers came from aboard such as Japan, Taiwan, Korea, Malaysia, Thailand, and Australia, Philiphine, Vietnam, Saudi Arabia. All the papers have been reviewed with the help of experts in the areas.


We wish to thank reviewers, plenary speakers, keynote speakers, and session moderators for their cooperation and valuable suggestions. We would like to extend our appreciation to members of organizing committees, International and National Scientific Committees for their valuable help and support.

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A-78 Enzymatic Hydrolysis of Alkali-Pretreated Sugar Cane Bagasse For Production of Biofuel
Arief Widjaja, Timoteus Yuwono and Eduward Rolanda
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A-79 Size Reduction, Steaming and Enzymatic Hydrolysis Of Palm Oil Empty Fruit Bunch
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A-80 Integrated System for Underutilised Biomass Supply Chain
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A-81 Effect of Bread Yeast and Tempeh Yeast on Total Titrable acidity (TTA) and pH during Cassava Fermentation
Setiyo Gunawan, Ary Yusen Pratama, Rima Nur Febriani, Sri Rachmania Juliastuti, Tontowi Ismail, and Tri Widjaja
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A-82 Composition and Analysis of Calophyllum Inophyllum Seed and It’s Oil
Setiyo Gunawan, Bayu Biru Chandra, Filan Setiawan, Mulyanto, Sri Rachmania Juliastuti, Arief Widjaja, Tri Widjaja
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A-83 In-Situ Production of Biodiesel from Rice Bran and Its Effect on Carbohydrate Recovery in Defatted Rice Bran
Siti Zullaikah, M. Rachimoellah, Sumarno and Tri Widjaja
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A-84 Biodiesel Production from Cottonseed Oil via Transesterification Method Using Cao as Catalyst
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A-85 Natrium Hydroxide (Naoh) As Alkaline Hydrolysis On Pretreatment Of Water Hyacinth (EichorniaCrassipes) As Raw Material In Biogas Production
Sri Rachmania Juliastuti, Nuniek Hendrianie, Jaka Abdillah, Gawa Reza Mahadin
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A-86 Agent-based Modeling of Visible Light-Driven Hydrogen Production
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B. Process System Engineering
B-01 Mathematical Modelling of a Solid Oxide Fuel Cell For The Thermal Modeling
Seyedahmad Hajimolana, Mohd Azlan Hussain, Jayakumar Natesan Subramanian Nayagar, Wan Wan Ashri Wan Daud, Mohammed Harun Chakrabarti
B-02 Thermal Conductivity Enhancement of Alumina Nanoparticles in an Aqueous [HMIM]LS Solution
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B-03 Discussion on Time Difference Models for Application of Soft Sensors
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B-04 A Statistical Approach for Selecting Control Components in Process Design
Trung Kim Nguyen, Tetsuo Fuchino
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B-05 The Treatment Of A Simulated Liquid Radioactive Waste Containing Tributyl Phosphate Using Ozone Followed By Adsorption
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B-06 PT Badak NGL Case: Optimum LNG Plant Operation
Akbar Surya Laksamana, Johan Anindito Indriawan
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B-07 PT Badak NGL Case: Optimization of Molecular Sieve Dehydration Regeneration
Dedik Rahmat Ermawan
Process Failure Of The High Pressure CO2 Stripper Urea Plant Pusri-IB
Andri Azmi, Devie Herdiansyah
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Next Generation in Biomass Processing: Extraction Process and Depolymerization
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Henry’s Constant Of Polar Solutes In Polymer Solutions
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Optimisation Of Ls54/Dx Aqueous Two Phase System Conditions for Cutinase Recovery
Fariza Akmal Abdul Mutalib, Jamaliah Md Jahima, Farah Diba Abu Bakar, Abdul Wahab Mohamad and Osman Hassan
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Principal Component Analysis of Optimum Linear Estimator in Chemical Processing System
Marthen Luther Doko
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State and Parameter Estimation of Large Scale Chemical Processing System
Marthen Luther Doko
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A decision modeling approach to evaluate the climate change mitigation options in the Philippines
Michael Angelo B. Promentilla, Katrina C. Angelesa Carla Angeline M. De la Cruz, Kathrina G. Tana
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B-15  Esterification of Phthalic Anhydride
Suprihastuti S Rahayu, Sofiyah, and Inga R Rossytha
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B-16  Optimization of Hydroxylation Reaction For Synthesis of Polyol From Epoxidized Palm Oil Methyl Ester
Edy Purwanto, Emma Savitri, Julian Wiriadi and Linvan Christinawati
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B-17  Design and Control of Alkali-Catalyzed Transesterification Reactors
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Department of Chemical Engineering, Faculty of Engineering, Kasetsart University, Bangkok, 10900, Thailand

B-18  A Dynamic Model for Ultrasonic – Assisted Extraction of Bio-Active Compounds from Natural Products
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B-19  Study on Chemical Reaction Equilibrium of Methanol Synthesis in Liquid Phase
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B-20  Different Types of Observers Applied in Process Systems
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B-21  The Development of Pertamax Racing
**B-22** Design and Control of Biodiesel Production in Esterification Section  
*Apichat Saejio, and Kulchanat Prasertsit*  
Department of Chemical Engineering, Prince of Songkla University, Hatyai Thailand

**B-23** Dynamic Simulation the Influence of Gas Compressor Suction Pressure Control to Improve Anti Surge Control System Performance in Two Stages Centrifugal Gas Compression System  
*Rudy Winarto, Tri Partono Adhi*  
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**B-24** Optimal Design Based RSM and ANN of High Vacuum Distillation for Beta-Carotene Recovery  
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Department of Chemical Engineering, Prince of Songkla University, Songkhla, 90112, Thailand  
Department of Chemical Engineering, Burapha University, Chonburi, 20131, Thailand

**B-25** Dynamic Simulation of Optimization of Load Sharing Compressor and Line Packing Utilization  
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**B-26** Optimization Process of Biodiesel Production with Ultrasound Assisted by Using Central Composite Design Methods  
*Widayat, Hantoro Satriadi, Oki Yuariski and Djoko Murwono*  
Department of Chemical Engineering, Diponegoro University Semarang Indonesia  
Center of Biomass and Renewable Energy (C-BIORE) Diponegoro University

**B-27** Dynamic Simulation and Control in A Non-Interacting-Tank System  
*Yulius Deddy Hermawan*  
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**B-28** Technical and Economics study of biodiesel production by supercritical transesterification  
*Tanya Tippayasri, Veerayut Lersbamrungsuk*
Modelling of Risk Assessment Using Layer of Protection Analysis (LOPA) on Enclosed Ground Flare at Onshore Facilities
Renanto Handogo, Hizkia Alexander Widianto Takasana, and Donnyanto Adrian Limadinata
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C. Chemical Engineering Fundamentals

C-01 Improvement of Antifouling Potential on Anion Exchange Membrane by Layer by Layer Deposition
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C-02 Effect of Coalescer Height to Oil Separation in Produced Water Using Gas Flotation Vessel Cell
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C-03 Comparison of Cutinase Separation in Different Chromatographic Media
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C-04 Hydrothermal Extraction of Valuable Compounds from Kikurage (*Auricularia auricula-judae*)
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C-05 PVT Properties for Mixtures of Ionic Liquid 1-Butyl-3-Methylimidazoliumbis(Trifluoromethylsulfonyl)imide\([C_{4}mim][NTf_{2}]\) with Anisole
Elisabeth Widowati, Ming-Jer Lee
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C-06  CFD Simulation and ERT visualization of Gas-Liquid Oscillatory Flow in a Baffled Column
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C-07  A Study on The Application of Orange Peel Waste as Low Cost Biosorbent for Dye Removal
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C-08  Simple Extraction Method of Galanthamine from Narcissus pseudonarcissus bulbs
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Leiden University, Institute of Biology, Natural Products Laboratory, 2300 RA, Leiden, The Netherlands

C-09  Incorporation of Fractional Surface Coverage on Extended Langmuir Isotherm: Binary Adsorption of Evans Blue and Malachite Green onto Organo-Bentonite
Suryadi Ismadji, Alfin Kurniawan, and Hogiartha Sutiono
Department of Chemical Engineering, Widya Mandala Surabaya Catholic University, Kalijudan 37, Surabaya 60114, Indonesia

C-10  Density Based Modeling of Epicatechin Solubility in Supercritical Carbon Dioxide Fluid
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C-11  Transesterification mechanism for PET recycle by molecular orbital method
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C-12  Kinetics of Amidation for The Synthesis of Diethanolamide From Methyl Ester and Diethanolamine by Using Sulfuric Acid Catalyst
**C-13** Effect of Agitation on the Metastable Zone, Nucleation and Growth of Struvite Crystals in a Batch Crystallizer
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**C-14** Shock Loads and Revival of Activity after Shutdown in Single Stage Stirred Tank Anaerobic Reactors fed Continuously and Intermittently
_Herawati Budiaustti, Pratap Pullammannappallil, and Ralf Cord-Ruwisch_
Chemical Engineering Department, The State Polytechnic of Bandung, Bandung 40012, Indonesia
Agricultural and Biological Engineering Department, University of Florida, Gainesville, USA
Environmental Sciences and Biotechnology, Murdoch University, Perth, Australia

**C-15** Bioproduct-Based Solvents for Dissolving Styrofoam and Comparison of its Solubility with Thermodynamic Model
_J.P. Sitompul, R. Simon, F.X. Ruben, and H.W. Lee_
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**C-16** Isolation and Physicochemical Properties of Starches from Vietnamese Limnophila aromatic
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**C-17** Mass Transfer of stevioside in stevia rebaudiana extraction
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**C-18** Thermophysical Characterization of Glycol (DEG/TEG/T₄EG) + TRIS + Water: Measurements and Correlation
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C-19 Liquid-Liquid Equilibrium of Acetonitrile + Water in the Presence of Biological Buffer MOPS
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C-20 Analysis of Flux Decline during Microfiltration of Different Types of Feed
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C-21 The Use of Ion-Exchange Resin in The Production of Clean Biodiesel
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C-22 Co-solvent Selection for Supercritical Fluid Extraction of Essential Oil and Bioactive Compounds from Polygonum minus
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C-23 Vegetable oil reforming for high-temperature PEMFCs
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C-24 Novel heterogeneous monolithic catalyst in biodiesel production: A review
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C-25 Comparison of Pyrolysis Products between Jatropha Curcas L Waste and Jatropha Curcas L Nut
Hary Sulistyo, Khaurusy Zulhilmi and Baskara Aji Nugraha
| C-26 | Enhancing CO2 Adsorption Using Strong Base Anion Exchange Resin  
Anies Mutiari, Wiratni, and Aswati Mindaryani  
Department of Chemical Engineering, Gadjah Mada University, Yogyakarta 55281, Indonesia  
Center for Material and Technical Product, Ministry of Industry, Bandung 40135, Indonesia |
| C-27 | Liquefaction of low-molecular-weight extracts obtained from low-rank coal and biomass by degradative solvent extraction under mild condition  
Dedy Eka Priyanto, Xian Li, Ryuichi Ashida, Kouichi Miura  
Department of Chemical Engineering, Kyoto University – Japan |
| C-28 | Effect of Paraffins on Benzene Photocatalytic Oxidation of Clean Room in Semiconductor Fab  
Yi-Ting Wu, Yi-Hui Yu, Jeffrey Chi-Sheng Wu, Angela Yu-Chen Lin, Luh-Maan Chang, and Ming-Hao Hsu  
Department of Chemical Engineering, National Taiwan University, Taipei 106 Taiwan  
Department of Civil Engineering, National Taiwan University, Taipei 106 Taiwan  
Graduate Institute of Environmental Engineering, National Taiwan University, Taipei 106 Taiwan |
| C-29 | Kinetic Evaluation of the Graft Copolymerization of Acrylic Acid onto Starch Based on Concentration Measurements and on Torque Observation  
Judy R. Witono, Hero J. Heeres, Leon P.B.M. Janssen, Inge W. Noordergraaf  
Department of Chemical Engineering Parahyangan Catholic University, Bandung 40141 Indonesia  
Department of Chemical Engineering University of Groningen, Groningen 9700AB The Netherlands |
| C-30 | Identification of Potential Dyes and Developing Methods to Improve Dye-sensitized Solar Cell’s Efficiency  
I. Noezar, A. Z. Abidin, J. Jaya, and Hendra  
Department of Chemical Engineering Faculty of Industrial Technology, Institut Teknologi Bandung Jl Ganesa 10 Bandung 40132 Indonesia |
| C-31 | Separation of Aromatic Hydrocarbons from Cracked Oils by Solvent Extraction  
Yoshihisa Yoshimura, Hiroaki Habaki, and Ryuichi Egashira  
Department of International Development Engineering, Tokyo Institute of Technology, 2-12-1 O-okayama, Meguro-ku, Tokyo 152-8550 Japan |
C-32  Prediction of Solubilities of CO, H2 and Its Mixture in Various Solvents  
Joko Waluyo and Herri Susanto  
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C-33  Optimizing Lipase Immobilization by Entrapment Method on Chitosan as Biocatalyst for Biodiesel Synthesis  
Heri Hermansyah, Merisa Bestari Faiz, Intan Afridawaty Sipangkar and Renly James Yosua  
Department of Chemical Engineering, University of Indonesia, Depok 16424, Indonesia

C-34  Miscibility Development Calculation in Model Oil Injection by Flare-Flue Gas Mixtures  
Tjokorde Walmiki Samadhi, Stephanie L.U. Sutoko, and Utjok W.R. Siagian  
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Petroleum Engineering Program, Bandung Institute of Technology, Bandung 40132, Indonesia

C-35  Adsorption of copper(II), cadmium(II) and zinc(II) ions by SDS-functionalized mesoporous silica  
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Department of Chemical Engineering, Faculty of Engineering and Industrial Technology, Silpakorn University, Nakhon Pathom 73000, Thailand.

C-36  Dye Adsorption on Silica-filled ENR/PVC Beads  
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C-37  Phase Behaviour Of CH4-CO2 Mixture in Cryogenic Heat Exchanger Process  
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Department of Chemical Engineering, Sepuluh Nopember Institute of Technology, Surabaya 60111, Indonesia

C-38  Optimization research into the ultrasonic-assisted extraction to separate polyphenol from green tea waste  
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Department of Quality Management, HUST, No. 1 Dai Co Viet Str., Hanoi, Vietnam.

C-39 Kinetic Reaction Comparison of CO2 Absorption Into Promoted Potassium Carbonate (K2CO3)
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C-40 Supercritical CO2 Extraction and Micronization of Carotenoids
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C-41 Kinetic studies on the removal of reactive blue 19 and reactive yellow 145 by Putsan(tiwi) clay
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C-42 Activation of Mesoporous Carbon Synthesized from SBA-16 for CO2 Storage
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C-44 A Review on CFD Modeling of Fluidization Bed Gas Phase Reactor For Polyolefin Production
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C-45 Growth of Carbon Nanotube from Banana Peel Activated Carbon with Simple Pyrolysis Methode and Methane Decomposition

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C-46 Mass Transfer Model for Basic Blue Adsorption onto Pillared Bentonite Clay by Taking Into Account the Intra Particle Concentration Gradient

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C-47 Removal of Terpenes from Citrus Oil Model Compounds with Supercritical CO\textsubscript{2} Fractionation

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C-48 Flow instabilities in Agitated Tanks with Side Entering Mixers

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C-49 A Computational Fluid Dynamics Study into Turbulent Characteristic that Affect the Combustion Process

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C-50 Liquid-Liquid Equilibria of Ternary System Eugenol + Isopropanol + Water at 303.15, 313.15, and 323.15 K

Zuhriyyah R.A, Rachma F., and Nur Andriani P.K, Kuswandi
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C-51 Bitumen Extraction from Asbuton Rock Using Pertasol

Susianto, Ali Altway, and Suprapto
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D-01 Investigation of Rice Husk Loading on The Characterization and Water Permeation of ENR/PVC Composite Membrane
Norfarhana Ab. Samad, Nazwa Jon, Rizafizah Othaman and Ibrahim Abdullah
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D-02 One step synthesis of hybrid single-wall carbon nanohorns with metallic nanoparticles using arc discharge in water with nitrogen gas injection
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D-03 Preparation of Amine-Grafted Mesoporous Material MCM-48 Using Geothermal Solid Waste Silica
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Argenia B. Co, Daryl Anne T. de Joya, Eunice H. Mabutas, and Rolly G. Santos
School of Chemical Engineering and Chemistry
Mapúa Institute of Technology, Manila Philippines

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Kristine Marfe S. Amer, Maria Lourdes P. Dalid, PhD, and Ming-Chun Lu, PhD
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**E-17** Two Stages Phytoremediations Of Palm Oil Mill Effluent (Pome) By Using Apu-Apu(Pistia Stratiotes) Plant And Algae Spirulina Sp For Protein Production
Hadiyanto and Danny Soetrisnanto
Center of Biomass and Renewable Energy (CBIORE)
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Ultrasound-Assisted Oxidative Desulfurization of Organosulfur Compounds using Ferrate (VI) from Sludge

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**Additional Paper**

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**Zilfahmiati, Ronny Purwadi**
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**Ad-2** Numerical Study on A Bead Mill by Lagrangian-Lagrangian Coupling Method
**Yoshinori YAMADA, Xiaosong SUN, and Mikio SAKAI**
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Research Fellow of the Japan Society for the Promotion of Science
Department of Nuclear Engineering and Management
School of Engineering, University of Tokyo

**Ad-3** Effect H₂O and SO₂ Concentration on Selective Catalytic Reduction of Nitrogen Oxide by Ammonia over V₂O₅-WO₃/TiO₂ Catalyst
**Piyasan Praserthdam and Phraewphan Kuntanate**
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**Ad-4** Synthesis of Gold Nanostructures Using Paper for Active SERS Substrate
**Yian Tai, Sudeshna Kar, and Christa Desmonda**
Department of Chemical Engineering, National Taiwan University of Science and Technology, Taipei 10607 Taiwan
Dynamic Simulation and Control in A Non-Interacting-Tank System

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Abstract

Relative Gain Array (RGA) analysis has been previously implemented on design of control configuration of Non-Interacting-Tank (NIT) system [Hermawan et al, 2010]. The previous work produced the process control configuration of NIT system. The aim of this research is to examine the resulted process control configuration of NIT system through closed loop dynamic simulation. The developed mathematical model is solved numerically. Trial and error method has been used for tuning of the feedback control parameters. According to my dynamic simulation, the resulted process control configuration of NIT system produces stable responses to a change in the input mass disturbance load.

Keywords: Closed Loop; Control Configuration; Dynamic Simulation; Non-Interacting-Tank.

1. Introduction

The multi-capacity processes such as Non-Interacting-Tank (NIT) and Interacting-Tank (IT) are frequently used in chemical process industries. However, the propagations of mass and thermal disturbances are possibly occurred in those multi-capacity processes. Therefore, implementation of automatic process control on the multi-capacity processes is very important to overcome the disturbances.

There are some contributions to the study of process dynamic and control. Composition dynamic in a mixing tank has been studied experimentally [Hermawan et al, 2012]. Dynamic simulation and composition control in a mixing tank has also been presented recently [Hermawan, 2012]. Process Reaction Curve was implemented for tuning of temperature control parameters in a stirred tank heater [Hermawan, 2011]. The use of Relative Gain Array (RGA) for design of process control configuration of NIT system has been studied experimentally [Hermawan et al, 2010]. This study produced the control configuration of NIT system, with 4 couples of CV-MV (Controlled Variable – Manipulated Variable).

The goal of this research is to examine the control configuration of NIT system which is resulted by our previous work [Hermawan et al, 2010]. The mass disturbance load is made to examine the performance of control configuration of NIT. PI (Proportional Integral) Control is implemented in all control loops of NIT system. PI Control parameters are tuned based on trial and error method. Dynamic behaviors of NIT’s control system will be explored through rigorous dynamic simulation. The Scilab software is utilized to carry out dynamic simulation.

2. Experimental

Experimental apparatus setup is shown in Figure 1. As can be seen from Figure 1, tanks No. 1 and No. 2 are considered as a NIT system. In this research, water was used as a fluid with both of its density and its heat capacity are assumed constant. Tank-1 has an input stream with volumetric rate of \( f_i \, (\text{cm}^3/\text{sec}) \) and temperature of \( T_i \, (\text{oC}) \). The output stream of Tank-1 is then flowed to Tank-2. Electric heater was employed in Tank-2 to heat liquid in the tank. The liquid levels of both Tank-1 and Tank-2 are indicated by means of glass level indicator. The liquid temperature and flowrate are measured by means of thermometer and U-tube manometer respectively. The steady state parameters of NIT system are shown in Table 1. This steady state parameters results are then used as the initial conditions for closed loop dynamic simulation.
Table 1. Steady state parameters of NIT System [Hermawan et al, 2010].

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<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
<th>Parameters</th>
<th>Value</th>
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<tbody>
<tr>
<td>Input flowrate, ( f_i ) [cm³/sec]</td>
<td>15.2</td>
<td>Input flowrate, ( f_i ) [cm³/sec]</td>
<td>15.2</td>
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<tr>
<td>Output flowrate, ( f_1 ) [cm³/sec]</td>
<td>15.2</td>
<td>Output flowrate, ( f_j ) [cm³/sec]</td>
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</tr>
<tr>
<td>Liquid level, ( h_i ) [cm]</td>
<td>15.5</td>
<td>Liquid level, ( h_j ) [cm]</td>
<td>15.1</td>
</tr>
<tr>
<td>Temperature, ( T_1 ) [°C]</td>
<td>28</td>
<td>Temperature, ( T_1 ) [°C]</td>
<td>39.5</td>
</tr>
<tr>
<td>Input valve open (%)</td>
<td>40</td>
<td>Electric heat, ( q_e ) [watt]</td>
<td>800</td>
</tr>
<tr>
<td>Output valve open (%)</td>
<td>50</td>
<td>Input valve open (%)</td>
<td>50</td>
</tr>
<tr>
<td>Tank surface area, ( A_j ) [cm²]</td>
<td>491</td>
<td>Output valve open (%)</td>
<td>50</td>
</tr>
</tbody>
</table>

Notes:
1: Tank-1 for NIT system
2: Tank-2 for NIT system
3: Storage Tank
4: Valve
5: Pump
6: Level Indicator
7: Thermometer
8: U-Tube Manometer
9: Electric Heater
10: Watt-meter
11: Electricity

Figure 1. Experimental apparatus setup [Hermawan et al, 2010].

Mass balance of Tank-1 can be written as follow:
\[
\frac{d h_1(t)}{dt} = \left[ f_i(t) - f_1(t) \right] / A_1
\] (1)

Mass and energy balance of Tank-2 are:
\[
\frac{d h_2(t)}{dt} = \left[ f_i(t) - f_2(t) \right] / A_2
\] (2)
\[
\frac{d T_2(t)}{dt} = \left[ f_i(t) T_1 - f_2(t) T_2 + q_e(t) / (\rho c_p) - T_2 \left( f_1(t) - f_2(t) \right) \right] / V_2
\] (3)

Control configuration of NIT system resulted by our previous work is illustrated in Figure 2. There are 4 couples of CV-MV in NIT’s control configuration as shown in Table 2; They are flow controller in the input stream of Tank-1, liquid level controller in Tank-1, liquid level controller in Tank-2, and liquid temperature controller in Tank-2. Tuning control parameters for all controllers are also listed in Table 2. In this work, feedback PI controls are implemented to maintain the controlled variables as its set point. Manupulated variables for all controllers are as follow:
Manipulated variable of FC-01: \( f_i(t) = f_i^{SP} + K_c e_1(t) + \frac{K_c}{\tau_I} \int e_1(t) dt \) (4)

Where: \( e_1(t) = f_i^{SP} - f_i(t) \) (5)

Manipulated variable of LC-01: \( f_1(t) = \tilde{f}_1 + K_c e_2(t) + \frac{K_c}{\tau_I} \int e_2(t) dt \) (6)

Where: \( e_2(t) = h_1^{SP} - h_1(t) \) (7)

Manipulated variable of LC-02: \( f_2(t) = \tilde{f}_2 + K_c e_3(t) + \frac{K_c}{\tau_I} \int e_3(t) dt \) (8)

Where: \( e_3(t) = h_2^{SP} - h_2(t) \) (9)

Manipulated variable of TC-01: \( q_e(t) = \bar{q}_e + K_c e_4(t) + \frac{K_c}{\tau_I} \int e_4(t) dt \) (10)

Where: \( e_4(t) = T_2^{SP} - T_2(t) \) (11)

The developed mathematical model of NIT control configuration system is solved numerically with the easiest way of explicit Euler. The free software Scilab is chosen to carry out the closed loop dynamic simulation. The input mass disturbance load is made in order to examine the performance of NIT control configuration. The closed loop responses of control system to a change in the mass disturbance load will then be explored in this work.

Table 2. Couples of CV-MV and tuning control parameters of NIT System

<table>
<thead>
<tr>
<th>Controller</th>
<th>CV</th>
<th>MV</th>
<th>Control Type</th>
<th>Tuning Control Parameters</th>
</tr>
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<tbody>
<tr>
<td>FC-01</td>
<td>( f_i )</td>
<td>( f_i )</td>
<td>PI</td>
<td>( K_c )</td>
</tr>
<tr>
<td>LC-01</td>
<td>( h_1 )</td>
<td>( f_1 )</td>
<td>PI</td>
<td>-5 [cm²/sec]</td>
</tr>
<tr>
<td>LC-02</td>
<td>( h_2 )</td>
<td>( f_2 )</td>
<td>PI</td>
<td>-5 [cm²/sec]</td>
</tr>
<tr>
<td>TC-01</td>
<td>( T_2 )</td>
<td>( q_e )</td>
<td>PI</td>
<td>15 [watt/°C]</td>
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Figure 2. Control configuration of NIT System
Figure 3. Dynamic responses of NIT control system to a change in set point of $f_i$. 
3. Results and Discussion

Figure 3 shows the closed loop responses to a change in the input flowrate of Tank-1 \((f_i)\). The set point of input flowrate \(f_i\) is increased by an amount of 10 cm³/sec at time equals 120 seconds (Figure 3.a). Since the input flowrate of Tank-1 increases, it is understandable that the liquid level in Tank-1 \((h_1)\) rises first, and then it can be returned to its set point of 15.5 cm at time about 960 seconds (Figure 3.b). The output flowrate of Tank-1 \((f_i)\) is manipulated to maintain the liquid level in Tank-1 at its set point (Figure 3.c). Finally, the flowrate \(f_i\) achieves new steady state value of 25 cm³/sec at time equals 960 seconds (Figure 3.c).

The characteristic change of Tank-1 propagates to the next tank, i.e. Tank-2. The dynamic behavior of liquid level in Tank-2 is similar with that in Tank-1. However, the liquid level of Tank-2 can be returned to its set point of 15.1 cm at time equals 1560 seconds (Figure 3.d). The output flowrate of Tank-2 \((f_i)\) is manipulated to keep the liquid level in Tank-2 constant. The flowrate \(f_i\) rises a new steady state value of 25 cm³/sec at time equals 1560 sec (Figure 3.e).

As can be seen from Figure 3.f, the liquid temperature of Tank-2 \((T_2)\) decreases first as the input flowrate increases. The liquid temperature \(T_2\) is controlled by manipulating the electric heat \(q_e\). The electric heat must be increased to rise the liquid temperature \(T_2\). Finally, the electric heat \(q_e\) achieves a new steady state value of 1200 watt at time equals 1560 sec (Figure 3.g).

4. Conclusion

This paper has discussed dynamic simulation and control in a NIT system. The resulted control configuration of NIT system has been examined through rigorous dynamic simulation. As can be seen from our closed loop dynamic simulation, the NIT control configuration gives stable responses to a change in the input mass disturbance load. This study also reveals that by developing the appropriate control configuration, i.e. proper couples of CV-MV, stable and fast responses can be achieved.

Acknowledgements

I appreciate the technical support on the use of free software SCILAB. I gratefully acknowledge Ir. Yogi Suksmono, MS of UPN “Veteran” Yogyakarta for valuable discussion. I also thank Ranggi Habibie Narno Putra ST and Mitha Puspitasari ST for helping me during my research in laboratory.

Nomenclature

- \(A_{1,2}\) surface area of Tank 1,2 (cm²)
- \(c_p\) heat capacity of fluid (J/(gr.°C))
- \(e_{1,2,3,4}\) error for FC-01, LC-01, LC-02, and TC-01
- \(f_{i,1,2}\) volumetric flowrate of stream i, 1, 2 (cm³/second)
- \(h_{1,2}\) liquid level of Tank 1, 2 (cm)
- \(h_{1,2}^{SP}\) set point of liquid level of Tank-1 (cm)
- \(h_2^{SP}\) set point of liquid level of Tank-2 (cm)
- \(K_c\) proportional gain controller
- \(q_e\) electric heat/energy (Watt or J/second)
- \(T_{1,2}\) liquid temperature of Tank 1, 2 (°C)
- \(T_2^{SP}\) set point of liquid temperature of Tank-2 (°C)
- \(t\) time (second)
- \(V_{1,2}\) liquid volume in Tank 1,2 (cm³)

Greek letters

- \(\rho\) liquid density (gr/cm³)
- \(\tau_i\) integral time constant (second)

Abbreviations

- CV Controlled Variable
- FC Flow Controller
- LC Level Controller
- MV Manipulated Variable
- NIT Non-Interacting-Tank
- TC Temperature Controller
References


