# 2024 ICACE CONFERENCE

The 5th International Conference on Applied Convergence Engineering

## August 12-13th, 2024

National Korea Maritime and Ocean University
Busan, Republic of Korea

# CONTENTS

WELCOME MESSAGE ..... 1

COMMITTEES ..... 2

CONFERENCE SCHEDULE ..... 5

CONFERENCE VENUE ..... 7

CONFERENCE SESSION PLACE ..... 8

BANQUET INFORMATION FOR ICACE 2024 ..... 10

FIELD TOUR INFORMATION ..... 11

SESSION SCHEDULE ..... 12

# WELCOME MESSAGE

## The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

On behalf of the ICACE 2024 organizing committee, I am honored and delighted to welcome you to the 5th International Conference on Applied Convergence Engineering (ICACE 2024). We are pleased to invite you to join us from August 12-13, 2024, at the National Korea Maritime & Ocean University in Busan, Republic of Korea.

Busan, with its rich cultural heritage and stunning landscapes, provides an inspiring backdrop for this year's conference. ICACE 2024 promises to deliver a diverse and impactful program, featuring cutting-edge research and industry insights across all areas of the maritime field. Whether you are from academia or industry, you will find our sessions thoughtfully designed to address the pressing challenges and explore the future opportunities within the maritime sector.

As the maritime industry navigates through financial uncertainties and a sluggish global economy, there is renewed optimism for a full recovery by 2024. This anticipated rebound presents a critical window to innovate and shape the future through new technologies and practices. We believe that ICACE 2024 will be at the forefront of these developments, providing a platform for meaningful dialogue and collaboration.

International cooperation and knowledge exchange are key to the progress of maritime engineering and technology. ICACE 2024 is more than just a conference; it's an opportunity to engage with forward-thinking professionals and to contribute to the sustainable growth of the maritime industry. We look forward to your active participation in the discussions that will help define the future of our field.

We are dedicated to ensuring that ICACE 2024 is a rewarding and memorable experience for all attendees. We warmly welcome you to be a part of this dynamic event.

Welcome to ICACE 2024!

**Prof. Hwan-Seong Kim**
Korea Maritime & Ocean University
General Chair
Organizing Committee, ICACE 2024

**Prof. You-Teak Kim**
Korea Maritime & Ocean University
Organizing Chair
Organizing Committee, ICACE 2024

# COMMITTEES

| COMMITTEES MEMBERS | |
|---|---|
| **CHAIRMAN** | Hwan-Seong Kim, KMOU, Korea |
| **ORGANIZING CHAIRMAN** | You-Taek Kim, KOSME, Korea |
| **CO-CHAIRMEN** | Tan Tien Nguyen, DCSELab, Vietnam |
| | Chao-Min Zhang, SUES, China |
| | SangBong Kim, PNFPT, Vietnam |
| **THE INTERNATIONAL ADVISORY COMMITTEE** | Trong Hieu Bui, HCMUT, Vietnam |
| | Duy Anh Nguyen, HCMUT, Vietnam |
| | Ngoc Hien Do, HCMUT, Vietnam |
| | Quoc Chi Nguyen, HCMUT, Vietnam |
| | Viet Thang Tran, NTTU, Vietnam |
| | Kweonha Park, KMOU, Korea |
| | Kyu-Jung Chae, KMOU, Korea |
| | Dongwoo Sohn, KMOU, Korea |
| | Shu-Meei Liu, SUES, China |
| | Jian Zhao, SUES, China |
| | Hong Phuc Bui Duc, TULSA, USA |
| | Daisuke Watanabe, TUMST, Japan |

## CONFERENCE SECRETARIAT

| | |
|---|---|
| **CONFERENCE SECRETARIAT** | Van Tu Duong, HCMUT, Vietnam |
| | Jaeha Lee, KMOU, Korea |
| | Truong Ngoc Cuong, KMOU, Korea |
| | Junghyuk Ko, KMOU, Korea |
| | Jian-Guang Zhai, SUES, China |

## THE TECHNICAL AND ORGANIZING COMMITTEE

| | |
|---|---|
| **THE TECHNICAL AND ORGANIZING COMMITTEE** | Huy Hung Nguyen, Saigon University, Vietnam |
| | Truong Long Nguyen, HCMUT, Vietnam |
| | Thanh-Long Le, HCMUT, Vietnam |
| | Thanh Tung Luu, HCMUT, Vietnam |
| | Van Tu Duong, HCMUT, Vietnam |
| | Thi-Hong-Nhi Vuong, HCMUT, Vietnam |
| | Jae-Hong Oh, KMOU, Korea |
| | Do-Sik Shim, KMOU, Korea |
| | Keun-Jae Yoo, KMOU, Korea |
| | Jun-Ho Huh, KMOU, Korea |
| | Min Yoon, KMOU, Korea |
| | Jin Yang, SUES, China |
| | Dong-Hong Wang, SUES, China |
| | Tian-Li Zhang, SUES, China |

| ORGANIZED BY | |
|---|---|
| ORGANIZED BY | National Korea Maritime & Ocean University, Korea |
| | National Key Laboratory of Digital Control and System Engineering (DCSELab), Vietnam |
| | Shanghai University of Engineering Science, China |
| | Global R&E Program for Interdisciplinary Technologies of Ocean Renewable Energy (KMOU BK21-Four group) |
| | Northeast-Asia Shipping and Port Logistics Research Center, KMOU, Korea |

| SPONSORED BY | |
|---|---|
| SPONSORED BY | Vietnam National University, Ho Chi Minh City |
| | Ho Chi Minh City Univ. of Technology (HCMUT), Vietnam |
| | Phuong Nam Fire Protection Technology (PNFPT) Company Limited |

# CONFERENCE SCHEDULE

| Monday, August 12th, 2024 | | | | |
|---|---|---|---|---|
| **Welcome Session** | | | | |
| **Start** | **End** | **Main contents** | **Speaker** | **Place** |
| **9:00** | **9:30** | Registration | | Rm 201 |
| **9:30** | **9:35** | Opening Address | Chairman, Prof. Hwanseong Kim | |
| **9:35** | **9:40** | Welcome Address | Vice President of KMOU, Prof. Yun-Su Ha | |
| **9:40** | **9:45** | Welcome Address | Co-Chairman, Prof. Tan Tien Nguyen | |
| **9:45** | **9:50** | Photo Time | | |
| **9:50** | **10:00** | Break Time | | |
| **10:00** | **10:25** | Keynote Lecture 1 | Prof. Jianguang Zhai | |
| **10:25** | **10:50** | Keynote Lecture 2 | Prof. Duy Anh Nguyen | |

| Monday, August 12th, 2024 | | | | |
|---|---|---|---|---|
| **Morning Session** | | | | |
| **Start** | **End** | **Session Name** | **Session Chairman** | **Place** |
| **11:00** | **12:30** | Special Session I: BK21 Four | Prof. Jaeha Lee<br>Prof. Keunje Yoo | Rm 807 |
| | | Session A: Smart Logistics | Prof. Sihyun Kim<br>Prof. Daisuke Watanabe | Rm 720 |
| | | Session B: Fusion Control | Prof. Duy Anh Nguyen<br>R. Prof. Truong Ngoc Cuong | Rm 718 |
| **12:30** | **14:00** | Lunch | | ALL |

# The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

**August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea**

| Monday, August 12th, 2024 | | | | |
|---|---|---|---|---|
| **Afternoon Session** | | | | |
| **Start** | **End** | **Session Name** | **Session Chairman** | **Place** |
| **14:00** | **16:00** | Special Session II: BK21 Four | Prof. Jaeha Lee<br>Prof. Jun-Ho Huh | Rm 807 |
| | | Session C: Intelligent Mechanism | Prof. Junghyuk Ko<br>Prof. Hoang Chieu Le Phan | Rm 720 |
| | | Session D: AI & Optimum (Poster) | Prof. Gyusung Cho<br>Prof. Van Tu Duong | Rm 718 |
| **18:00** | **20:00** | Banquet | Grand apple in Haeundae | |

| Tuesday, August 13th, 2024 | | | |
|---|---|---|---|
| **Technical Tour** | | | |
| **Start** | **End** | **Place** | **Activity** |
| **13:30** | **14:30** | Boarding the Busan North Port Guide Boat | Busan North Port sightseeing from the BPA boat |
| **14:30** | **15:10** | Busan International Passenger Terminal | Walking/Taxi |
| **15:00** | **16:00** | North Port Redevelopment Promotion Center and a visit to the Sky Garden | Explore with guidance in English |

# CONFERENCE VENUE

**Korean Maritime & Ocean University address**

- 727 Taejong-ro, Yeongdo-Gu, Busan 49112, Republic of Korea

**About Korean Maritime & Ocean University**

Based on the Jinhae Marine Officer School established in 1919, the Korea Maritime & Ocean University (KMOU) was opened in 1945 to pursue the goal of strengthening the country through the ocean. Since then, it has been producing experts in the maritime field, including the shipping industry, based on the noble educational philosophy of truth-finding, cultural creation, and character development, through which it has contributed to the development of the nation and society. While its past history focused on the development of KMOU as Korea's only specialized maritime university, its future is to lead the worlds oceans with the vision of becoming the world's best global maritime university. Lead a maritime nation by teaching and researching profound theories and methods of study under the educational philosophy of the Republic of Korea, and cultivate talents who can contribute to the development of the nation and society as well as the prosperity of mankind.

**From Gimhae International Airport**

- Take the Subway Busan Gimhae (Purple line) → Sasang Station(get off) → Take the bus bound for Taejongdae No. 8

※ Take the bus bound for Taejongdae, get off at the entrance of Haeyangdae; walk to the campus or travel by bus.

※ Bus No. 190 runs to the campus.

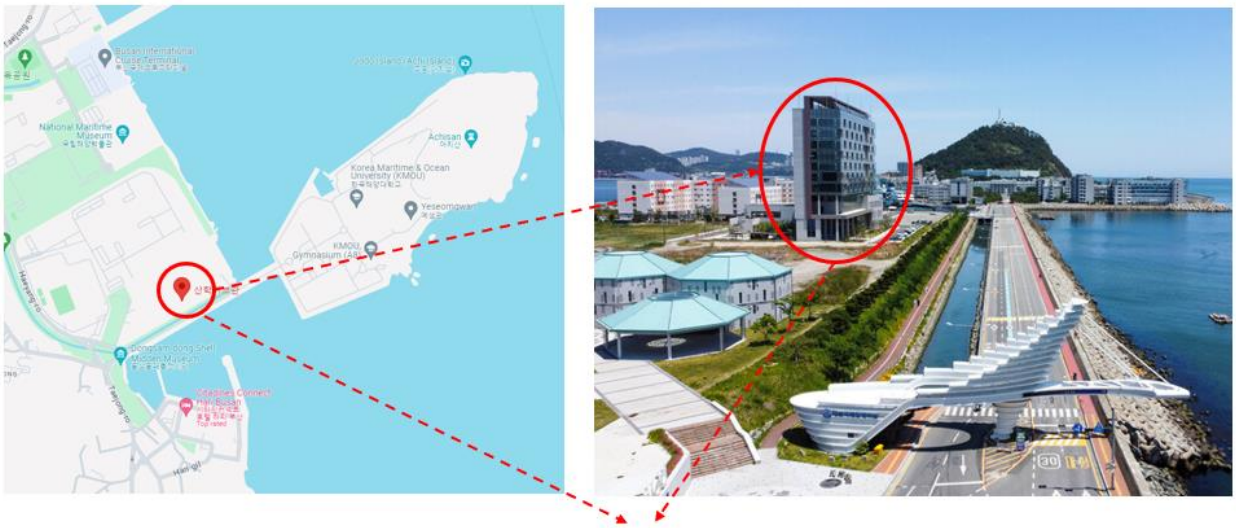

**< Korean Maritime & Ocean University Campus>**

# CONFERENCE SESSION VENUE

The conference session venue is approximately 50 meters (a 3-minute walk) from the KMOU main campus.

- **Place: Industry-Academic Hub Hall in KMOU (G2)**

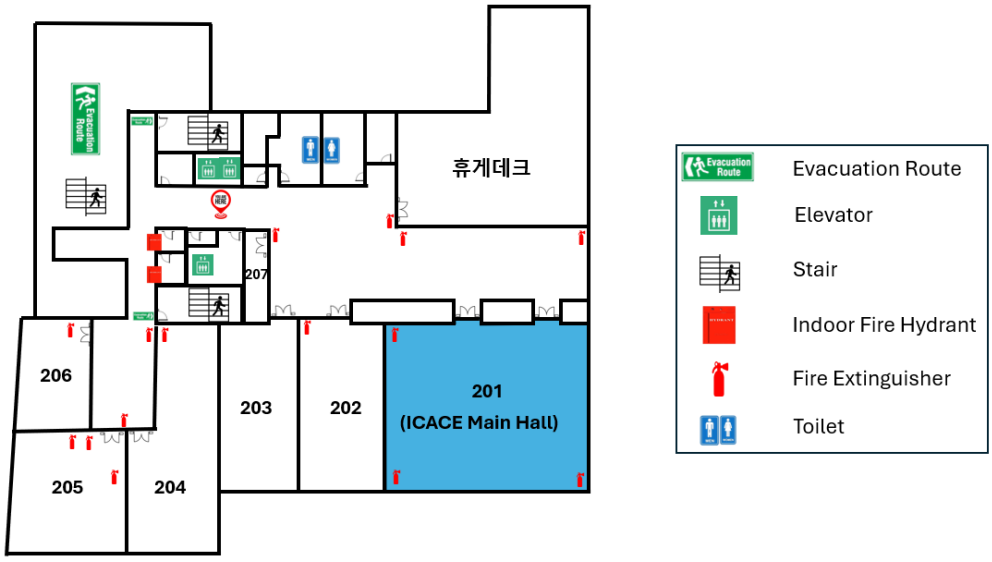
  Address : 1168-1 Dongsam-dong, Yeongdo-gu, Busan




**Conference session venue : Industry-Academic Hub Hall**

**< ICACE 2024 venue>**

- **The welcome session will take place in Room 201-G2 (Industry-Academic Hub Hall).**



- **The morning and afternoon session will be held on the 7th and 8th floors of G2 (Industry-Academic Hub Hall).**


| Session | Room |
|---|---|
| **Morning Session** | |
| **Special Session I: BK21 Four** | **Rm 807** |
| **Session A: Smart Logistics** | **Rm 720** |
| **Session B: Fusion Control** | **Rm 718** |
| **Afternoon Session** | |
| **Special Session II: BK21 Four** | **Rm 807** |
| **Session C: Intelligent Mechanism** | **Rm 720** |
| **Session D: AI & Optimum (Poster)** | **Rm 718** |

- **Lunch: All attendees will be provided with a lunch box at the conference venue in G2.**

# BANQUET INFORMATION FOR ICACE 2024

We are delighted to announce that the banquet for the ICACE 2024 conference will be held at the prestigious **Grand Apple Restaurant in Haeundae**.

**Venue Details:**

- Place: **Soho Hall (6 floor)**, Grand Apple Restaurant
- Address: 25 Centum 1-ro, Haeundae-gu, Busan


**Date and Time:**

- Date: August 12, 2024
- Time: from 18:00 to 20:00

**About the Venue:** **<Grand Apple restaurant>**

The Grand Apple Restaurant is renowned for its exquisite cuisine and elegant ambiance, offering a perfect setting for our conference banquet. Located in the vibrant district of Haeundae, the restaurant is easily accessible and provides a delightful dining experience with a variety of culinary delights.

**How to Get There (from KMOU):**

- By Taxi: Easily accessible by taxi from any location in Busan.

We look forward to enjoying a wonderful evening with you at the Grand Apple Restaurant. This will be an excellent opportunity to network, relax, and celebrate the success of the ICACE 2024 conference. If you have any dietary restrictions or special requests, please let us know in advance. For any inquiries regarding the banquet, please contact us via email: icace2024@kmou.ac.kr

**We look forward to your presence at the banquet!**

# FIELD TOUR INFORMATION

The field tour (from 13:30 to 15:30, August 13, 2024) offers an exploration of Busan North Port aboard a Guide Boat, along with insights into the North Port Redevelopment Promotion Center and a visit to the Sky Garden. Below is the detailed plan.

| Start | End | Place | Activity | Picture |
|---|---|---|---|---|
| 13:30 | 14:30 | Boarding the Busan North Port Guide Boat | ○ Meet in the BPA 1st floor parking lot at 13:20<br>○ Busan North Port sightseeing from the BPA boat (There is a commentary in English by BPA) |    |
| 14:30 | 14:50 | Busan International Passenger Terminal | TAXI |  |
| 14:50 | 15:30 | North Port Redevelopment Promotion Center and a visit to the Sky Garden | Explore with guidance in English from the staff |  |

**Meeting location (at 1:20 PM, August 13, 2024): 부산광역시 중구 대교로 122 (1st-floor parking area)**

**Detail map:**


**< Meeting place: BPA Office>**

# SESSION SCHEDULE

| Keynote Session: (10:00 - 10:50, Meeting Room 201) | | |
|---|---|---|
| **Chairman: Prof. Chiyeol KIM** | | |
| **Time** | **Paper ID** | **Title and Authors** |
| 10:00 - 10:25 | K-01 | **Joining of metal to plastic by laser welding**<br>Jianguang Zhai |
| 10:25 - 10:50 | K-02 | **The Development of E-Logistics in Vietnam**<br>Duy Anh Nguyen |

| Special Session I: BK21 Four (Monday, August 12th, Room 807) | | |
|---|---|---|
| Chairman: Prof. Jaeha Lee/ Prof. Keunje Yoo | | |
| **Time** | **Paper ID** | **Title and Authors** |
| 11:00 - 11:15 | BKI-01 | **Structural Analysis of Block-type Seawater Exchange Breakwater**<br>Jeongho Kim, Seungbok Lee, Meeju Lee, Dongwoo Sohn, Jaeha Lee |
| 11:15 - 11:30 | BKI-02 | **Effect of Polymer Type and Exposure Period of Marine Microplastics on Microbial Assemblage and Antibiotic Resistance Gene Enrichment**<br>Hyunsu Kim, Keunje Yoo |
| 13:30 - 11:45 | BKI-03 | **Study on CFD Simulation of Thunniform Shark Swimming**<br>Phan Huy Nam Anh, Hyeung-Sik Choi |
| 11:45 - 12:00 | BKI-04 | **Optimization of Crossflow Air Turbines for Enhanced Wave Energy Conversion Efficiency in Oscillating Water Columns**<br>B.H.B.P.D. Baddegamage, Seong Jong Bae, Seung Hyun Jang, Min Yoon |
| 12:00 - 12:15 | BKI-05 | **Comparison of microbial communities in different types of pig and samples in swine farms**<br>Gihan Lee, Keunje Yoo |
| 12:15 - 12:30 | BKI-06 | **Fabrication of Wear-Resistant Hardfacing of WC10%-Ni60AA Cermet/Inconel 718 via Laser Directed Energy Deposition**<br>Shanshan He, Sanghu Park, Do-sik Shim |

# The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

**August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea**

| Session A: Smart Logistics (Monday, August 12th, Room 720) | | |
|---|---|---|
| **Chairman: Prof. Sihyun Kim/Prof. Daisuke Watanabe** | | |
| **Time** | **Paper ID** | **Title and Authors** |
| 11:00 - 11:15 | A-01 | **Impact of hybrid loading system of CAVs and HDVs at Roll-On/Roll-Off Ports**<br>Sanghyung Park, Sihyun Kim |
| 11:15 - 11:30 | A-02 | **A Study on the Current State and Issues of Open Public Platforms in the Japanese Logistics Sector: A Case Study of General Logistics Company Seino Holdings**<br>Tetsuro Saisho |
| 13:30 - 11:45 | A-03 | **Evaluating the technical efficiencies in container terminal automation technologies using DEA**<br>Naleen De Alwis, Nam Hyung-Sik, Chang-Hoon Shin |
| 11:45 - 12:00 | A-04 | **An Economic Evaluation of EV Truck Introduction Based on Payback Period**<br>Weiyi Liu, Daisuke Watanabe |
| 12:00 - 12:15 | A-05 | **Assessing the Effectiveness of Cyber Risk Control Measures: A maritime stakeholders' perspective on mitigation measures**<br>Changki Park, Tran Thi Nguyet Minh, Nam Hyung-Sik |
| 12:15 - 12:30 | A-06 | **Track Check Locate Application: RFID-Based Smart Shopping Assistant**<br>Pham Quang Minh, Cho Gyu Sung |

| Session B: Fusion Control (Monday, August 12th, Room 718) | | |
|---|---|---|
| **Chairman: Prof. Duy Anh Nguyen/ R. Prof. Truong Ngoc Cuong** | | |
| **Time** | **Paper ID** | **Title and Authors** |
| 11:00 - 11:15 | B-01 | **Optimize Weighting Coefficients of Complementary Filter for IMU Sensors Utilizing the Golden Section Method**<br>Nhut Thang Le, Nguyen Toan Thang Huynh, Cong Toai Truong, Huy Hung Nguyen, Van Tu Duong, Tan Tien Nguyen |
| 11:15 - 11:30 | B-02 | **Dynamic Learning Policies and Predictive System for Enhanced Machine Failure Prediction in Stochastic Environments**<br>Le Quoc Thang, Bui Duc Hong Phuc, Truong Ngoc Cuong |
| 13:30 - 11:45 | B-03 | **Multi-Mode DC Electronic Load With Hybrid Control System**<br>Minh Nhat Huynh, Quoc Minh Lam, Cong Toai Truong, Ngoc Van Vu Thi, Huy Hung Nguyen |
| 11:45 - 12:00 | B-04 | **Optimizing the Traveling Salesman Problem with Gurobi and Mixed Integer Programming**<br>Dang Hoang Gia Bao, Hwan-Seong Kim |
| 12:00 - 12:15 | B-05 | **Root Locus Technique-based PID Control for Inspiratory Cycle Volume Control Mode of Two Double-Acting Piston Pump Ventilator**<br>Trung Dat Phan, Cong Toai Truong, Van Tu Duong, Huy Hung Nguyen, Tan Tien Nguyen |
| 12:15 - 12:30 | B-06 | **Estimating Object Dimensions Using Object Detection and SAM for Obstacle Avoidance in Autonomous Mobile Robots**<br>Long Le Ngoc Bao, Hwan-Seong Kim, Sam-Sang You |

| Special Session II: BK21 Four (Monday, August 12th, Room 807) | | |
|---|---|---|
| **Chairman: Prof. Jaeha Lee/Prof. Prof. Jun-Ho Huh** | | |
| **Time** | **Paper ID** | **Title and Authors** |
| 14:00 - 14:15 | BKII-01 | **Synergistic meet of dark fermentation and microbial electrolysis cell for biohydrogen recovery during swine manure treatment**<br>Mohammed Hussien, Dipak A. Jadhav, Su-Min Jo, Hai Yen Nguyen, Jin-Hyeok Jang, Ju-Hyeong Kim, Jae Young Kwon, Jae Kyung Jang, Enas Taha Sayed, Mohammad Ali Abdelkareem |
| 14:15 - 14:30 | BKII-02 | **Automated Detection System for Preventing Lonely Deaths of Elderly People Living Alone**<br>Ye-Hoon Kim, Yeon-Woong Park, Su-Min Lee, Jun-Ho Huh |
| 14:30 - 14:45 | BKII-03 | **Influence of Guide Vanes on the Performance of Biradial Turbine for Wave Energy Conversion in Oscillating Water Columns**<br>Seong Jong Bae, Seung Hyun Jang, B.H.B.P.D. Baddegamage, Min Yoon |
| 14:45 - 15:00 | BKII-04 | **Comprehensive Labeled Oyster Dataset for Improved Segmentation**<br>Thi-Ngot Pham, Hee-Jung Lee, Jun-Ho Huh |
| 15:00 - 15:15 | BKII-05 | **Energy Clustering Computing Based Micro Grid Management: Digital Twins Empowered Design**<br>Ngoc-Bao-Van Le, Hong-Danh Thai, Jun-Ho Huh, Seung-Mo Je |
| 15:15 - 15:30 | BKII-06 | **Analysis of Flow Dynamics for Tandem Rotating Airfoils**<br>Seung Hyun Jang, Seong Jong Bae, B.H.B.P.D. Baddegamage, Min Yoon |

| Session C: Intelligent Mechanism (Monday, August 12th, Room 720) | | |
|---|---|---|
| **Chairman: Prof. Junghyuk Ko/Prof. Hoang Chieu Le Phan** | | |
| **Time** | **Paper ID** | **Title and Authors** |
| 14:00 - 14:15 | C-01 | **Application of Spherical Four-Bar Linkage Mechanism in Fin-Ray Structure Design for Fish Robots**<br>Van Binh Duong Nguyen, Minh Khoi Nguyen Tien, Huy Hung Nguyen, Van Tu Duong, Tan Tien Nguyen |
| 14:15 - 14:30 | C-02 | **From Depletion to Continuity: Improving FDM with Automatic Filament joining Technology and Parameter Optimization**<br>Dam Lee, Junghyuk Ko |
| 14:30 - 14:45 | C-03 | **Distance-Adjustable Magnetic Flux Leakage Detection Using Archimedean Spiral Cam Slots for Pipeline Inspection Gauge**<br>Thanh Nhu Nguyen, Minh Tri Tran, Minh Khoi Nguyen Tien, Huy Hung Nguyen, Van Tu Duong |
| 14:45 - 15:00 | C-04 | **Enhancing Autonomous Mobile Robot Safety with Camera-Based Object Detection and Tracking**<br>Trinh Tran Vinh An, Hwan-Seong Kim, Sam-Sang You |
| 15:00 - 15:15 | C-05 | **Research on Transporting Anchovy to Salt-Brined Fish Tank in Fish Sauce Factory**<br>Ngoc Hung Nguyen, Cong Toai Truong, Minh Triet Huynh, Van Tu Duong, Tan Tien Nguyen |
| 15:15 - 15:30 | C-06 | **Tower-typed Smart Farm using automatic cultivation machine**<br>Seokhyeon Jeon, Jaewon Choi, Taegang Kim, Guenho Do, Minseok Kim, Junghyuk Ko |
| 15:30 - 15:45 | C-07 | **Utilizing MFL Signal Mapping Techniques for Defects and Corrosion Detection on Ferromagnetic Surfaces**<br>Quoc Minh Lam, Cong Toai Truong, Quang Linh Vo, Huy Hung Nguyen, Van Tu Duong |
| 15:45 - 16:00 | C-08 | **Development of the Automated Multi-Pipette System Using CNC Machine**<br>Minsoo Kang, Jonghyuk Im, Mingi Kim, Minjeong Kim, Jiyoung Heo, Junghyuk Ko |

| Session D: AI & Optimum (Poster) (Monday, 14:00-16:00, August 12th, Room 718) | |
|---|---|
| **Chairman: Prof. Kyusung Cho/ Prof. Van Tu Duong** | |
| **Paper ID** | **Title and Authors** |
| D-01 | **Indoor mobile robot localization system based on object detection and optical character recognition**<br>Bui Minh Hau, Hwan-Seong Kim |
| D-02 | **Cargo Detection for AGV Support System in Warehouse using Advanced Computer Vision**<br>Ho Van Roi, Hwan-Seong Kim, Sam-Sang You |
| D-03 | **A hybrid MCDM approach for container terminal selection based on cumulative prospect theory**<br>Pham Thi Yen, Hwan-Seong Kim, Truong Ngoc Cuong |
| D-04 | **3D Construction and Object Positioning Support for Autonomous Mobile Robots in Warehouses**<br>Nguyen Duy Tan, Hwan-Seong Kim, Sam-Sang You |
| D-05 | **A Study on the Possibility of Construction 3D Printer with Multi-Layer Nozzle**<br>Inwoo Kim, Junghyuk Ko |
| D-06 | **Ammonia Leakage Characteristics in Enclosed Spaces**<br>Jin-Woo Bae, Kweon-Ha Park |
| D-07 | **Automating container damage detection with YOLOv8 deep learning model**<br>Nguyen Thi Phuong Thanh, Cho Gyu Sung, Indranath Chatterjee |
| D-08 | **Efficient synthesis of zeolite X and calcium carbonate from blast furnace slag**<br>Seonmi Shin, Myoung-Jin Kim |
| D-09 | **Enhancing economic viability of indirect carbonation: Utilization of Ca(OH)2 as an alkaline additive**<br>Won Jo, Myoung-Jin Kim |
| D-10 | **Application of 3D Techniques in Manufacturing Orthopedic Instruments**<br>Hoang Chieu Le Phan, Minh Khoi Nguyen Tien |
| D-11 | **Design and Control of a Testing Machine for Fire Sprinkler K-factor Evaluation** |

| | |
|---|---|
| | Hai Dang Ho, Huu Nhan Nguyen, Cong Toai Truong, Huy Hung Nguyen, Van Tu Duong |
| D-12 | **Design and Control of Pressure Exposure Testing Machine for Fire Extinguishers**<br>Huu Nhan Nguyen, Cong Toai Truong, Van Tu Duong, Huy Hung Nguyen, Tan Tien Nguyen |

# KEYNOTE SESSION

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Keynote Session (Monday, August 12th, Room 201)
Paper ID: K-01

# Joining of metal to plastic by laser welding

Zhai, Jianguang*, Wang Ruijun ,and Jin Yang** ,
*Shanghai University of Engineering Science, Shanghai, China, 201620*
[3]*Business or Academic Affiliation, City, Country, Pin Code*
*zhai_jianguang@sues.edu.cn

## Abstract

304 stainless steel (304SS) and polyethylene terephthalate (PET) were lapped joined by laser conduction welding using a semiconductor laser with a flat-top thermal distribution. Experimental investigation and numerical simulation were conducted to analyze the weld morphology, pores distribution, interfacial microstructure, temperature field, joint strength and fracture behavior of the laser dissimilar joints. Because of the uniform thermal distribution of the laser, the decomposition of the PET base material was well controlled with pore-free joints obtaining at the welding speed over 25 mm/s. Besides, a compound layer was generated at the interface between 304SS and PET with its thickness decreased when the welding speed increased. Chemical reactions and mechanical anchoring were both observed at the interface suggesting a dual joining mechanism. The joint fracture load first increased then decreased with the increased welding speed. Besides, a ductile to brittle failure transition was clearly seen. The underlying mechanism was also discussed.
**Keywords:** dissimilar materials laser welding, numerical simulation, mechanical properties

## Acknowledgments

This work was supported by the National Natural Science Foundation of China, and I would like to thank the excellent technical support for Mrs. Wang Runjun and her team.

## References

[1] Grujicic M and Sellappan V, "An overview of the polymer-to-metal direct-adhesion hybrid technologies for load bearing automotive components". J Mater Process Technol 2008;197:363–73.

[2] Sultana T, Georgiev GL, Baird RJ, Auner GW, Newaz G, Patwa R, et al. " Study of two different thin film coating methods in transmission laser micro-joining of thin Ti film coated glass and polyimide for biomedical applications". J Mech Behav Biomed Mater 2009;2:237–42.

[3] Jaime SBM, Alves RMV, Bocoli ´ PFJ. "Moisture and oxygen barrier properties of glass, PET and HDPE bottles for pharmaceutical products". J Drug Deliv Sci Technol 2022;71:103330.

[4] David E, Lazar A. "Adhesive bonding between aluminium and polytetrafluoroethylene". J Mater Process Technol 2003;143(144):191–4.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Keynote Session (Monday, August 12th, Room 201)
Paper ID: K-02

# The Development of E-Logistics in Vietnam

Duy Anh Nguyen[1,2 *], Duy Anh Nguyen[1,2], Thanh Nhat Luong[1,2], Ngo Le Hoang Long[1,2,]
[1] *Department of Mechatronics, Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam*
[2] *Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam*
*Corresponding author. E-mail: duyanhnguyen@hcmut.edu.vn

## Abstract

E-logistics is a transformative force in the global supply chain, significantly enhancing the efficiency, transparency, and competitiveness of logistics companies. By integrating advanced IT and communication solutions, e-logistics allows firms to better meet growing market demands and optimize their operational processes. This evolution in logistics management brings numerous benefits, including increased transparency and traceability, improved efficiency and productivity, reduced operating costs, enhanced responsiveness and flexibility, and an overall better customer experience. In Vietnam, the logistics sector faces unique challenges, with costs remaining significantly higher compared to global standards. Key factors contributing to these elevated costs include underdeveloped transportation infrastructure, a fragmented logistics industry, reliance on manual processes, a shortage of skilled logistics professionals, and inventory management challenges. To address these issues and align with global trends, Vietnam's logistics sector is increasingly adopting technologies such as IoT and smart devices, machine learning and AI, robotics, autonomous vehicles, and 5G communication. Emphasizing sustainability, the sector is also integrating green technologies and human-machine collaboration. Solutions like automated warehousing, real-time tracking, advanced data analytics, and AI-driven decision-making are crucial for the industry's modernization. Additionally, the focus on cybersecurity, data protection, and standardization ensures that Vietnam's logistics sector remains resilient and competitive in the evolving global market.

**Keywords:** E-logistics, Supply chain, Advanced IT solutions, Logistics costs, Sustainability

# MORNING SESSION

# SPECIAL SESSION I: BK21 FOUR

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Special Session I: BK21 Four (Monday, August 12th, Room 807)
Paper ID: BKI-01

# Structural Analysis of Block-type Seawater Exchange Breakwater

Jeongho Kim[1,2], Seungbok Lee[1,2], Meeju Lee[1,2], Dongwoo Shon[1,3], Jaeha Lee[1,2*]
[1] *Interdisciplinary Major of Ocean Renewable Energy Engineering, Korea Maritime & Ocean University, Busan, 49112, Republic of Korea,*
[2]*Department of Civil Engineering, Korea Maritime & Ocean University, Busan, 49112, Republic of Korea,*
[3]*Department of Mechanical Engineering, Korea Maritime & Ocean University, Busan, 49112, Republic of Korea*
[*]Corresponding author. E-mail: jaeha@kmou.ac.kr

## Abstract

Recent increases in annual temperatures and precipitation trends have made the stability of breakwaters a critical issue due to intensified wave forces, typhoons, and abnormal high waves resulting from climate change. For gravity-type breakwaters on land, long caisson technology is required to ensure safety and stability. Precast concrete breakwater structures, through strong interlocking with adjacent precast concrete blocks, can reduce the maximum external forces caused by phase differences in wave pressure acting at different locations. This allows for stability with less weight compared to traditional caissons, leading to cost savings. Recently, there has been active research on seawater-permeable precast concrete breakwater structures that leverage these advantages (Lee et al., 2023; Kim et al., 2023). This study proposes a basic shape for a detailed examination of block-type connections and evaluates the structural performance through three-dimensional finite element analysis. After evaluating the structural performance, a fluid simulation was conducted to examine the stability, comprehensively assessing the structural safety of seawater-permeable precast concrete breakwater structures under wave forces.

**Keywords:** Water exchange, Precast concrete, Multi Physics, CFD, FEM

## Acknowledgments

Following are results of a study on the “Leaders in Industry-university Cooperation 3.0” Project, supported by the Ministry of Education and National Research Foundation of Korea.

## References

S. Lee, J. Kim, M. Lee, S. Kim, and J. Lee, "Structural Performance Evaluation of Seawater Exchange Block Breakwater," Korea Institute for Structural Maintenance and Inspection Conference, 27(2) (2023) pp. 67-67. Yangyang, Korea.

S. Kim, J. Lee, and K. Kim, "Introduction to Spherical-Shaped Wave-Dissipating Breakwater for Natural Disasters," The Magazine of the Korean Society of Civil Engineers, 71(11) (2023) pp. 58-63.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Special Session I: BK21 Four (Monday, August 12th, Room 807)
Paper ID: BKI-02

# Effect of Polymer Type and Exposure Period of Marine Microplastics on Microbial assemblage and Antibiotic Resistance Gene Enrichment

Hyunsu Kim[1,2] and Keunje Yoo[1,2 *]
[1]*Department of Environmental Engineering, National Korea Maritime and Ocean University, Busan, Republic of Korea, 49112*
[2]*Interdisciplinary Major of Ocean Renewable Energy Engineering, National Korea Maritime and Ocean University, Busan, Republic of Korea, 49112*
[*]Corresponding author. E-mail: kjyoo@kmou.ac.kr

## Abstract

As a significant emerging environmental concern, many studies have focused on identifying and quantitatively analyzing suspended plastics in surface and sub-surface seawater. Recently, microplastics (MPs) are becoming new carriers for antibiotic resistance genes (ARGs) in marine environments. Specific biofilms on MP called plastisphere can provide an ideal niche to increase ARG spread through horizontal gene transfer (HGT), increasing the risk to ecosystems and human health. However, microbial communities formed on different plastic types, and ARG abundance has remained unclear. In this study, four types of MPs (polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC)) were periodically cultivated in the marine environment (46, 64, and 102 days) to investigate microbial communities and abundance of ARGs. Real-time qPCR was used to quantify ARGs including the *blaTEM*, *ermB*, *mexF*, *qnrS*, *sul1*, *sul2*, *tetA*, *tetC*, *tetQ*, *vanA* and *intl1* gene. The α-diversity and microbial compositions differed significantly from seawater ($p < 0.05$). β-diversity analysis indicated that the microbial communities were temporally changed by the cultivated period to the marine environment rather than polymer types of MPs (ANOSIM, $p = 0.0003$, $R = 0.9699$). *Flavobacteriaceae* and *Rhodobacteraceae* (approximately 21.36 ± 6.32 % of the total abundance) were relatively high abundances of MPs. Additionally, qPCR results showed MPs selectively enriched ARGs. Especially, sul1, tetA, tetQ, and qnrS genes had relatively high abundances in PVC types of MPs. The abundances of intl1, mobile genetic elements (MGEs), were consistently identified as high levels compared to other MGEs during all periods (46, 63, and 102 days). According to co-occurrence analysis, *Methylotenera*, *Coxiella*, and *Pseudahrensia* are potential hosts for the *ermB*, *tetA*, and *tetQ* genes in the plastispheres. The findings of this study suggest that the accumulation of ARGs and the *intl1* gene in marine MPs can potentially accelerate transmission through HGT in the plastisphere.
**Keywords:** Microplastic, Plastisphere, Antibiotic resistance genes, Mobile genetic elements, Horizontal gene transfer

## Acknowledgments

This study was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (Ministry of Science, ICT & Future Planning, [No. 2020R1C1C1008951] and MIST, [RS-2023-00219497]).

## References

L.A. Amaral-Zettler, E.R. Zettler and T.J. Mincer, “Ecology of the plastisphere”, Nature Reviews Microbiology 18 (2020), pp. 139-151.

S. Bae and K. Yoo, Microplastic contamination and microbial colonization in coastal area of Busan City, Korea”, Frontiers in Marine Science 9 (2022).

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Special Session I: BK21 Four (Monday, August 12th, Room 807)
Paper ID: BKI-03

# Study on CFD Simulation of Thunniform Shark Swimming

Phan Huy Nam Anh[1,2], Hyeung-Sik Choi[1,*]
[1] *Department of Mechanical Engineering, Korea Maritime and Ocean University, Busan 49112, Korea*
[2] *Interdisciplinary Major of Ocean Renewable Energy Engineering, Korea Maritime & Ocean University, Busan 49112, Republic of Korea*
[*]Corresponding author. hchoi@kmou.ac.kr; Tel.: +82-10-5581-2971

## Abstract

This study aims to investigate the design of robotic fish by simulating the swimming dynamics of thunniform sharks using computational fluid dynamics (CFD). The fish-like movement is described by the approximate trajectory of the midline body, characterized by lateral oscillations in the form of a wave traveling longitudinally, akin to the backbone undulation observed in swimming fish. The research comprises two main parts: swimming forward and turning. For swimming forward, the standard is set with a body length-to-diameter ratio (L/D) of 1.5/0.3, achieving a speed of 7 knots. Variations in L/D ratios of 4/1 and 7/1 are examined to assess the propulsive force derived from the mean force in the x-direction over time. In the turning simulations, additional parameters such as half of the tail amplitude, dorsal fin angle, and the positional ratio of the dorsal fin to the longitudinal center of mass are considered to explain the trade-off between forward motion and turning efficiency when changing the dorsal fin position. The targets considered are the tangential speed of 4 knots, the states when turning 90 degrees and 180 degrees. The accelerations are calculated from force and moment equilibria, simulating the dynamics based on input parameters such as mass (m), length (L), moment of inertia (I), and fluid density ($\rho$). This simulation study identifies conditions that affect the hydrodynamic design and operation of robotic fish. This simulation study identifies conditions that affect the hydrodynamic design and operation of robotic fish. Further development is needed to adjust the elevator for left-right maneuvering and to study the relative influences of the waveform on swimming performance.

**Keywords:** Thunniform shark swimming, Computational fluid dynamics (CFD), Swimming forward, Turning dynamic, Adjusting the shape fish design

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Special Session I: BK21 Four (Monday, August 12th, Room 807)
Paper ID: BKI-04

# Optimization of Crossflow Air Turbines for Enhanced Wave Energy Conversion Efficiency in Oscillating Water Columns

B.H.B.P.D. Baddegamage[1,2], Seong Jong Bae[1,2], Seung Hyun Jang[1,2], Min Yoon[1,2,*]
[1]*Department of Mechanical Engineering, National Korea Maritime and Ocean University, Busan, Republic of Korea, 49112*
[2]*Interdisciplinary Major of Ocean Renewable Energy Engineering, National Korea Maritime and Ocean University, Busan, Republic of Korea, 49112*
[*]Corresponding author. E-mail: minyoon@kmou.ac.kr

## Abstract

The global energy crisis and climate change are major worldwide concerns, driving attention toward renewable energy sources. Among these, wave energy stands out for its renewable nature and potential, given the extensive coverage of oceans, yet it remains underutilized. Among the various wave energy converters (WECs) being developed, the Oscillating Water Column (OWC) stands out due to its relatively simple mechanism, involving fewer moving parts above the water level. The Wells turbine, commonly used as the power take-off (PTO) system for OWCs, offers high peak efficiency but is limited by the aerodynamic stalling effect at higher flow ranges. This issue can be mitigated by employing Crossflow Air Turbines (CFATs), which demonstrate potential for broader operational capabilities. This study aims to develop a numerical model to explore the effects of nozzle shape optimization on CFAT performance. The reference model is validated against experimental data in reciprocating flow. Geometric parameters, such as nozzle entry arc angle, nozzle starting angle, and blade inlet angle, are optimized under steady-state conditions to enhance performance. The nozzle entry arc angle of CFAT is varied from 90° to 150°, revealing that an angle of 150° yields the highest efficiency. The optimization process identifies an optimal starting angle of 15° for the nozzle entry, coupled with further adjustments to the blade angles and the nozzle inlet angle to minimize disturbances in the fluid's path toward the runner blades. The optimized model achieves a peak efficiency of 68%, maintaining high efficiency across a broader operational range in steady-state unidirectional flow. Further simulations in bidirectional wave conditions validate the improved design, confirming its performance capabilities. The findings address the limitations of the Wells turbine and enhance the operational efficiency of the CFAT model. By expanding the operational range and efficiency, the optimized CFAT model offers a promising solution for increasing the viability and effectiveness of wave energy conversion, potentially accelerating the adoption of this renewable energy technology. This study demonstrates the potential of CFAT as a superior PTO for OWCs, contributing to the advancement of marine renewable energy technologies.

**Keywords:** Crossflow air turbine (CFAT), Wave energy, Oscillating water columns (OWC), Power Take-off system (PTO), Computational fluid dynamics (CFD)

## Acknowledgments

This research was supported by the Korea Institute of Marine Science & Technology Promotion (KIMST) funded by the Ministry of Oceans and Fisheries, Korea (RS-2023-00254688, Advancement of Wave Energy Converters Applicable to Breakwater for Commercialization)

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Special Session I: BK21 Four (Monday, August 12th, Room 807)
Paper ID: BKI-05

# Comparison of microbial communities in different types of pig and samples in swine farms

Gihan Lee[1,2], and Keunje Yoo[1*]

[1]*Department of Environmental Engineering, National Korea Maritime and Ocean University, Busan, 49112, Republic of Korea*

[2]*Interdisciplinary Major of Ocean Renewable Energy Engineering, National Korea Maritime and Ocean University, Busan, 49112, Republic of Korea*

[*]Corresponding author. E-mail: kjyoo@kmou.ac.kr

## Abstract

Although swine farms have different operation methods depending on the stage of pig growth, most previous studies do not consider airborne bacteria stage of pig growth. In addition, the continuous aerosolization of fecal particles is affected by various factors including the barn structure, ventilation system, sanitation measures, and climatic conditions. Airborne bacteria on swine farms can have a negative impact on the health of pigs and livestock workers. It was hypothesized in this study that the distribution of microbial communities in swine farms would vary depending on the stage of the pig. Therefore, in this study 30 samples were collected from different type of swine farms to comprehensively understand the microbial communities of bioaerosols, feces, and surface microorganisms. As a result of 16S rRNA gene amplicon sequencing from Miseq, there were different microbial communities. The alpha diversity indices did not show a significant difference between pig and piglet ($p > 0.05$). However, NMDS based on the Bray-Curtis distance results revealed distinct clustering based on pig type, sample type (stress = 0.1266, PERMANOVA $p < 0.0007$) indicating variations in bacterial taxa. In addition, *Staphylococcus* genera were significantly more prevalent in bioaerosols than in fecal samples from the stage of pig growth ($p<0.05$). These results were identified as the effects of more antibiotic usage during the weaning piglet. This research represents a significant data that the microbial community in the swine farms depending on the different types of pig, and more effect the amount of antibiotic use with growth. Furthermore, we also found that aerosolization inside pig farms can occur in stages, from feces to surface to aerosol, and from surface to aerosol. These findings demonstrate that the aerosolization of feces and surfaces within swine farms can selectively influence bacterial compositions. Although the microbial risk of bioaerosols remains unclear, our findings provided essential insights into the understanding of bacterial communities in distinct types of different types of pig samples in swine farms.
Key words: Swine farm, Bioaerosol, Surface, Antibiotic, Microbial community, SourceTracking

## Acknowledgments

This research was supported by Animal and Plant Quarantine Agency (Z-1543081-2023-25-0101).

## References

e.g. M.T. Capizzi and R. Ferguson, "Loyalty trends for the twenty-first century", Journal of Consumer Marketing 22(2) (2005) pp.72-80.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Special Session I: BK21 Four (Monday, August 12th, Room 807)
Paper ID: BKI-06

# Fabrication of Wear-Resistant Hardfacing of WC10%-Ni60AA Cermet/Inconel 718 via Laser Directed Energy Deposition

Shanshan He [1], Sanghu Park [2,*] and Do-sik Shim [3,*]
[1]*Graduate School of Mechanical Engineering, Pusan National University, Republic of Korea*
[2]*School of Mechanical Engineering, Pusan National University, Republic of Korea*
[3] *Department of Ocean Advanced Materials Convergence Engineering, Korea Maritime and Ocean University, Republic of Korea*
[*]Corresponding author. E-mail: sanghu@pusan.ac.kr and think@kmou.ac.kr

## Abstract

Laser directed energy deposition (DED) is a cutting-edge additive manufacturing technology. Unlike traditional subtractive manufacturing methods, additive manufacturing fabricates components layer by layer, offering unprecedented design flexibility and ability to create complex geometries. Inconel 718 is a nickel-chromium-based superalloy that holds a pivotal role in the advanced materials field owing to its outstanding mechanical strength, corrosion resistance, and high-temperature performance. However, owing to its low hardness and resistance to frictional wear, Inconel 718 is often strengthened by the addition of ceramic components. In this study, crack-free composite coatings with ratios of 40%, 50%, and 60% WC10%-Ni60AA cermet/Inconel 718 were successfully prepared using laser directed energy deposition. WC10%-Ni60AA cermet, as a reinforced particle, consists of 10% tungsten carbide (WC) particles and 90% nickel-based alloy. The bottom layers of the composite coatings were metallurgically well-bonded with substrates. The microstructures of the middle and top layers exhibited a novel eutectic precipitate skeleton structure (Cr23C6 phase), accompanied by an embedded nano-precipitate (MC (M: Nb, Mo) phase). The proportion of the eutectic precipitate skeleton structure increased with an increase in cermet content; in particular, the 60% cermet/Inconel 718 coating exhibited the largest proportion of the skeleton structure, with an area density of 86.15%. An increase in the cermet content improved the grain refinement in the composite coating. Fine equiaxed crystals were obtained in the 60% cermet/Inconel 718 coating, in which the proportion of high-angle grain boundaries (>15°) was 85.7% and the average grain size was 35.77 μm. Furthermore, the hardness and wear resistance of the composite coatings improved as the cermet content increased. The average hardness of the 60% cermet/Inconel 718 coating was 503 HV0.1 and wear loss was 107.9 mg, thereby exhibiting the best wear resistance owing to the synergistic effects of precipitation strengthening, grain refinement strengthening, and dispersion strengthening (unmelted and retained WC particle). Adhesive and abrasive wear were dominant wear mechanisms in the 40% cermet/Inconel 718 coating, whereas oxidative wear and abrasive wear were dominant in the 50% and 60% cermet/Inconel 718 coatings.

**Keywords:** Laser directed energy deposition, Cermet/Inconel 718 composite coating, Wear resistance, Eutectic skeleton structure

## Acknowledgments

We would like to acknowledge the financial supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT)(No. 2023R1A2C1007231).

## References

[1] L. Wang, P. Song, H. Wu, W. Wang, B. Tu, M. Yan, et al. Laser cladding of electroplated Ni-WC on surface of TA2: microstructure and mechanical properties. J. Alloys Compd. 2023, 967: 171715.

[2] I.D. Olumor, M. Wiśniewska, E. Torresani, E.A. Olevsky. Additive manufacturing and spark plasma sintering as effective routes for manufacturing of AISI 316L austenitic stainless steel-WC composites. J. Mater. Res. Technol. 2023, 26: 3234-3244.

[3] J. Xie, R.N. Raoelison, N. Kang, P.E. Mazeran, M. Rachik. Study on the in situ strengthening and toughening mechanism of H13 tool steel/WC-12Co composite using laser-based directed energy deposition. Compos. Part B Eng. 2023, 266: 111011.

# SESSION A: SMART LOGISTICS

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Session A: Smart Logistics (Monday, August 12th, Room 720)
Paper ID: A-01

# Impact of hybrid loading system of CAVs and HDVs at Roll-On/Roll-Off Ports

Sanghyung Park[1], Sihyun Kim[2,*]
[1,2] *Department of Logistics, Korea Maritime and Ocean University, Busan 49112, Republic of Korea*
[*]Corresponding author. E-mail: *sihyunkim@kmou.ac.kr*

## Abstract

Numerous studies have suggested that Connected and Autonomous Vehicles (CAVs) can improve traffic volume, enhance traffic flow stability, increase traffic safety, and reduce fuel consumption and emissions. However, it will take a considerable amount of time before all vehicles are fully autonomous. Thus, a mixed traffic flow scenario with both Human-Driven Vehicles (HDVs) and CAVs will persist for a significant period, during which these vehicles will interact with each other on the road. Consequently, mixed traffic flow scenarios involving CAVs and HDVs have been the subject of extensive research. However, research on the mixed scenario of CAVs and HDVs at Ro-Ro ports, where vehicles must first pass through in the process of import and export, remains insufficient. Therefore, this study aims to investigate a hybrid loading system in Ro-Ro ports that involves both CAVs and HDVs. Previous studies have defined the gradual increase in the proportion of autonomous vehicles in a mixed system as the Market Penetration Rate (MPR) of autonomous vehicles and have discussed the impacts of increasing MPR on future traffic systems and flows. This study investigates the impact of CAVs at Ro-Ro ports in the step of increasing MPR. The port environment was developed using the simulation of urban mobility (SUMO) simulation, and loading system scripts were created through SUMO's TRACI interface. Subsequently, the loading system was evaluated under various scenarios involving 2,736 vehicles in a mixed environment of autonomous and non-autonomous vehicles. The impact of hybrid loading system was investigated in terms of port productivity and emissions. The results indicate substantial enhancements in productivity and significant reductions in emissions and fuel consumption as the penetration of CAVs rises. Notably, achieving 100% CAV penetration results in a productivity boost of up to 71.14%, along with a marked decline in carbon monoxide, hydrocarbons, and nitrogen oxide emissions. Additionally, fuel consumption decreases by more than 70% in a double-ramp scenario. The study provides valuable insights into the practical implementation and phased transition towards fully automated vehicle operations in Ro-Ro ports.

**Keywords:** Roll-on and Roll-off ports, Mixed traffic simulation, VT-Micro model, Hybrid loading system

## Acknowledgments

An Acknowledgments section, if used, immediately precedes the References. Sponsorship and financial support acknowledgments should be included here.

## References

1. Qiangqiang Guo, Xuegang (Jeff) Ban, and H. M. Abdul Aziz, "Mixed Traffic Flow of Human Driven Vehicles and Automated Vehicles on Dynamic Transportation Networks," Transportation Research Part C 128 (2021), pp. 103159. https://doi.org/10.1016/j.trc.2021.103159.
2. Ying Shang, Feng Zhu, Rui Jiang, Xingang Li, and Shupei Wang, "Trajectory Planning at a Signalized Road Section in a Mixed Traffic Environment Considering Lane-Changing of CAVs and Stochasticity of HDVs," Transportation Research Part C 158 (2024), pp. 104441. https://doi.org/10.1016/j.trc.2023.104441.
3. Li Song, Wei (David) Fan, and Pengfei Liu, "Exploring the Effects of Connected and Automated Vehicles at Fixed and Actuated Signalized Intersections with Different Market Penetration Rates," Transportation Planning & Technology 44(6) (2021), pp. 577-593. https://doi.org/10.1080/03081060.2021.1943129.
4. Behzad Bamdad Mehrabani, Jakob Erdmann, Luca Sgambi, Seyedehsan Seyedabrishami, and Maaike Snelder, "A Multiclass Simulation-Based Dynamic Traffic Assignment Model for Mixed Traffic Flow of Connected and Autonomous Vehicles and Human-Driven Vehicles," Transportmetrica A (2023), pp. 1-32. https://doi.org/10.1080/23249935.2023.2257805.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Session A: Smart Logistics (Monday, August 12th, Room 720)
Paper ID: A-02

# A Study on the Current State and Issues of Open Public Platforms in the Japanese Logistics Sector: A Case Study of General Logistics Company Seino Holdings

Tetsuro Saisho [1, 2,*]
[1] *Faculty of Business, Kokushikan University, 4-28-1, Setagaya, Setagaya-ku, Tokyo, Japan, 154-8515*
[2] *Faculty of Economics, Nagasaki University, 4-2-1, Katafuchi, Nagasaki City, Nagasaki, Japan,850-8506*
[*] E-mail: tsaisho@kokushikan.ac.jp saisho.nagasaki@gmail.com

## Abstract

Currently, the Japanese logistics industry is facing a variety of major challenges in its operations, including a shortage of truck drivers, a sharp increase in small-lot deliveries due to the rise in demand for e-commerce, inefficiencies due to the delay in digitalization, and aging information systems that have resulted in overdependence on personalized skills of individuals. As each company struggles to solve such crucial issues, the Japanese logistics industry is finally seeing some collaboration efforts based on the open public platform (OPP) concept. An OPP is a concept that enables all participants to collaborate in logistics operations while transcending the barrier of individual organizations and industries, thereby improving operational efficiency, reducing costs, and increasing the value delivered to all parties. An OPP also functions as a social infrastructure that aims to contribute to the industry, the environment, and people's lives through the use of logistics. Despite being an important theme, research on OPP in Japan has rarely been covered in both Japanese and English literature. In this study, we examine the efforts of Seino Holdings, a general logistics company, in constructing an OPP in Japan and discuss the current state and issues involved.
**Keywords:** Japanese logistics industry, open public platform (OPP), HACOBELL, logistics DX system, open innovation

## Introduction

Japan's logistics industry is now encountering a slew of serious issues. Challenges include the shrinking pool of truck drivers in the country, the drastic spread of e-commerce and the accompanying rise in small-lot deliveries, insufficient use of IT in businesses, and outdated systems that cause companies to rely heavily on personal or analog skills. Against this backdrop, players in the Japanese logistics industry are joining forces under the open public platform (OPP) concept to collaboratively tackle a wide range of structural issues. Despite being a vital topic, not a lot of research on OPPs in Japan has been conducted thus far, both in Japanese literature and English literature [2][4].

## What is an Open Public Platform?

In an OPP, all stakeholders involved, regardless of the organization or industry they are associated with, work in collaboration with the aim of streamlining operations, cutting costs, and bolstering business value. An OPP also serves as a social infrastructure as it brings merits to not only companies but also the industries involved, the environment as a whole, and the daily lives of the people using logistic services.

One representative initiative based on the OPP concept is "HACOBELL," which is a joint venture business between general logistics provider Seino Holdings Co., Ltd. (Seino HD) and IT services company RAKSUL INC. (RAKSUL), launched for the purpose of improving the efficiency of logistics operations [1][5].

Seino HD is a leading logistics provider in Japan, offering comprehensive logistics services such as motor truck transportation, consigned freight forwarding, warehousing, air transport agent, customs broker, and international intermodal transportation businesses [6][7].

RAKSUL, meanwhile, is an IT service company that operates a printing business, advertising business, and integrated management service for IT devices and Software as a Service (SaaS).

The logistics platform HACOBELL was initially launched in 2015 by RAKSUL based on the OPP concept. It was originally a matching platform that directly connects customers/shippers with carriers/drivers in order to streamline logistics operations of truck transportations, as well as to provide software to support digitalization.

In August 2022, the HACOBELL business was revamped accompanying the establishment of a new joint venture company, HACOBELL INC, with investments from Seino HD. HACOBELL has since evolved into a digital logistics OPP that uses the power of technology to reduce excess transportation and delivery costs while drastically shortening the time spent on truck dispatching, which is the process of coordinating the movements of trucks and cargo.

In addition, the transportation arrangement service allows customers to easily place orders online, effectively utilizing the free time of carriers and drivers to ensure low-cost, high-quality, and reliable deliveries.

While it is difficult for logistics companies to solve major structural problems on their own, HACOBELL is "open" to the "public," with all involved in truck logistics able to use its services. By building a "platform" that serves as a foundation for logistics, HACOBELL INC aims to make this business evolve into an open innovation.

With the establishment of HACOBELL INC, the two companies are resolved to achieve business growth through synergies generated among the participants of the platform and to utilize RAKSUL's technology (logistics DX system) along with Seino HD's nationwide customer and transportation company network to ultimately transform the entire logistics industry.

Furthermore, RASKUL's logistics DX system combines digitalization services for achieving automation and optimization in such operations as dispatch planning, dispatch and dynamics management, and billing.

## Conclusion

In Japan's logistics industry, there are still cases where information is exchanged based on analog communication means, represented by telephone and fax. Although some logistics companies, especially major enterprises, are engaged in cutting-edge operations, the majority of others are still not capable of efficiently exchanging data by leveraging an OPP.

One of the factors that make the digital transformation of operations (logistics DX system) difficult to achieve is the characteristics of the logistics industry, such as the multiple layers of subcontracting similar to that of the system development industry.

In the subcontracting hierarchy of logistics operations, many small and medium enterprises (SMEs) and micro enterprises are engaged in delivery operations. However, there is generally no scheme for achieving coordination among such enterprises. Another issue is the lack of standardization of logistics operations as well as the existence of analog operations in the transactions between companies [3].

In addition, each company faces the challenges of rising logistics costs, a shortage of truck driver labor, and an aging truck driver workforce. If the logistics industry continues to maintain current business models, it will surely face an industrial demise. There is a growing need for smooth logistics operations among the participants riding on the rapid digitalization of the industry and the introduction of OPPs.

## References

[1] HACOBELL INC. website, HACOBELL, 2024. Retrieved from: https://corp.hacobell.com/ (confirmed 10 June 2024)

[2] Google Scholar (English Literature Database). website, Google, 2024. Retrieved from: https://scholar.google.com/ (confirmed 10 June 2024)

[3] Japan Trucking Association (JTA). "Japan's Trucking Industry - Current Status and Issues - 2023," JTA (2023). Retrieved from: https://jta.or.jp/wp-content/themes/jta_theme/pdf/yusosangyo2023.pdf (confirmed 10 June 2024)

[4] National Diet Library NDL Search (Japanese Literature Database). website, NDL, 2024. Retrieved from: https://ndlsearch.ndl.go.jp/ (confirmed 10 June 2024)

[5] RAKSUL INC. website, RAKSUL, 2024. Retrieved from: https://corp.raksul.com/ (confirmed 10 June 2024)

[6] SEINO HOLDINGS CO., LTD. website, SEINO HD, 2024. Retrieved from: https://www.seino.co.jp/seino/shd/ (confirmed 10 June 2024)

[7] SEINO TRANSPORTATION CO., LTD. website, SEINO TRANS, 2024. Retrieved from: https://www.seino.co.jp/seino/shd/overall-condition/ (confirmed 10 June 2024)

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Session A: Smart Logistics (Monday, August 12th, Room 720)
Paper ID: A-03

# Evaluating the technical efficiencies in container terminal automation technologies using DEA

Naleen De Alwis[1], Nam Hyung-Sik[2] and Chang-Hoon Shin[3*]
[1,2,3]*Korea Maritime & Ocean University, Busan, South Korea, Pin Code*
[1]*Ocean University of Sri Lanka, Colombo, Sri Lanka, Pin Code*
[*]Corresponding author. E-mail: shinjy@kmou.ac.kr

## Abstract

Driven by the innovations of the industry 4.0, shipping and port industries are rapidly developing new technologies to introduce automated processes and systems into their operational procedures. Since the introduction of the first automated container terminal (ACT) in the early 90s at the Rotterdam port, container terminal automation has gained prominence worldwide in the past decade. By 2020, there were about 50 ACTs in operation around the world. However, the Covid-19 pandemic has significantly accelerated this trend, with the number of operational ACTs reaching 62 by 2022, recording an average growth of 12% per annum. Ports and terminals today utilize various automation technologies to complement or even substitute the human interaction from the port production processes. With a variety of automation technologies available, varying from simple planning and appointment systems to semi or fully automated terminals, recognizing the operational performance of such automations allows the ports and terminals to select the best technologies fitting to their circumstances. To this end, the study aims to measure the performance of container terminals in the port of Busan, which employ various levels of automation, comparing them to derive insights on the operational efficiency of the different technologies applied in the dynamic port environment. The window variant of the Data Envelopment Analysis (DEA) employed in this study provides accurate estimations of the technical efficiency of container terminals which has been used widely in the literature. The efficiency scores derived from the DEA are then compared with the automation level of the terminals in order to derive insights on the technical efficiency of the different automation technologies. Considering the capital-intensive nature of port automation initiatives, it is vital for the port management to recognize the true efficiency gains of such interventions to select the best suited technologies among the variety of alternatives available, where the results of this study assist the port managers to make accurate automation investment decisions.

**Keywords:** Smart Ports, Container, Terminal Automation, DEA, Busan

## References

N. De Alwis, and H.S. Nam, “Pre-pandemic comparison of container terminal efficiency in Colombo and Busan”, 해운물류연구 39(2) (2023) pp.327-349.

G. Knatz et al., “Container terminal automation: revealing distinctive terminal characteristics and operating parameters”, Maritime Economics & Logistics 24(3) (2022) pp.537.

T. Notteboom et al., “Port economics, management and policy” (2022) Routledge.

J.P. Rodrigue and T. Notteboom, “Automation in container port systems and management”, TR news 334 (2021) pp.20-25.

e.g. M.T. Capizzi and R. Ferguson, "Loyalty trends for the twenty-first century", Journal of Consumer Marketing 22(2) (2005) pp.72-80.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)
August 12-13, 2024, National Korea Maritime & Ocean University, Busan, Republic of Korea

Session A: Smart Logistics (Monday, August 12th, Room 720)
Paper ID: A-04

# An Economic Evaluation of EV Truck Introduction Based on Payback Period

Weiyi Liu, Daisuke Watanabe*
*Tokyo University of Marine Science and Technology, Tokyo, Japan, 135-8533*
*Corresponding author. E-mail: daisuke@kaiyodai.ac.jp

## Abstract

In this study, an economic evaluation model for the introduction of EV trucks was constructed using net present value (NPV) and payback period to evaluate the economic feasibility of heavy-duty EV trucks and power exchange EV trucks developed in China in long-distance transportation. First, this study examined the feasibility of long-distance transportation by considering the overall relationship between battery weight and mileage of EV trucks through numerical information and physical models for all EV trucks commercially available in China. On the other hand, based on information on trucks marketed in China and actual truck travel data from Japan, we estimated the average speed of a 466-km long-distance trunk line between Atsugi-Nishinomiya by totaling the distance traveled, travel time, rest time, and number of trips. The calculated average speed was substituted into an electricity consumption estimation model to derive the amount of electricity required per trip for heavy-duty EV trucks and power exchange EV trucks, and to estimate the number of times electricity can be replenished and the SA/PAs where electricity can be replenished. Finally, labor costs, fuel or electricity costs, and highway tolls for diesel trucks, heavy-duty EV trucks, and power exchange EV trucks were estimated and compared based on the results of the operation analysis, and an economic evaluation model was used to determine the amount of reduction in operating costs that could be expected for EV trucks and power exchange EV trucks. Calculate how many years the vehicle purchase cost will be recovered by the reduction in operating costs.

**Keywords:** Net present value, Payback period, Power exchange EV truck, Electricity consumption estimation

## 1. Introduction

In recent years, the electric vehicle market has been growing rapidly to achieve carbon neutrality around the world. However, commercial vehicles, which are larger and heavier than passenger cars, require more energy to drive, so the shift to EVs for commercial vehicles, especially heavy-duty trucks, faces problems such as insufficient driving range, reduced payload capacity due to large batteries, and high purchase costs. The popularity of heavy-duty EV trucks is quite difficult (Vijayagopal and Rousseau 2021). In this study, an economic evaluation model is developed using net present value (NPV) and payback period to evaluate the economic efficiency of two types of EV trucks in long-distance transportation.

## 2. Model Description

### 2.1 Economic Evaluation Model

The economic evaluation model uses two economic evaluation indices, net present value (NPV) and payback period, to evaluate the economic efficiency of round-trip transportation between two locations on expressways (Nishimiya 2021). Specifically, the operating costs of diesel trucks, heavy-duty EV trucks, and power exchange EV trucks are compared, and the number of years in which the vehicle purchase costs for EV trucks and power exchange EV trucks will be recovered is calculated based on the amount of reduction in operating costs.

Net present value (NPV) is the difference between the present value of future cash inflows (cash inflows) and the present value of future cash outflows (cash outflows), and is an indicator of the profitability of an investment and one of the most common investment decision criteria. The net present value is determined by converting future cash inflows and outflows

into present value by the present value coefficient of the projected discount rate for each period; the higher the NPV, the better the project and the better the investment returns.

This study calculates the net present value (NPV) of replacing a diesel truck with an EV truck to determine if the initial investment to purchase an EV truck or power exchange EV truck is recoverable. In this case, the power systems of EV trucks and regular diesel trucks are different, and even though the trucks have the same vehicle weight, the EV trucks have a smaller payload capacity than regular trucks because of the battery pack. Therefore, as in Equation (2), assuming that the truck's loading ratio is 100%, the annual operating cost is divided by the annual transportation volume to convert it into an operating cost per unit transportation volume for comparison. Similarly, the initial investment is converted into vehicle purchase cost per unit transport volume as in Equation (3) for comparison.

$$NPV_t = \sum_{i=1}^{n} \frac{V_t}{(1+r)^i} - I_t \tag{1}$$

$$V_t = \frac{C}{W} - \frac{C_e}{W_e} \tag{2}$$

$$I_t = \frac{P}{W_e} \tag{3}$$

$V_t$: operating cost reduction (JPY)
n: planning period (year)
r: discount rate
$I_t$: initial investment (JPY)
C: annual operating costs of diesel trucks (JPY)
$C_e$: annual operating costs of EV trucks (JPY)
W: annual transportation volume of diesel trucks (kg)
$W_e$: annual transportation volume of EV trucks (kg)
P: purchase cost of EV trucks (JPY)

The payback period is the period during which the funds recovered from the investment can recover the initial investment. In other words, when NPV reaches 0, it is the threshold of the period during which the initial investment can be recovered, and the payback period "n" can be calculated. Using the formula of summation for geometric sequence, the formula for calculating NPV can be expanded as in Equation (4), and the payback period "n" can be derived as in Equation (5).

$$NPV_t = \frac{\frac{V_t}{1+r}[1-(\frac{1}{1+r})^n]}{1-\left(\frac{1}{1+r}\right)} - I_t = 0 \tag{4}$$

$$n = \log_{\frac{1}{1+r}}\left(1 - \frac{I_t}{V_t}r\right) \tag{5}$$

**2.2 Electricity Consumption Estimation Model**

In this study, the driving condition of EV trucks is assumed to be horizontal uniform rectilinear motion, and the traction force generated by battery power generation is balanced by the combined force of rolling resistance generated by the friction between the tires and the ground and air resistance during driving, as shown in Equation (6).

$$F_t = F_f + F_w \tag{6}$$

$F_t$: traction force
$F_f$: rolling resistance
$F_w$: air resistance

The formula for calculating air resistance is as shown in Equation (7). The definition of windward area refers to the method of reflecting aerodynamic drag in fuel consumption values in the "Standard Vehicle Specifications Table" published by the Ministry of Land, Infrastructure, Transport and Tourism, and the value of windward area is the front projected area of the truck. The aerodynamic drag coefficient varies depending on the shape of the truck. In this study,

the aerodynamic drag coefficient is set to 0.8, referring to the "Heavy Duty Commercial Vehicles Fuel Consumption Estimation Method" published by the Ministry of Industry and Information Technology of the People's Republic of China.

$$F_w = \frac{1}{2} * C_D * A * \rho * v^2 \quad (7)$$

ρ: air density value (1.2258N·s$^2$·m$^{-4}$)

$C_D$: aerodynamic drag coefficient

A: windward area (m$^2$)

v: velocity (m/s)

The formula for calculating rolling resistance is as shown in Equation (8). To set the rolling resistance coefficient, the calculation is performed with reference to the "Estimation Method for Fuel Consumption of Large Commercial Vehicles" published by the Ministry of Industry and Information Technology of the People's Republic of China.

$$F_f = mgf \quad (8)$$

m: gross vehicle weight

g: acceleration of gravity (9.8 m/s2)

f: rolling resistance coefficient

Electric power consumption is the work done by the traction force generated by battery power generation. Combining the above force equations with the motor power equation (9) and the mileage equation (10), the electricity consumption equation can be derived as in Equation (11).

$$P = \frac{v}{\eta_e} * \left(\frac{mgf}{3600} + \frac{C_D * A * v^2}{76140}\right) \quad (9)$$

$$S = \frac{W_b v}{P} \eta_t \quad (10)$$

$$W_b = \frac{S}{\eta_t \eta_e} * \left(\frac{mgf}{3600} + \frac{C_D * A * v^2}{76140}\right) \quad (11)$$

P: electric motor output (kW)

v: velocity (km/h)

ηe: overall efficiency of electric motors

ηt: truck transmission efficiency

Wb: electricity consumption (kWh)

S: mileage (km)

**2.3 Composition of Operating Costs**

Operating costs consist of labor costs, fuel costs (or electricity costs in the case of EV trucks), and highway tolls, with an additional battery replacement fee in the case of power exchange EV trucks, and do not include maintenance costs. The annual operating cost is calculated here by multiplying the cost per trip by the number of trips per year.

$$C = (L + F) * N + H \quad (12)$$

$$C_e = (L + F_e) * N + H \quad (13)$$

$$C_b = (L + F_e) * N + H + E \quad (14)$$

C: annual operating costs of diesel trucks (JPY)

$C_e$: annual operating costs of EV trucks (JPY)

H: highway tolls (JPY)

E: battery replacement fee (JPY)

N: annual number of trips(time/year)

$C_b$: annual operating costs for trucks with interchangeable batteries (JPY)

F: fuel costs (JPY) = fuel consumption (L/100km) × mileage (km)/100 × Fuel unit price (JPY/L)

$F_e$: electricity costs (JPY) = electricity consumption (kWh) × electricity unit price (JPY/kWh)

L: labor cost (JPY) = labor time (hour) × hourly wage (JPY/hour)

Labor hours are the time required from the point of origin to the point of destination, and include operating time and rest time, but exclude loading and unloading time. In addition, unlike the fuel refueling method of diesel trucks, quick recharging of EV trucks at highway SA/PAs takes about 30 minutes each time, and labor costs are incurred by assuming that the recharging time is also rest time. In the case of power exchange EV trucks, battery replacement can be completed in about 5 minutes, so this time is not considered and only the time required is assumed.

Fuel costs are calculated based on the truck's mileage, fuel consumption, and unit price of fuel. Since the trucks used in this study were all made in China, the definition of fuel consumption follows the Chinese market and is defined as the fuel required to travel a certain distance, as used in Europe and China, rather than the distance traveled per unit capacity as is generally used in Japan. In other words, it should be noted that the unit is not "km/L" but "L/100km.

Regarding the battery replacement fee, this study assumes that the battery replacement station billing system sells electricity at the same price as a regular charging station and adds a battery replacement fee on top of that. To estimate the battery replacement fee, it is assumed that the initial construction cost of the battery replacement station is recovered entirely from the profit of the battery replacement fee, and maintenance and labor costs of the battery replacement station are not considered.

Using the payback period model and assuming that the planning period is a fixed value and that the planning period is the period when the NPV is zero, the annual profit amount required by the battery replacement station can be calculated as in Equation (15).

$$NPV_e = \sum_{i=1}^{n} \frac{V_e}{(1+r)^i} - I_e \quad (15)$$

$V_e$: annual profit (JPY/year) n: planning period (year) $I_e$: initial investment (JPY)

The calculated annual profit of the battery replacement station is divided by the annual number of battery replacements to derive the per battery replacement charge.

## 3. Relationship Between Battery Weight and Mileage

### 3.1 Data Source

The data used in this study is based on the "List of New Energy Vehicles Exempt from Vehicle Acquisition Tax" and the "Key Parameters of Vehicles in the "List of Recommended New Energy Vehicles for Popularization and Application" published by the Ministry of Industry and Information Technology of the People's Republic of China.

This study focused on two vehicle types, "trucks" and "special-purpose vehicles," and extracted information on four parameters: vehicle weight, gross vehicle weight, battery pack weight, and battery capacity for 2251 electric vehicles.

### 3.2 Analytical Method

To explore the relationship between battery weight and driving range, it is necessary to convert battery capacity and gross vehicle weight to battery weight. Based on the compiled data, regression analysis was performed to derive the three relationships between battery weight and vehicle weight, battery weight and gross vehicle weight, and battery weight and battery capacity, which were then substituted into the power consumption estimation model to determine the overall relationship between battery weight and driving range for EV trucks sold in the Chinese market to date.

### 3.3 Analysis Result

Looking at information on heavy-duty EV trucks currently on the market, most of them are equipped with batteries weighing around 2000 kg, and as shown in Figure (1), when traveling at a constant speed of 80 km/h, they can travel only about 250 km when fully loaded with cargo.

In other words, when traveling at a constant speed of 80 km/h on an expressway, it is impossible for a heavy-duty EV truck to travel the long distance of about 500 km from Tokyo to Osaka, and it is necessary to install a charging station to replenish power to the battery. With current charging technology, recharging large trucks requires several hours of recharging time, even with quick recharging, which significantly increases the transportation time of heavy-duty EV

trucks for long-distance transportation and raises labor costs that logistics companies must pay their drivers. In addition, switching to heavier batteries would significantly increase the vehicle weight of EV trucks, which would not only reduce their payload capacity, but also decrease their transportation efficiency.

Analysis of the above transportation situations shows that for long-distance operations, battery-switchable EV trucks with smaller batteries and shorter recharging times are highly advantageous. Not only the transport times will not increase, they can achieve higher payloads than the average truck, ensuring transport efficiency and cost.

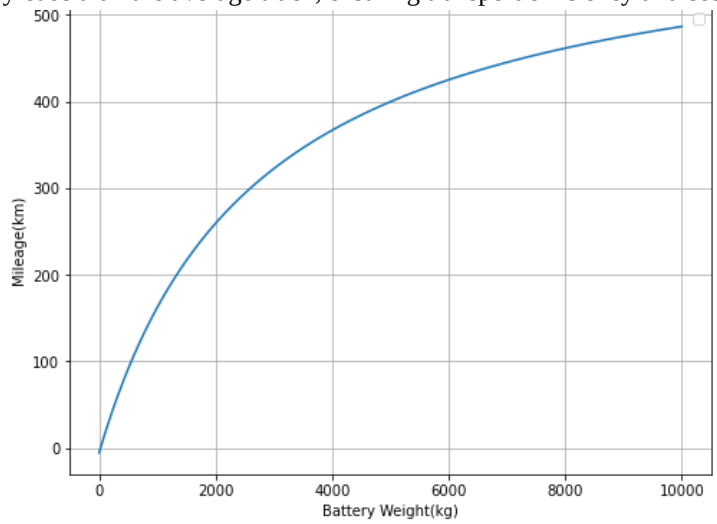



**Figure 1 The relationship between battery weight and mileage**

## 4. Calculation of Payback Period

### 4.1 Vehicle Information

In order to conduct a comparative analysis of diesel trucks, EV trucks and power exchange EV trucks, this study will use each parameter value of a truck called "FAW J6P" sold in the Chinese market.

**Table 1 Parameter values of each car model**

| Car Model | Diesel Truck | BEV | PEBEV |
|---|---|---|---|
| Purchase Cost (ten-thousand JPY) | 709.26 | 1,804.39 | 1,697.49 |
| Length (m) | 7.315 | 7.405 | 7.365 |
| Width (m) | 2.55 | 2.55 | 2.55 |
| Height (m) | 3.56 | 3.56 | 3.56 |
| Vehicle Weight (kg) | 8870 | 11450 | 10890 |
| Gross Vehicle Weight (kg) | 40000 | 37420 | 37980 |
| Battery Capacity (kWh) | | 422.87 | 282 |

### 4.2 Conditions Regarding Operating Costs

In order to investigate the calculation of the battery replacement fee, the actual construction cost of the battery replacement station, and the operation method, the author participated in an internship at the "Sichuan ShuDao New Energy Technology Development Company", which is in charge of new energy charging infrastructure construction in Sichuan, and determined that the initial construction cost of the battery replacement station would be The initial construction cost of the battery exchange station was set at 60 million yen and the planning period at eight years. Regarding the number of recharges, one battery exchange station can exchange batteries up to 168 times throughout the day. In this study, the utilization rate of the battery exchange station is assumed to be 70%, and the annual profit from the battery exchange fee is divided by the number of times the battery is exchanged to calculate the exchange fee per battery exchange.

The unit price of electricity is based on the recharging plan for passenger cars of a company called e-Mobility Power, which was introduced at expressway SA/PAs, and the unit price of fuel is the price of diesel fuel at 154.7 yen per liter as

of December 11, 2023, as surveyed by the Gasoline and Kerosene Price Information NAVI. Expressway tolls and labor costs are based on Nishimiya 2021. The discount rate is based on the "Technical Guidelines for Cost-Benefit Analysis of Public Works Evaluation (Common Edition)" published by the Ministry of Land, Infrastructure, Transport and Tourism in September 2023, and is set at a social discount rate of 4% for all projects for the time being.

### 4.3 Operation Analysis

In this study, the high-capacity vehicle operation data was used to derive the actual travel time, distance traveled, and average speed of the five trucks between Sagamihara and Nishinomiya, with reference to the operation analysis method and the aggregation of travel time and rest time (Nishimiya 2023).

Based on the information on the trucks in 4.1, the maximum driving distance of the two types of EV trucks was calculated, and the number of times required to recharge the batteries and the number of times to replace the batteries were determined. In this study, assuming that the maximum driving distance of the vehicle is 80% of the theoretical maximum, a trip of about 466 km between Sagamihara and Nishinomiya requires at least three times quick charge for a heavy-duty EV truck and at least two times battery replacement for a power exchange EV truck.

We divided the route into four equal parts for the heavy-duty EV truck and three equal parts for the power exchange EV truck, and estimated the power replenishment points for the two types of trucks according to the number of times they need to replenish power. The results show that heavy-duty EV trucks need to be recharged at Shimizu PA, Hamamatsu SA and Suzuka PA, and power exchange EV trucks need to have their batteries replaced at Kakegawa PA and Suzuka PA.

### 4.4 Result of Payback Period

The 12-year NPV (net present value) evolution of the heavy-duty EV truck and the power exchange EV truck is shown in Figure (2), and the payback period is the intersection of the NPV evolution and the zero-reference line. As a result, a power exchange EV truck can recover the vehicle purchase cost in 4.26 years, while the payback period for a heavy-duty EV truck is 4.84 years. This means that the power exchange EV truck can recover the vehicle purchase cost about half a year before the heavy-duty EV truck. The reason for this is that the batteries used in interchangeable battery EV trucks are smaller than those used in heavy-duty EV trucks, resulting in lower vehicle production costs and lower sales prices, allowing the truck purchase cost to be recovered in a shorter time than for the same annual operating cost per unit transport volume.

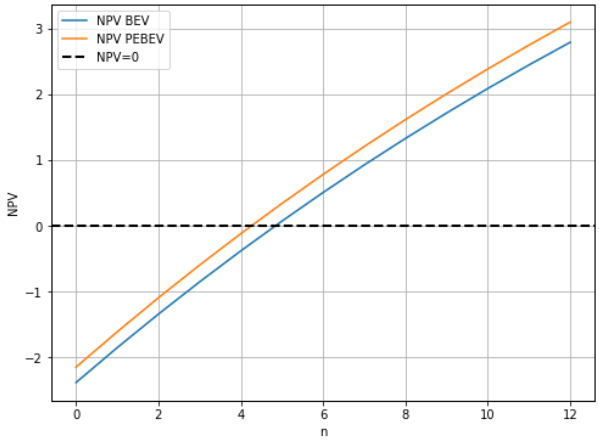



**Figure 2** Result of net present value

**Table 1 Result of payback period**

| Car Model | Payback Period (year) |
|---|---|
| EV Truck | 4.84 |
| Power Exchange EV Truck | 4.26 |

## 5. Conclusion

The advantage of lower energy costs for heavy-duty EV trucks and power exchange EV trucks naturally becomes more advantageous the longer the distance traveled. However, EV trucks have the disadvantage that the efficiency of power replenishment is lower than that of power exchange EV trucks, which may result in higher time costs for long-distance transportation. Based on the results of this study, in the case of long-distance transportation between Nishinomiya and Sagamihara, the introduction of heavy-duty EV trucks and power exchange EV trucks can recover the vehicle purchase cost within five years and continue to reduce truck operation costs for logistics companies after five years. The EV truck introduction is considered beneficial and effective for logistics companies that require long-distance transportation.

## References

R. Vijayagopal and A. Rousseau, “Electric Truck Economic Feasibility Analysis”, World Electric Vehicle Journal, 12(2021), 75.

H. Nishimiya, D. Watanabe and T. Hyodo, "Economic Evaluation of Deployment of High-Capacity Vehicle by Payback Method", Journal of Japan Logistics Society, 30(2022) pp.195-202.

Y. Shenze, "Research on Battery Life Prediction Method of Electric Vehicle Based on Real-Time Data", Master thesis of Harbin Institute of Technology (2021)

Z. Liu, Y. Lei, H. Zhai and X. Wang, "Research on Power Matching and Cruising Range of Pure Electric Vehicle", Mechanical Research & Application, 36(185) (2023) pp.128-132.

H. Nishimiya " Analysis of Operational Behavior of High-Capacity Vehicle on Expressways Using Travel Data", Master thesis of Tokyo University of Marine Science and Technology (2023).

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session A: Smart Logistics (Monday, August 12th, Room 720)

Paper ID: A-05

# Assessing the Effectiveness of Cyber Risk Control Measures: A maritime stakeholders' perspective on mitigation measures

Changki Park[1], Tran Thi Nguyet Minh[2] and Nam Hyung-Sik[3*]

[1]*Northeast-Asia Shipping and Port Logistics Research Center, Busan, South Korea*

[2,3]*Korea Maritime & Ocean University, Busan, South Korea*

[*]Corresponding author. E-mail: hsnam@kmou.ac.kr

## Abstract

The maritime industry is vital for global economic stability, with over 80% of international trade by volume transported by sea. The advent of Shipping 4.0, which builds on Industry 4.0, has led to the extensive use of advanced software and hardware systems on ships and in shore-based facilities. These technologies are critical for navigation, power management, and safe maritime operations. Furthermore, digital connectivity and online communication access are crucial for the well-being, crew cohesion, and social isolation of seafarers. However, the increased dependence on IT systems, automation, and digitization has highlighted the modern security challenge of cybersecurity. Onboard systems that control navigation, engine and power management, and damage control now rely on these technologies, raising concerns about maritime cybersecurity. This growing dependency on IT and operational technology systems has made cybersecurity risks a major issue in the maritime sector. Consequently, the industry is urgently pursuing strategies to mitigate these cyber risks from both administrative and regulatory perspectives, such as those provided by the International Maritime Organization (IMO), as well as from operational perspectives involving shipowners and operators. Effective measures are crucial to safeguard maritime operations and ensure the continued stability of global trade facilitated by the maritime industry.

This research aims to develop a novel methodology for assessing the effectiveness of risk control measures (RCMs) in cybersecurity. Through an extensive literature review, six criteria that influence the selection of cybersecurity RCMs are identified. Expert opinions are then used to evaluate significant cybersecurity RCMs using the fuzzy TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method. This approach prioritizes the most viable RCMs based on primary data gathered from 100 experts. The findings show that the most effective cybersecurity control measures, according to stakeholders, are 'Effective antivirus software management,' 'Management of network devices,' and 'Developing a cybersecurity strategy.' This study provides valuable contributions to maritime cybersecurity policy by offering empirical evidence and introducing a new decision-making tool to help stakeholders select the most appropriate measures to address cybersecurity risks effectively.

**Keywords:** Smart Shipping, Maritime cybersecurity, Cyber risk control, Risk control measures, Fuzzy TOPSIS

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session A: Smart Logistics (Monday, August 12th, Room 720)

Paper ID: A-06

# Track Check Locate Application: RFID-Based Smart Shopping Assistant

Pham Quang Minh and Gyu Sung Cho*

*Department of Port Logistics System, Tongmyong University, Busan, South Korea, 48520*

*Corresponding author. E-mail: gscho@tu.ac.kr

## Abstract

Improving the shopping experience and streamlining the supply chain are critical in the quickly changing retail environment. The Track-Check-Locate (TCL) application, which uses radio frequency identification (RFID) technology, is developed and implemented in this study. With features including accurate product positioning, in-store navigation, real-time inventory management, and a smooth mobile self-checkout procedure, the TCL app seeks to completely transform the shopping experience. The TCL app enhances the shopping experience for consumers by reducing time spent searching for items and minimizing unnecessary purchases. Its mobile self-checkout feature enables automatic payment without manual scanning, and real-time tracking helps users navigate stores efficiently. For retailers, the app improves inventory accuracy, reduces labor costs, and maintains optimal stock levels through RFID technology. This leads to better resource management and increased customer satisfaction. For suppliers and distributors benefit from the app's real-time inventory visibility, which facilitates timely restocking, optimizes supply chain operations, and reduces costs related to overstocking or stockouts. Delivery employees also gain from quicker identification of goods and more efficient order fulfillment, leading to time savings and increased revenue. Overall, the app helps streamline operations and enhance efficiency across the supply chain. This study explores the technical implementation of the TCL app, detailing the RFID infrastructure setup, system integration, and user interface design. It also examines the challenges and limitations encountered during the project and provides insights into future research directions to further enhance the application. Future enhancements could include integrating artificial intelligence (AI) for voice chatting to assist customers and staff, auto alarms for stock alerts, and predictive analytics to check and forecast inventory needs. These AI-driven features will further streamline operations, personalize the shopping experience, and enhance overall efficiency. Through the innovative use of RFID technology, the TCL app sets a new standard for smart retail solutions, driving operational excellence and transforming the shopping experience for all stakeholders involved.

**Keywords:** RFID Integration, Inventory Management, Product Location, Navigation, Real-Time Tracking.

## Acknowledgments

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (MOE) (2023RIS-007).

## References

1. A. Haibi, K. Oufaska, K. E Yassini, M. Boulmalf "Systematic Mapping Study on RFID Technology", Article in IEEE Access 10(1) (2022) pp.5-11.
2. C. Loebbecke "RFID Technology and Applications in the Retail Supply Chain: The Early Metro Group Pilot", Bled eConference eIntegration in Action Bled, Slovenia 8(42) (2005) pp.1-12.
3. G. Alfian, M.Q.H. Octava "Customer Shopping Behavior Analysis Using RFID and Machine Learning Models", The Special Issue Technoeconomics of the Internet of Things 14(10) (2023) pp.1-20.
4. J. Melià-Seguí, R. Pous, A. Carreras, M. Morenza-Cinos, R. Parada, Z. Liaghat, R.D. Porrata-Doria "Enhancing the shopping experience through RFID in an actual retail store", UbiComp '13 Adjunct: Proceedings of the 2013 ACM conference on Pervasive and ubiquitous computing adjunct publication (2013) pp.1029-1036
5. K. Jung & S. Lee "A systematic review of RFID applications and diffusion: key areas and public policy issues", Journal of Open Innovation: Technology, Market, and Complexity 1(1) (2015) pp.6-13.
6. N. Kasiri "RFID Applications in Retail", Electromagnetic Wave Propagation for Industry and Biomedical Applications (2021) pp.2-5

# SESSION B: FUSION CONTROL

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session B: Fusion Control (Monday, August 12th, Room 718)

Paper ID: B-01

# Optimize Weighting Coefficients of Complementary Filter for IMU Sensors Utilizing the Golden Section Method

Nhut Thang Le[1,2], Nguyen Toan Thang Huynh[1,2], Cong Toai Truong[1,2], Huy Hung Nguyen[3], Van Tu Duong[1,2], Tan Tien Nguyen[1,2,*]

[1] *National Key Laboratory of Digital Control and System Engineering (DCSELab), Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam*

[2] *Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam*

[3] *Faculty of Electronics and Telecommunication, Sai Gon University*

[*]Corresponding author. E-mail: nttien@hcmut.edu.vn

## Abstract

Associated with the evolution of robotics in recent decades, sensors play exceptionally crucial roles and are regarded as the foundational elements that empower robots to understand and interact with the world around them. In reality, every sensor inherently has systematic errors depending on its principles of design and operation, consequently diminishing the dependability of the collected data. Numerous studies have been carried out to address the aforementioned problem, particularly methods that integrate multiple sensors. Accordingly, the complementary filter stands out as an effective data fusion algorithm for enhancing the precision of response signals derived from two sensors with complementary characteristics. However, a considerable hurdle when utilizing a complementary filter is the determination of the weighting coefficient, which serves as an adjustable parameter dictating the degree of confidence between two sensors. This paper proposes a method to determine the weight coefficient in the complementary filter using the Golden Section Method. The gyroscope and accelerometer are multi-sensor systems with complementary characteristics, used as the application object of the filter in this study. The effectiveness of the weighting coefficient is evaluated using the theory of Mean Squared Error between response data through the complementary filter and reference data from the sensor tester. In the simulation scenario of harmonic rotation around the X-axis with an amplitude of 30 degrees and a cycle of 10 seconds, the optimal weighting coefficient is 0.817 after 12 iterations with a desired error margin of 0.01 and a mean square error of 3.468. Furthermore, the scenarios of harmonic rotation around the X-axis with an amplitude of 15 degrees with cycle of 5 seconds 10 second are performed to evaluate the accuracy of the response signal through a complementary filter with an optimal weighting factor. The results show that the mean square error is 6.28 for the first scenario and 5.65 for the other scenario.

**Keywords:** Golden Section method, Complementary filter, Inertial measurement unit, Mean square error.

### Acknowledgments

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number TX2024-20b-01. We acknowledge the support of time and facilities from the National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

### References

[1] H. Henna, H. Toubakh, M. R. Kafi, and M. Sayed-Mouchaweh, "Towards fault-tolerant strategy in satellite attitude control systems: A review," *Proc. Annu. Conf. Progn. Heal. Manag. Soc. PHM*, vol. 12, no. 1, pp. 1–14, 2020, doi: 10.36001/phmconf.2020.v12i1.1272.

[2] S. Park, M. S. Gil, H. Im, and Y. S. Moon, "Measurement noise recommendation for efficient kalman filtering over a large amount of sensor data," *Sensors (Switzerland)*, vol. 19, no. 5, 2019, doi: 10.3390/s19051168.

[3] C. K. Mummadi *et al.*, "Real-time and embedded detection of hand gestures with an IMU-based glove," *Informatics*, vol. 5, no. 2, pp. 1–18, 2018, doi: 10.3390/informatics5020028.

[4] N. T. Le, T. D. Phan, M. D. Nguyen, and C. Toai, "Development of Two-Axes Gimbal System Testing Platform for Validating Tilt Sensor Precision," *8rd Int. Conf. Adv. Eng. – Theory Appl. AETA 2023*, pp. 1–6, 1994.

[5] M. Bourogaoui, H. Berriri, H. Ben Attia Sethom, and I. Slama Belkhodja, "Encoder disturbance fault detection in PMSM drives," *J. Electr. Syst.*, vol. 10, no. 2, pp. 194–208, 2014.

[6] M. Welcer, C. Szczepański, and M. Krawczyk, "The Impact of Sensor Errors on Flight Stability," *Aerospace*, vol. 9, no. 3, 2022, doi: 10.3390/aerospace9030169.

[7] P. Narkhede, S. Poddar, R. Walambe, G. Ghinea, and K. Kotecha, "Cascaded complementary filter architecture for sensor fusion in attitude estimation," *Sensors*, vol. 21, no. 6, pp. 1–18, 2021, doi: 10.3390/s21061937.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session B: Fusion Control (Monday, August 12th, Room 718)

Paper ID: B-02

# Dynamic Learning Policies and Predictive System for Enhanced Machine Failure Prediction in Stochastic Environments

*Le Quoc Thang*[1], *Truong Ngoc Cuong*[1*] *and Bui Duc Hong Phuc*[2*]

[1]*Department of Logistics, Korea Maritime and Ocean University, Busan, Republic of Korea*

[2]*Department of Engineering Technology, Gadomski School of Engineering, Christian Brothers University, Memphis, TN, 38104, USA*

## Abstract

This study examines the failure prediction of a machine in a complicated context. External factors typically cause machine performance to diminish over time. A dynamic learning policy is required to adjust parameters depending on new data. In machine learning, this can refer to algorithms that learn from streaming data and alter their predictions accordingly. The artificial intelligence-based High-Order Neural Network (HONN) model is used as an intelligent method to imitate the stochastic environment's complex dynamic behavior. The proposed methodologies improve accuracy and efficiency in predicting when a machine may break. The performance difference between the offered algorithms indicates that the error does not exceed the required limit (<1%). This suggests that the analytical and numerical solutions can be utilized interchangeably in reality. Finally, all validation tests indicate that the proposed decision support system can assist policymakers in controlling stochastic prediction with low effort and implementing error-minimization strategies.

**Keywords:** Machine learning, High-Order Neural Network (HONN), Machine failure prediction, Stochastic environments.

## References

Lei, Y., Li, N., Guo, L., Li, N., Yan, T., & Lin, J. (2018). Machinery health prognostics: A systematic review from data acquisition to RUL prediction. *Mechanical Systems and Signal Processing, 104*, 799-834.

Zhao, R., Yan, R., Chen, Z., Mao, K., WU, J., & Wang, P. (2019). Deep learning and its applications to machine health monitoring. *Mechanical Systems and Signal Processing, 115*, 213-237.

Jia, F., Lei, Y., Lin, J., Zhou, X., & Lu, N. (2016). Deep neural networks: A promising tool for fault characteristic mining and intelligent diagnosis of rotating machinery with massive data. *Mechanical Systems and Signal Processing, 72*, 303-315.

Wang, D., & Miao, Q. (2020). Remaining useful life prediction based on an integrated health index and Wiener process model. *Reliability Engineering & System Safety, 193*, 106678.

Liu, R., Yang, B., Zio, E., & Chen, X. (2018). Artificial intelligence for fault diagnosis of rotating machinery: A review. *Mechanical Systems and Signal Processing, 108*, 33-47.

Guo, L., Li, N., Jia, F., Lei, Y., & Lin, J. (2017). A recurrent neural network based health indicator for remaining useful life prediction of bearings. *Neurocomputing, 240*, 98-109.

Zhang, W., Peng, G., Li, C., Chen, Y., & Zhang, Z. (2018). A new deep learning model for fault diagnosis with good anti-noise and domain adaptation ability on raw vibration signals. *Sensors, 18*(12), 4250.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session B: Fusion Control (Monday, August 12th, Room 718)

Paper ID: B-03

# Multi-Mode DC Electronic Load With Hybrid Control System

Minh Nhat Huynh[1,2], Quoc Minh Lam[1,2], Cong Toai Truong[1,2], Ngoc Van Vu Thi[4], Huy Hung Nguyen[3*]

[1] *National Key Laboratory of Digital Control and System Engineering (DCSELab), Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam*

[2] *Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam*

[3] *Faculty of Electronics and Telecommunication, Sai Gon University*

[4] *High Technology Department, Ministry of Science and Technology*

[*]Corresponding author. E-mail: nhhung@sgu.edu.vn

## Abstract

In the realm of electronic testing and evaluation of power supplies, the demand for versatile and efficient testing equipment continues to rise. This paper addresses this problem by introducing the design and implementation of a multi-mode DC electronic load incorporating a hybrid control system, specifically tailored to enhance the testing and evaluation of battery systems and chargers. At the heart of innovation lies a strategic focus on improving both efficiency and adaptability. Leveraging the characteristics of power Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs) operating in the ohmic region, this electronic load replaces conventional dissipative resistors in the discharge performance test of DC power supply, so that improving efficiency and performance. One of the key features of the electronic load is its support for multiple operational modes, including constant current (CC), constant resistance (CR), and constant power (CP), each provides precise and reliable testing for various types of electronic devices and power supplies. Moreover, the electronic load is further enhanced by its modular design, which allows multiple units to be connected in parallel, forming a larger load capable of handling higher power ratings. This modular approach enables the load to handle higher power ratings, making it ideal for testing high-power applications with utmost reliability. In terms of control, to optimize power distribution and maintain system stability, a hybrid control system is integrated, facilitating efficient power sharing both within individual modules and across multiple interconnected modules. This control strategy ensures that the load operates reliably under various testing conditions, providing accurate and consistent results. Experimental results demonstrate the effectiveness of the multi-mode DC electronic load in performing precise tests on battery systems and chargers. The proposed system not only improves the flexibility and scalability of electronic load testing but also offers a cost-effective and efficient solution for various testing requirements in research, development, and manufacturing environments.

**Keywords:** DC Electronic Load, Power MOSFETs, Modular Design, High-Power Application, Hybrid Control System.

## Acknowledgments

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number TX2024-20b-01. We acknowledge the support of time and facilities from the National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

Session B: Fusion Control (Monday, August 12th, Room 718)

Paper ID: B-04

# Optimizing the Traveling Salesman Problem with Gurobi and Mixed Integer Programming

*Dang Hoang Gia Bao*[1], *Hwan-Seong Kim*[1,*]

[1]*Department of Logistics, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan 49112, Republic of Korea.*

[2]*Northeast-Asia Shipping and Port Logistics Research Center, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan 49112, Republic of Korea*

[*]Corresponding author. E-mail: kimhs@kmou.ac.kr

## Abstract

The Traveling Salesman Problem (TSP) is a well-known issue in combinatorial optimization that holds significant relevance in the fields of logistics, manufacturing, and bioinformatics. This research delves into the utilization of Mixed Integer Programming (MIP) methods for efficiently and accurately resolving TSP, employing the Gurobi optimization library within a Python setting, to determine the most efficient route for a vehicle to traverse points while minimizing the distance. The emphasis of our approach lies in managing secondary tour restrictions by incorporating supplementary constraints that seamlessly integrate with the advanced functionalities of the Gurobi solver. Our method is compared with traditional MIP formulations as well as heuristic and metaheuristic techniques, including Genetic Algorithms (GA) and Ant Colony Optimization (ACO). The outcomes illustrate that our constraint-driven methodology, supported by Gurobi, consistently delivers high-quality solutions within acceptable computational durations. More precisely, our approach enables the attainment of optimal or nearly-optimal solutions through the utilization of Gurobi's sophisticated optimization methodologies. In essence, this research offers significant perspectives on the application of MIP techniques for addressing the Traveling Salesman Problem through the utilization of the Gurobi optimization toolkit within the Python programming language. Our methodology showcases tangible advantages in tackling diverse instances of the Traveling Salesman Problem and underscores its relevance in addressing practical challenges. Subsequent studies will concentrate on amalgamating this MIP framework with heuristic and metaheuristic strategies to improve scalability and efficacy, thereby paving the way for more resilient and adaptable solutions to the Traveling Salesman Problem.

**Keywords:** Traveling Salesman Problem, Mixed Integer Programming, Python, Gurobi, Vehicle.

## Acknowledgments

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea (NRF) funded by the Ministry of Education(MOE)(2023RIS-007).

## References

Clímaco, Glaubos, Luidi Simonetti, and Isabel Rosseti. "A branch-and-cut and MIP-based heuristics for the prize-collecting travelling salesman problem." RAIRO-Operations Research 55 (2021): S719-S726.

Kitjacharoenchai, Patchara, et al. "Multiple traveling salesman problem with drones: Mathematical model and heuristic approach." *Computers & Industrial Engineering* 129 (2019): 14-30.

Kitjacharoenchai, P., Ventresca, M., Moshref-Javadi, M., Lee, S., Tanchoco, J. M., & Brunese, P. A. (2019). Multiple traveling salesman problem with drones: Mathematical model and heuristic approach. *Computers & Industrial Engineering*, *129*, 14-30.

Session B: Fusion Control (Monday, August 12th, Room 718)

Paper ID: B-05

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

# Root Locus Technique-based PID Control for Inspiratory Cycle Volume Control Mode of Two Double-Acting Piston Pump Ventilator

Trung Dat Phan[1,2], Cong Toai Truong[1,2], Van Tu Duong[1,2], Huy Hung Nguyen[3], Tan Tien Nguyen [1,2,*]

[1]*National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam.*

[2]*Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam.*

[3]*Faculty of Electronics and Telecommunication, Sai Gon University.*

[*]Corresponding author. E-mail: nttien@hcmut.edu.vn

## Abstract

In recent years, medical equipment has garnered unprecedented attention, and mechanical ventilators are no exception. Numerous studies have proposed various types of simple mechanical ventilators and control methods. Despite the mechanical simplicity of these ventilators, control of volume and pressure mode is crucial to ensuring effective and safe ventilation. However, these methods generally aim to control two critical parameters: volume and pressure control. Notably, the mechanical ventilator controller must be designed to handle the dynamic nature of respiratory demands by continuously monitoring various parameters. Specifically, these parameters such as airflow rate, pressure, and volume adjust the operation of the two double-acting piston pumps in real time to meet the patient's needs. To address this issue, this paper proposes designing a PID controller based on a numerical trajectory to modulate the output airflow to follow a square wave profile and to ensure the tidal volume remains within a 15% error margin of the actual value. First, the performance criteria for the controller are outlined. Then, a PD compensator is added to improve the transient response of the system. If the steady-state error is not achieved, a PI compensator is added to eliminate this error. The process of tuning the P, I, and D parameters is repeatedly performed until the specified criteria are met. Finally, the tidal volume error is evaluated via simulation based on the parameters of a 70 kilograms male patient in three scenarios: normal lungs, COPD, and ARDS. Furthermore, simulation results in three different scenarios demonstrate that the airflow follows the square wave signal accurately, and the relative error of the tidal volume remains within the 5% error margin. Above all, the addition of the controller significantly improves the transient response and steady-state error of the output flow compared to the original system.

**Keywords:** COVID-19, Two Double-Acting Piston Pump, Inspiratory Cycle, Volume Control.

## Acknowledgments

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number TX2024-20b-01. We acknowledge the support of time and facilities from the National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session B: Fusion Control (Monday, August 12th, Room 718)

Paper ID: B-06

# Estimating dimension of Cargo Boxes with Object Detection and SAM

Long Le Ngoc Bao[1], Hwan-Seong Kim[2,*] and Sam-Sang You[3]

[1,2]*Department of Logistics, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan, South Korea, 49112.*

[3]*Northeast-Asia Shipping and Port Logistics Research Center, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan, South Korea, 49112.*

[*]Corresponding author. E-mail: kimhs@kmou.ac.kr

## Abstract

This paper proposes an approach to estimate dimension of cargo boxes in 3D by non-contact metric. In order to estimate the dimensions, some pre-designed rectangular stickers with known shape and sizes are attached near the edges of the box, ensuring that two orthogonal sides of the sticker are always parallel to two orthogonal edges. A segmentation model named Segment Anything (SAM) is used to detect the appearance of the stickers from the box and separate them into groups of distinct pixels. Next, Sobel operator is used for detect the lines in the masked binary image to narrow down the list of points. After that, some geometry properties will be used to identify all corner points of the stickers and the box. Finally, by using the transformation property between coordinates, the real dimensions of cargo will be computed based on the pixel coordinates of the detection result. The obtained result reveals a flexible yet robust way of non-contact measuring objects in the warehousing area in which users can get the sizes of a package by taking photos.

**Keywords:** Distance estimation, Object detection, Sobel operator, Monocular depth estimation, Segment Anything Model

## Acknowledgments

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (MOE) (2023RIS-007)

## References

J. Lin, L. Liu, D. Lu and K. Jia, "SAM-6D: Segment Anything Model Meets Zero-Shot 6D Object Pose Estimation", Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), (2024) pp. 27906-27916.

Y. Ming, X. Meng, C. Fan and H. Yu, "Deep learning for monocular depth estimation: A review", Neurocomputing 438(28) (2021) pp.14-33.

T. Watanabe and D. Wolf, "Distance to Center of Mass Encoding for Instance Segmentation", in 2018 21st International Conference on Intelligent Transportation Systems (ITSC), USA (2018).

F. Wei, X. Sun, H. Li, J. Wang and S. Lin, "Point-Set Anchors for Object Detection, Instance Segmentation and Pose Estimation", in Computer Vision – ECCV 2020, Lecture Notes in Computer Science 12355 (2020).

D. Wofk, F. Ma, T.J. Yang, S. Karaman, V.Sze et al., "FastDepth: Fast Monocular Depth Estimation on Embedded Systems", in 2019 International Conference on Robotics and Automation (ICRA), Canada (2019).

L. Xin, H. Lin, X. Liu and S. Wang, "A Method for Unseen Object Six Degrees of Freedom Pose Estimation Based on Segment Anything Model and Hybrid Distance Optimization", Electronics 13(4) (2024).

# AFTERNOON SESSION

# SPECIAL SESSION II: BK21 FOUR

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Special Session II: BK21 Four (Monday, August 12th, Room 807)

Paper ID: BKII-01

# Synergistic meet of dark fermentation and microbial electrolysis cell for biohydrogen recovery during swine manure treatment

Mohammed Hussien[a,b,d,#], Dipak A. Jadhav[a], Su-Min Jo[a,b], Hai Yen Nguyen[a,b], Jin-Hyeok Jang[a,b], Ju-Hyeong Kim[a,b], Jae Young Kwon[a,b], Jae Kyung Jang[c], Enas Taha Sayed[d], Mohammad Ali Abdelkareem[d,e,*], Kyu-Jung Chae[a,b,*]

[a] *Department of Environmental Engineering, College of Ocean Science and Engineering, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan 49112, Republic of Korea*

[b] *Interdisciplinary Major of Ocean Renewable Energy Engineering, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan 49112, Republic of Korea*

[c] *National Institute of Agricultural Sciences, Department of Agricultural Engineering Energy and Environmental Engineering Division, 310 Nongsaengmyeong-ro, Deokjingu, Jeonju-si, Jeollabuk-do, Republic of Korea*

[d] *Chemical Engineering Department, Faculty of Engineering, Minia University, Egypt*

[e] *Department of Sustainable and Renewable Energy Engineering, University of Sharjah, P.O. Box 27272, Sharjah, United Arab Emirates*

***Corresponding authors:** M.A. Abdelkareem (E-mail addresses: mabdulkareem@sharjah.ac.ae), Kyu-Jung Chae (E-mail: ckjdream@kmou.ac.kr)

## Abstract

High concentrations of organic pollutants and high levels of nitrogen and sulfur contents make swine manure (SM) treatment complex and energy-intensive. Anaerobic dark fermentation (DF) is a promising and environmentally friendly technology for producing biohydrogen (bio-$H_2$) from high-strength organic waste. Nevertheless, the relatively low hydrogen yield (HY) on substrates and the generation of numerous by-products pose challenges to scaling up DF. However, the unconverted volatile fatty acids (VFAs) accumulated in the fermentation step can serve as a substrate in the subsequent stage to maximize hydrogen production and treatment efficiency. Therefore, this study integrated a 5 L DF and 0.2 L microbial electrolysis cell (DF-MEC) to maximize bio-$H_2$ recovery during SM treatment. To optimize the performance; the effect of different substrate concentrations was assessed using doses of 3.5, 7, 10, and 20 g COD/L in MEC. An optimal chemical oxygen demand (COD) concentration of 7 g/L was determined for the DF-MEC process, achieving an overall hydrogen production rate (HPR) of 1687.32 L/$m^3$·d and an HY of 264.13 mL/g·COD. COD removal efficiency reached 68%, significantly higher than DF alone. The results underscore the potential of DF-MEC coupling as an augmentative avenue for effective high-strength organic wastewater treatment and substantial hydrogen production through bioelectrochemical means.

**Keywords:** Dark fermentation; Hydrogen production; Integrated system; Microbial electrolysis cell; Swine manure.

## Acknowledgments

This project was supported by National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT). No. RS-2023-00209009, RS-2023- 00219497, RS-2023-00265777, and the “Cooperative Research Program for Agriculture Science and Technology Development (Project No. PJ016259022023)” funded by Rural Development Administration in Republic of Korea.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Special Session II: BK21 Four (Monday, August 12th, Room 807)

Paper ID: BKII-02

# Automated Detection System for Preventing Lonely Deaths of Elderly People Living Alone

Ye-Hoon Kim[1,2], Yeon-Woong Park[3,4], Su-Min Lee[3,4], Jun-Ho Huh[5,6*]

[1] *Master Course of Department of Data Informatics, National Korea Maritime and Ocean University, Republic of Korea.*

[2] *Master Course of Interdisciplinary Major of Ocean Renewable Energy Engineering (Concurrent Position), National Korea Maritime and Ocean University, Republic of Korea.*

[3] *Bachelor & Master Program of Department of Data Informatics, National Korea Maritime and Ocean University, Republic of Korea.*

[4] *Bachelor & Master Program of Interdisciplinary Major of Ocean Renewable Energy Engineering (Concurrent Position), National Korea Maritime and Ocean University, Republic of Korea.*

[5] *Associate Professor (Tenured) of Dept. of Data Science, National Korea Maritime and Ocean University, Republic of Korea.*

[6] *Associate Professor (Tenured) of Interdisciplinary Major of Ocean Renewable Energy Engineering (Concurrent Position), National Korea Maritime and Ocean University, Republic of Korea.*

[*]Corresponding author. E-mail: 72networks@kmou.ac.kr

## Abstract

Since the 21st century, especially in the 2010s, the number of elderly people has been steadily increasing. The percentage of people aged 65 and older was 13.8% in 2017 and 18.2% in 2023, and it is projected to reach 34.3% in 2040. However, in the past five years, the number of unattended deaths and unattended deaths of people over 65 has been increasing. To prevent this, our goal is to develop a critical situation detection and prevention network and manage these cases diligently. By integrating various sensors into the living environments of elderly people, we aim to continuously monitor their conditions. This network will enable caregivers and nearby social welfare centers to assess if they are in danger, providing many elderly people with smart care services. To summarize, we aim to introduce artificial intelligence and machine learning technologies to monitor the emergencies, health, and daily life of elderly people living alone, to understand different lifestyles, and to accurately assess emergencies.

**Keywords:** Lonely Death, Decision Tree, Sensor Fusion, Elders.

## References

1. Seojin Won, "The Role of Poverty on Depression and Self-Rated Health of Older Adults Living Alone: The Mediating Effect of Social Participation," Journal of the Korea Academia-Industrial Cooperation Society, vol. 21, no. 6, pp. 520-526, 2020.
2. KOSIS, “Future Population Projections,” July 19, 2024, Major Population Indicators (Sex Ratio, Population Growth Rate, Population Structure, Dependency Ratio, etc.) / Nationwide (In Korean)
3. Lubben, J. E. / 1988 / Assessing social networks among elderly populations / Family Community Health / 11: 45.
4. Evard, K. M. / 2000 / Relationship of activity and social support to the functional health of older adults / Journal of Gerontology, Series B: Psychological Sciences and Social Sciences / 55B: S208.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Special Session II: BK21 Four (Monday, August 12th, Room 807)

Paper ID: BKII-03

# Influence of Guide Vanes on the Performance of Biradial Turbine for Wave Energy Conversion in Oscillating Water Columns

Seong Jong Bae [1,2], Seung Hyun Jang [1,2], B.H.B.P.D. Baddegamage[1,2] and Min Yoon[1,2,*]

[1]*Department of Mechanical Engineering, National Korea Maritime and Ocean University, Busan, Republic of Korea, 49112*

[2]*Interdisciplinary Major of Ocean Renewable Energy Engineering, National Korea Maritime and Ocean University, Busan, Republic of Korea, 49112*

[*]Corresponding author. E-mail: minyoon@kmou.ac.kr

## Abstract

The present study examines the impact of guide vanes on the performance of the biradial turbine designed as a power take-off (PTO) system in oscillating water columns (OWC) for wave energy conversion. The OWC, a promising wave energy converter (WEC), operates by converting the oscillation-induced airflow within its chamber into mechanical energy through the PTO, which is subsequently converted into electrical energy. Conventional PTO systems such as Wells and impulse turbines, while widely used, suffer from limitations including narrow operational ranges, high noise levels, lower efficiency, and maintenance challenges. Biradial turbines offer a potential solution with their self-rectifying bidirectional flow, where the fluid enters and exits radially. These turbines are characterized by a symmetrical design perpendicular to the rotational axis, featuring radially oriented blades and disks at the inlet and the outlet. The guide vanes, positioned at regular intervals around the rotor axis in a multi-stage configuration, are included in the design. In the present research, the biradial turbine is numerically modeled, and its performance is analyzed using computational fluid dynamics (CFD). The CFD results are validated against existing experimental data. To determine the influence of guide vanes on turbine performance, simulations are conducted with and without guide vanes at the outlet. The results indicate an efficiency of 0.77 without guide vanes and 0.72 with guide vanes at a flow coefficient of 0.12, showing a higher efficiency when the guide vanes are absent at the outlet. This 5% efficiency gain is attributed to a reduction in the downstream pressure coefficient by 0.05, resulting from the removal of guide vanes. Despite the decrease in performance with the presence of guide vanes at the outlet, their necessity due to the bidirectional nature of the turbine is highlighted. The present study underscores the significant role of guide vanes in the performance of biradial turbines, providing valuable insights for optimizing wave energy converters.

**Keywords:** Computational Fluid Dynamics, Oscillating water columns, Biradial turbine

## Acknowledgments

This research was supported by the Korea Institute of Marine Science & Technology Promotion (KIMST) funded by the Ministry of Oceans and Fisheries, Korea (RS-2023-00254688, Advancement of Wave Energy Converters Applicable to Breakwater for Commercialization)

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Special Session II: BK21 Four (Monday, August 12th, Room 807)

Paper ID: BKII-04

# Comprehensive Labeled Oyster Dataset for Improved Segmentation

Thi-Ngot Pham[1,2], Hee-Jung Lee[3,*], Jun-Ho Huh[4,5,**]

[1]*Ph.D Candidate of Department of Data Informatics, National Korea Maritime and Ocean University, Republic of Korea.*

[2]*Ph.D Candidate of Interdisciplinary Major of Ocean Renewable Energy Engineering, National Korea Maritime and Ocean University, Republic of Korea.*

[3]*Researcher(Ph.D) of Southeast Sea Fisheries Research Institute, National Institute of Fisheries Science, Sanyang ilju-ro, Sanyang-eup, Tongyeong-si, Gyeongsangnam-do, 53085, Republic of Korea.*

[4]*Associate Professor (Tenured) of Dept. of Data Science, (National) Korea Maritime and Ocean University, Republic of Korea.*

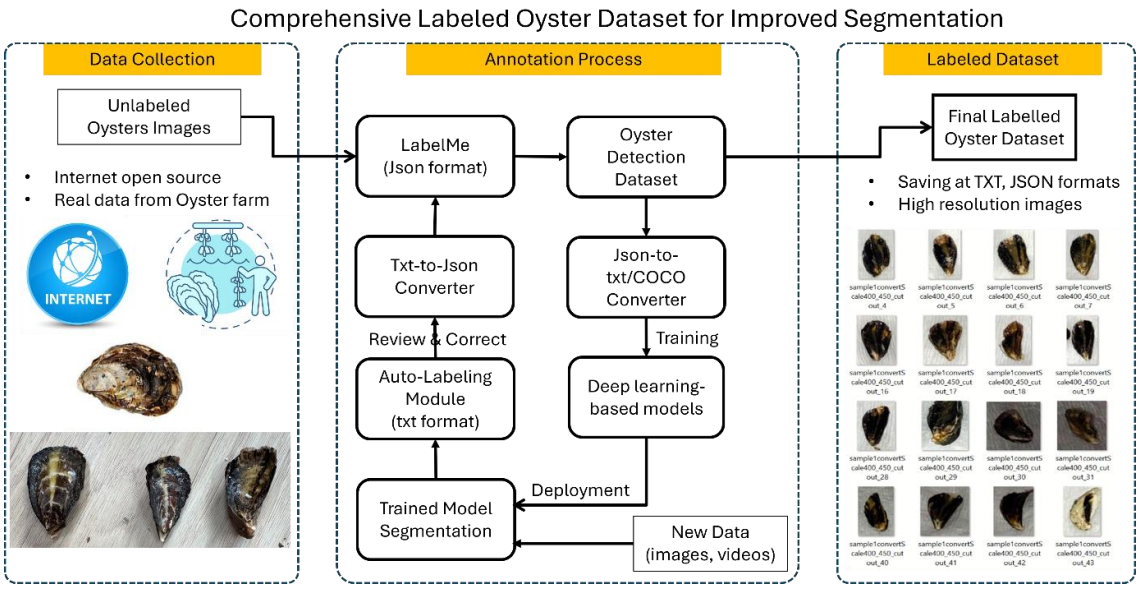
[5] *Associate Professor (Tenured) of Interdisciplinary Major of Ocean Renewable Energy Engineering, National Korea Maritime and Ocean University.*

[*]Corresponding author. E-mail: sobht@korea.kr [**]Corresponding author. E-mail: 72network@kmou.ac.kr

## Abstract

Oysters play a significant ecological and economic role, necessitating accurate and efficient species identification and quality assessment classification systems. Deep-learning networks for oyster classification have been integrated into packaging systems, but they face limitations due to a lack of labeled datasets for segmentation. To address this, we propose a labeled oyster dataset generated by combining multiple open-source datasets with real data from Korean oyster farms. To significantly reduce the time and effort required for dataset preparation, we introduce a semi-automatic labeling method integrated with a deep learning model. Firstly, we collected data from open-source datasets and re-labeled them to create a small oyster dataset comprising 1058 images. Then, this dataset was used to train various real-time deep learning object detector such as YOLOv5s-segmentation, YOLOv6s-segmentation, YOLOv8s-segmentation, YOLOv9s-segmentation, and RTMDet models. Among these, YOLOv9s-seg achieved the highest accuracy with 73.4% at mAP@0.5. Finally, the best-performing model, YOLOv9-seg, is implemented into our auto-labeling module. To create a new image dataset, data from oyster farms is fetched into our auto-labeling module, which automatically generates annotation files in TXT and JSON formats. These annotation files, along with the images, are saved in storage, and then, we use an open-source tool called LabelMe to review and correct the auto-labeled data. This process resulted in a labeled oyster dataset with approximately 2,000 images in two formats (TXT and JSON). With this work, creating a labeled oyster dataset becomes faster and can be directly utilized for deep learning models that accept TXT and JSON input training formats, such as the YOLO series, Mask R-CNN.

## Graphical Abstract




**Keywords:** Oyster detection, Segmentation, Deep-learning, YOLO, Oyster farming.

## References

1. Zhang, Ruihua & Chen, Xujun & Wan, Zhengzhong & Wang, Meng & Xiao, Xinqing. (2023). Deep Learning-Based Oyster Packaging System. Applied Sciences. 13. 13105. DOI: 10.3390/app132413105.

2. Feng Zhao, Jinyu Hao, Huanjia Zhang, Xiaoning Yu, Zhenzhen Yan, Fucun Wu, Quality recognition method of oyster based on U-net and random forest, Journal of Food Composition and Analysis, Volume 125, 2024, DOI: 10.1016/j.jfca.2023.105746.

3. https://universe.roboflow.com/curvy-oysters/oysters-cjt7n

4. https://universe.roboflow.com/631classwork/oyster-shell-classifier

5. Basu, A., Senapati, P., Deb, M. et al. A survey on recent trends in deep learning for nucleus segmentation from histopathology images. Evolving Systems 15, 203–248 (2024). DOI: 10.1007/s12530-023-09491-3

6. https://learnopencv.com/yolov5-instance-segmentation/

7. Lyu, Chengqi & Zhang, Wenwei & Huang, Haian & Zhou, Yue & Wang, Yudong & Liu, Yanyi & Zhang, Shilong & Chen, Kai. (2022). RTMDet: An Empirical Study of Designing Real-Time Object Detectors.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Special Session II: BK21 Four (Monday, August 12th, Room 807)

Paper ID: BKII-05

# Energy Clustering Computing Based Micro Grid Management: Digital Twins Empowered Design

Ngoc-Bao-Van Le[1,2], Hong-Danh Thai[1,2] Jun-Ho Huh[4,5*], Seung-Mo Je[1,3,6,**]

[1] *Ph.D Candidate of Department of Data Informatics, National Korea Maritime and Ocean University, Busan, Republic of Korea*

[2]*Ph.D Candidate of Department of Interdisciplinary Major of Ocean Renewable Energy Engineering (Concurrent Position), National Korea Maritime and Ocean University, Busan, Republic of Korea.*

[3]*Adjunct Professor of Department of Energy Convergence Security, Catholic University of Pusan, Busan 46252, Republic of Korea*

[4]*Associate Professor (Tenured) of Dept. of Data Science, National Korea Maritime and Ocean University, Republic of Korea.*

[5]*Associate Professor (Tenured) of Interdisciplinary Major of Ocean Renewable Energy Engineering (Concurrent Position), National Korea Maritime and Ocean University, Republic of Korea.*

[6]*Associate of Information Security Department, Information Communication Team, Korea Midland Power Plant Company Ltd., Republic of Korea*

[*]Co Corresponding author. E-mail: *72networks@kmou.ac.kr* [**]Corresponding author. E-mail: *jsm3316@korea.ac.kr*

## Abstract

To ensure global competitiveness and address climate change and energy shortage issues, the growing adoption of distributed energy resources and renewable energy sources has led to the rise of Micro Grids. The Republic of Korea is also focusing on developing IoT-based Micro Grids as a promising approach to enhance different energy integration, improve grid resilience, and enable innovative energy sharing and trading models at the local level. However, the complexity and dynamic characteristics of microgrid operations bring significant challenges to efficient and reliable management. To deal with these problems, we propose a framework for smart microgrid management that integrates energy clustering computing and digital twins technology. First, energy cluster computing is designed to optimize the operation of microgrids and energy sharing in smart grids by performing complex simulations and energy management algorithms. The research investigates energy clustering computing to create a Micro Grid community using IoE technology, DC communication, and sub-GHz wireless network technology. The technology enhances reliability, security, and quality of service convergence networks by implementing QoS and encryption. Next, to enhance the capabilities of the smart microgrid management system, this research integrates a digital twins-empowered design. Our system can create a virtual representation of the physical microgrid, allowing for real-time monitoring, simulation, and validation of management strategies before their implementation in the real-world system. This system can help to empower a green-energy community by monitoring and managing information on community energy consumption and distributed resource metering. As a result, our approach enables data-driven decision-making, predictive maintenance, and proactive adaptation to changing conditions to improve the overall efficiency and sustainability of the microgrid. We hope these research findings can help contribute to the advancement of smart microgrid management solutions and sustainable and reliable energy systems at the local level.

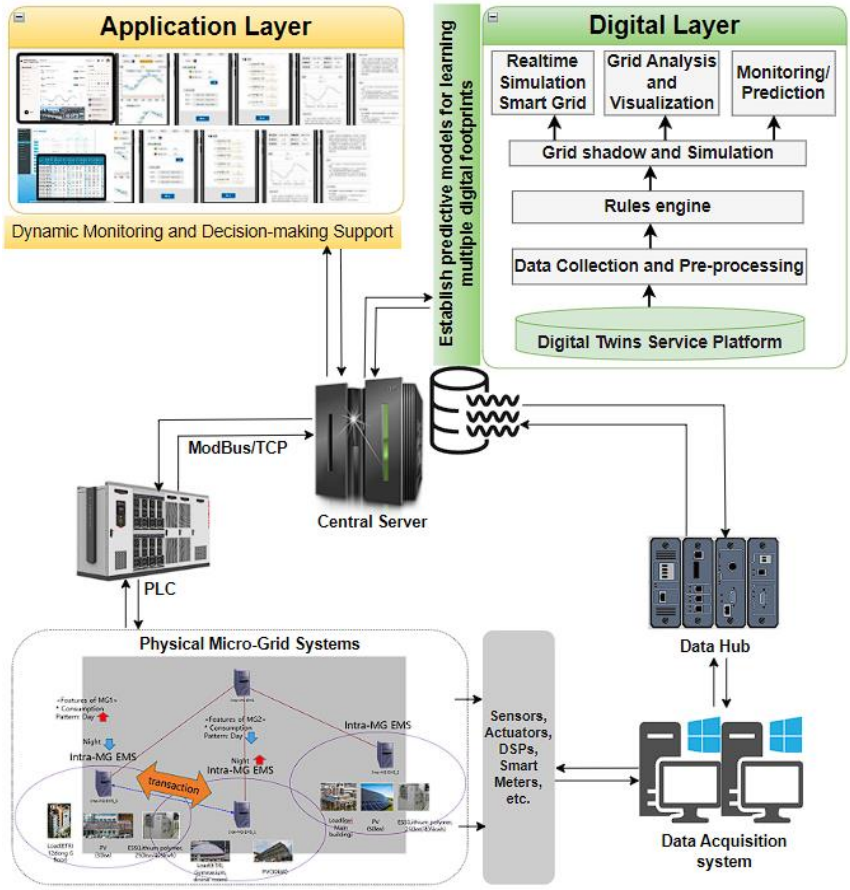
## Graphical Abstract

The main architecture of our energy cluster computing solution and test bed experiment in the digital twin smart grid is presented in Graphical Abstract, including three main layers. First, the physical micro-grid system collects data from various sources, including Intra-MG EMS, consumption data, inter-MG EMS, multi-sensors, actuators, DSPs, and smart meters, which is then consolidated by the data acquisition system and sent to a data hub, forwarded to a central server and data warehouse, with system data from ESSs also sent to the central server.

The energy cluster computing solution forms the computational importance of the digital twin layer, enabling advanced analytics, simulation, and optimization capabilities, where predictive models are established to learn from the multiple digital footprints of the grid. The digital twins service platform hosts the virtual representations of the physical grid assets. In the digital twin layer, predictive models are established to learn from the digital footprints of the grid, enabling a Digital Twins Service Platform to host virtual representations of the physical assets. This layer also includes

data pre-processing, a rules engine, grid shadow and simulation capabilities, real-time grid simulation, analysis, visualization tools, and monitoring and prediction functions. The cluster performs data collection and pre-processing, applies a rules engine, supports grid shadow and simulation, executes high-fidelity, real-time simulations, provides grid analysis and visualization, and enables monitoring and prediction capabilities.

Finally, the insights and recommendations generated by energy cluster algorithms in the digital twin layer are fed into the application layer, which focuses on the dynamic monitoring of the grid's real-time performance and status, leveraging the cluster's analytics and simulation capabilities to optimize grid operations, enhance reliability, and support the transition to a more sustainable, resilient, and intelligent power system, with the cluster's computational power enabling integration with control systems for automated grid optimization, anomaly detection, and early warning mechanisms and predictive maintenance and asset management solutions, and supporting scenario planning, what-if analysis, and user-friendly dashboards and reporting tools for grid operators and stakeholders.




Graphical Abstract. The architecture of Micro Grid management system integrated energy clustering computing and digital Twins technology

**Keywords:** Micro Grid, Smart Grid, Energy Clustering Computing, Energy Management, Digital Twins.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Special Session II: BK21 Four (Monday, August 12th, Room 807)

Paper ID: BKII-06

# Analysis of Flow Dynamics for Tandem Rotating Airfoils

Seung Hyun Jang[1,2], Seong Jong Bae[1,2], B.H.B.P.D. Baddegamage[1,2] and Min Yoon[1,2,*]

[1]*Department of Mechanical Engineering, National Korea Maritime and Ocean University, Busan, Republic of Korea, 49112*

[2]*Interdisciplinary Major of Ocean Renewable Energy Engineering, National Korea Maritime and Ocean University, Busan, Republic of Korea, 49112*

[*]Corresponding author. E-mail: minyoon@kmou.ac.kr

## Abstract

In this study, the flow characteristics of tandem rotating airfoils were investigated using a combined shape of Symmetric Joukowsky airfoil and cylinder. The airfoil length was 38 cm with a 3.8 cm cylinder attached to its leading edge, separated by a 1 mm gap. The design aimed to enhance lift due to the Magnus effect from rotation and leverage the airfoil's inherent ability to increase lift and reduce drag. A Realizable k-ε model was employed for turbulence modeling, with enhanced wall treatment applied. The setup included two airfoils arranged in tandem, at a Reynolds number of $4.62\times10^6$. Key variables were tip speed ratio (TSR = 0, 1, 2, 3), angle of attack (0°, 4°, 8°, 12°, 16°, 20°), and the distance between airfoils (1C, 2C, 3C, 4C, 5C, where C is the chord length). For the leading airfoil, closer spacing increased the lift coefficient, while for the trailing airfoil, greater spacing resulted in higher lift coefficients. This was due to delayed flow separation on the trailing airfoil, leading to lower drag and varying results based on distance. When all airfoils' cylinders rotated at TSR = 3, the average lift coefficient increased from 1C to 5C for angles of attack up to 12°, but for angles of attack 16° and above, it increased from 5C to 1C. This study highlights the impact of angle of attack and spacing on flow distribution and airfoil performance.

**Keywords:** Computational fluid dynamics, Rotating airfoil, Tandem arrangement, aerodynamic coefficient

## Acknowledgments

This research was supported by the Korea Institute of Marine Science & Technology Promotion (KIMST) funded by the Ministry of Oceans and Fisheries, Korea (RS-2023-00254688, Advancement of Wave Energy Converters Applicable to Breakwater for Commercialization)

# SESSION C: INTELLIGENT MECHANISM

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session C: Intelligent Mechanism (Monday, August 12th, Room 720)

Paper ID: C-01

# Application of Spherical Four-Bar Linkage Mechanism in Fin-Ray Structure Design for Fish Robots

Van Binh Duong Nguyen[1,2] , Minh Khoi Nguyen Tien[1,2], Huy Hung Nguyen[3], Van Tu Duong[1,2], Tan Tien Nguyen[1,2,*]

[1] *National Key Laboratory of Digital Control and System Engineering (DCSELab), Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam*

[2] *Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam*

[3] *Faculty of Electronics and Telecommunication, Sai Gon University*

*Corresponding author. E-mail: nttien@hcmut.edu.vn

## Abstract

This paper investigates the application of a spherical four-bar linkage mechanism in the design of fin-ray structures for biomimetic fish robots. Following an introduction to the significance and background of the research, the study proceeds to the synthesis and design of the mechanism, detailing the process of constructing the linkage from given parameters while considering geometrical and mechanical constraints. Comprehensive kinematic analysis is conducted to explore the motion capabilities of the mechanism, examining the range of motion and the relationship between input and output angles. Following this, dynamic analysis assesses the forces and torques required to drive the mechanism, ensuring efficient and effective operation under realistic conditions. The paper concludes with a comparison and evaluation of the spherical four-bar linkage mechanism against other potential mechanisms, highlighting its advantages and limitations. These findings aim to advance the design and functionality of biomimetic fish robots, providing crucial insights into the mechanical and control aspects of fin-ray structures.

**Keywords:** Undulating fin robot, four-bar mechanism, fin-ray robot, fish robot.

## Acknowledgments

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number TX2024-20b-01. We acknowledge the support of time and facilities from the National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session C: Intelligent Mechanism (Monday, August 12th, Room 720)

Paper ID: C-02

# From Depletion to Continuity: Improving FDM with Automatic Filament joining Technology and Parameter Optimization

Dam Lee[1] and Junghyuk Ko[1,*]

[1]*Department of Mechanical Engineering, Korea Maritime and Ocean University, Busan, Korea*

[*]Corresponding author. E-mail: jko@kmou.ac.kr

## Abstract

3D printing, also known as additive manufacturing and rapid prototyping, creates three-dimensional objects by layering material based on a digital model. This technology is broadly classified based on the material used into solid-based, liquid-based, and powder-based processes. Among these, Fused Deposition Modeling (FDM) is the most widely used method, employing thermoplastic polymers such as ABS, PLA, nylon, and TPU. PLA is particularly favored for its low melting point, excellent mechanical properties, thermal stability, biodegradability, and superior dimensional stability. Despite its widespread adoption, FDM faces significant challenges, including print quality issues, system and output problems, software and control issues, and filament depletion. Various studies have aimed to address these challenges. Kristiawan et al. highlighted that all input parameters of the FDM process affect the quality and mechanical properties of the printed parts. Aljarrah et al. developed a data-driven framework integrating self-organizing maps for data classification and a hybrid predictive model to predict part distortion. Shen et al. utilized a learning-based framework with 3D convolutional neural networks to enhance accuracy over time, reducing discrepancies between intended designs and actual printed parts. Wang et al. researched adaptive slicing methods to reduce manufacturing time while maintaining visual quality. Despite these advancements, further improvements are necessary. To address filament depletion, Mateev et al. developed a detection system for managing filament supply interruptions during FDM printing. This system monitors filament status using real-time temperature feedback, thermal control, resistance control, and capacitance measurement to prevent interruptions due to filament depletion or blockage. However, gaps remain in ensuring smooth printing continuity after filament replacement. This paper proposes equipment that automatically joins next filament with the remaining filament during printing, without requiring replacement. The joining process involves applying heat to the filament ends, and experiments were conducted to determine optimal parameters for joining, including heating temperature, cooling temperature, and pushing length. Heating temperatures were adjusted in 10-degree intervals from the printing temperatures specified by filament manufacturers. Cooling temperatures were similarly optimized. Pushing length was experimented with incrementally to find the optimal range for joining. A tensile test was conducted to ensure the joined filament has similar physical properties to the filament. The experimental results suggest that this approach can reduce material waste and costs, and improve print quality by minimizing defects that occur when printing is stopped and restarted due to filament depletion. This innovation is expected to contribute significantly to the advancement of FDM technology.

**Keywords:** Fused deposition modeling, filament depletion, heating temperature, cooling temperature, pushing length

## References

O. Aljarrah, et al., "Predicting part distortion field in additive manufacturing: a data-driven framework," Journal of Intelligent Manufacturing, vol. 34, no. 4, 2023, pp. 1975-1993.

V. Mateev, M. Ralchev, and I. Marinova, "Filament Supply Sensing and Control for FFF/FDM 3D Printing Technology", in Sensing Technology: Proceedings of ICST 2022, Cham: Springer International Publishing, 2022, pp. 301-313.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session C: Intelligent Mechanism (Monday, August 12th, Room 720)

Paper ID: C-03

# Distance-Adjustable Magnetic Flux Leakage Detection Using Archimedean Spiral Cam Slots for Pipeline Inspection Gauge

Thanh Nhu Nguyen[1,2], Minh Tri Tran[1,2], Minh Khoi Nguyen Tien[1,2], Huy Hung Nguyen[3], Van Tu Duong[1,2 *]

[1] *National Key Laboratory of Digital Control and System Engineering (DCSELab), Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam*

[2] *Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam*

[3] *Faculty of Electronics and Telecommunication, Sai Gon University*

[*]Corresponding author. E-mail: dvtu@hcmut.edu.vn

## Abstract

Pipeline Inspection Gauges (PIGs) are essential for maintaining oil pipelines by cleaning, removing debris, and ensuring optimal flow conditions. Modern PIGs use advanced sensors and diagnostic tools, such as Magnetic Flux Leakage (MFL) technology, to non-destructively evaluate pipelines by detecting corrosion, pitting, and other forms of degradation through magnetic field anomalies. However, traditional MFL systems struggle with adjusting the sensor-to-pipe distance, affecting defect detection accuracy and limiting versatility across different pipeline diameters. This paper introduces an innovative solution: integrating distance-adjustable Archimedean spiral cam slots into PIGs. These cam slots control the magnetic sensor's distance from the pipeline surface by converting rotational motion into linear displacement, ensuring accurate sensor positioning and high-fidelity data acquisition across various pipeline conditions. The research includes a comprehensive analysis of the cam slots' mechanical design and operation, supported by SolidWorks simulation software, evaluating material, thickness, stress, displacement, and deformation. The adjustable MFL detection mechanism adapts effectively to dynamic environments, maintaining high detection efficacy. Additionally, the adjustability feature extends the sensor lifespan and reduces maintenance needs, enhancing cost efficiency in pipeline monitoring. This approach significantly improves PIGs' versatility, accuracy, and reliability in pipeline maintenance, representing a valuable advancement in pipeline inspection technology.

**Keywords:** Pipeline Inspection Gauges, Magnetic Flux Leakage test, Archimedean spiral cam slots.

## 1. Introduction

The pipeline system is one of the most widely employed methods for transporting oil, gas, and liquids, owing to its safety and efficiency. With approximately 3.5 million kilometers of pipelines installed in 120 countries, the diameters of these pipelines range from 4.5 inches to 20 inches [1]. However, pipeline integrity diminishes over time, primarily due to internal corrosion, which increases the roughness of the pipe walls and reduces the inner diameter [2]. This degradation leads to operational interruptions, decreased efficiency, and increased maintenance costs. To mitigate these issues, pipelines require regular pigging and the implementation of proactive leak detection methods [3]. One effective tool for pigging is the Pipeline Inspection Gauge (PIG) [4]. The PIG is a device designed to detect leakages within pipelines; it is inserted into the pipeline system and travels through it during inspection. The PIG plays a crucial role in maintaining smooth operations and enhancing efficiency by cleaning the pipelines, removing debris, and ensuring stable flow conditions.

Given the necessity to detect defects and the susceptibility of pipelines to external factors, various methods can be incorporated into PIGs, such as Ultrasonic Testing, Dye Penetrant Test (DPT), and Electromagnetic Inspection (EMI) [5]. Among these, the EMI method has proven effective for surface inspection. Currently, alternative technologies such as Magnetic Flux Leakage (MFL) are being proposed for metal loss surveys.

To ensure the safety and functionality of Hall sensors in a pipeline inspection gauge (PIG), it is crucial to maintain an optimal distance of 3-5mm between the sensors and the pipeline's internal wall [6]. This paper introduces a design that incorporates Archimedean spiral cam slots to regulate this lift-off distance. Archimedean spiral cam slots, characterized by a spiral shape where the distance between turns increases uniformly, allow precise adjustment of the sensor-containing

arms within a 20-inch pipeline. By adjusting the lift-off distance, these slots ensure the sensors maintain the optimal gap, enhancing the reliability and efficiency of MFL detection, and thereby improving the overall performance of the PIG system.

## 2. System description

This research presents the design and development of a pipeline inspection system based on the unsteady/steady bypass flow modeling system [2]. The proposed system integrates a MFL module to acquire defect parameters within the pipeline during operation. The system comprises three main components: the PIG body, centering cups, and the MFL module.

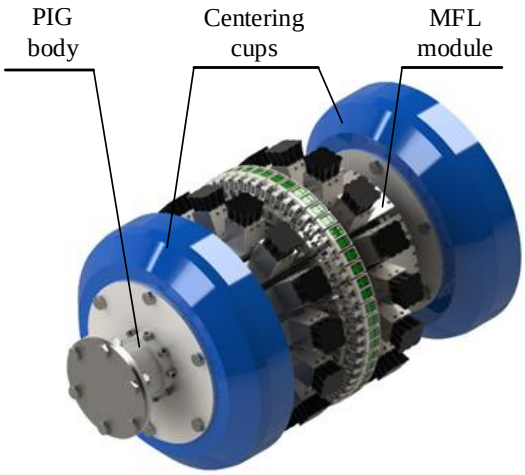



**Figure 1. 3D design of PIG system with MFL module**

**Figure 1** illustrates the 3D design of the overall pipeline inspection system. From a mechanical design perspective, the PIG consists of a rigid body, centering cups, and optional components such as the MFL module described in this work. The centering cups play a crucial role in maintaining the PIG's alignment within the pipeline. The frictional contact between the cups and the inner pipe wall determines the pigging capability of the system [7]. The MFL module, also referred to as a U-shaped magnetization frame, consists of mounted permanent magnets and steel brush sensors. The upper part of the frame houses the Hall effect sensors, which measure internal pipe defects. Moreover, the U-shaped magnetization frames are arranged side-by-side, forming complete circumferential coverage within the pipeline. This arrangement ensures that the magnetic field generated by the permanent magnets is applied evenly around the entire internal surface of the pipe, enabling comprehensive defect detection.

As mentioned above, the Archimedean cam mechanism is used to ensure an optimal distance of 3 to 5 mm between the Hall sensors and the pipe's internal wall for safe operation. This mechanism consists of two distinct cam disks interconnected by a cam roller. The first cam disk is fixed to the PIG body and serves as the driving component. As this rotary cam disk rotates, the cam roller actuates the linear cam disk, which is linked to the magnetization frame. This configuration functions as a spatial slider-crank mechanism, allowing precise control over the lift-off distance and ensuring reliable and efficient magnetic flux leakage detection.

**Figure 2a** and **Figure 2b** depict the operational states of 14 MFL modules, showcasing their retracts and extract configurations, respectively. These modules are powered by an HF-KP43(B) AC servo motor using a gearbox and gearset transmission system with a maximum transmission ratio of 1:500. This robust transmission setup ensures ample torque output, crucial for counteracting the suction forces that could otherwise pull the MFL modules back into the pipeline wall during operation.

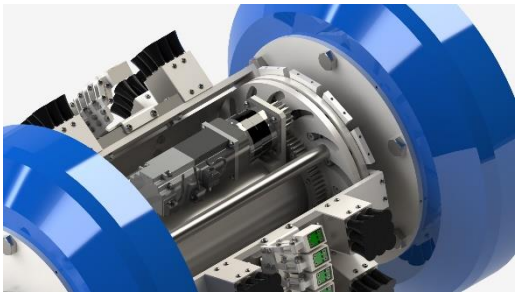


Figure 2a. MFL module when it retracts

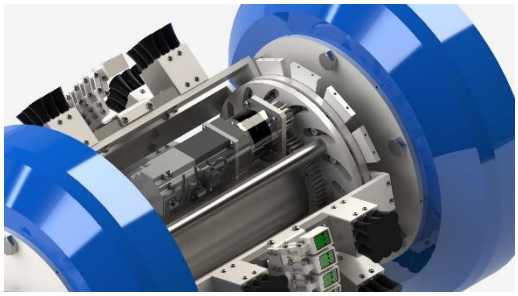


Figure 2b. MFL module when it extracts

## 3. Methodology

The Archimedean spiral, also referred to as the arithmetic spiral, describes the trajectory of a point moving at a constant speed away from a fixed point along a line that rotates with uniform angular velocity. Given the specified parameters such as the internal diameter of the pipe and dimensions of the magnetization frame, the formula governing the design of the Archimedean spiral can be expressed as follows:

$$\boldsymbol{r - h = a \times \theta} \tag{1}$$

Where: r is the length of the radius from the center of the spiral, h is the height of the magnetizer, a is a constant and θ is the polar angle. Therefore, the equations for the Archimedean spiral for 14 cam slot is described in **Equations (2).**

$$\begin{cases} \boldsymbol{x_{spiral} = x(i) + \left[r_{min} + (r_{max} - r_{min}) \times \dfrac{\theta}{12}\right] \times \cos\left[\theta + (i-1) \times 2 \times \dfrac{\pi}{14}\right]} \\ \boldsymbol{y_{spiral} = y(i) + \left[r_{min} + (r_{max} - r_{min}) \times \dfrac{\theta}{12}\right] \times \sin\left[\theta + (i-1) \times 2 \times \dfrac{\pi}{14}\right]} \end{cases} \tag{2}$$

Where: $i$ represents the serial number of the cam slot; $r_{max}$, and $r_{min}$ denote the radii of the two circles passing through the highest and lowest points of the cam slot, with values of 60mm and 43.75mm respectively. The projection of the 14 Archimedean spiral cam slots onto the coordinate axis is illustrated in Figure 4.

To determine the optimal equation for the Archimedean spiral applicable within a 20-inch pipe, a comprehensive analysis is necessary. This involves examining the kinematics of the cam mechanism to gain essential insights. Given the dimensions of the magnetization frame width, it is deduced that a maximum of 14 magnetization frame assemblies can be accommodated within the 20-inch pipe, as depicted in Figures 3a.

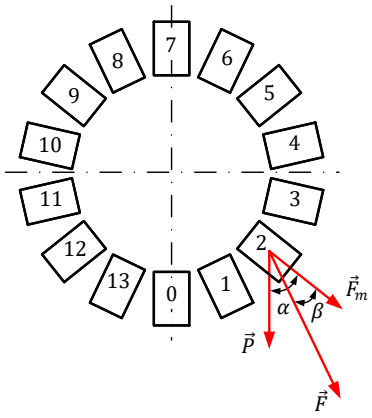



**Figure 3a. General parameters of the force analysis.**

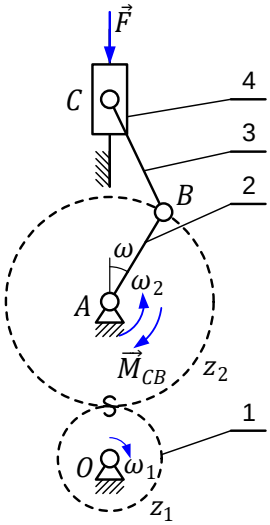



**Figure 3b. Kinematic diagram of distance-adjustable mechanism in MFL module.**

To provide a more comprehensive analysis, it is essential to examine the forces acting on the magnetization frames, as illustrated in Figure 3a. In this figure, the forces do not necessarily align at a specific angle. The general equation for the resultant force acting on the magnetization frames can be derived, as shown in Equation (3).

$$F = \sqrt{P^2 + F_m^2 + 2PF_m \cos\alpha} \tag{3}$$

Where: P is the gravitational force; F_m is the magnetic force; F is the total force acting on the magnetization frame; α is the angle between the gravitational force and the magnetic force. Utilizing Equation (2), the angle β between the total force and the magnetic force as described in Equation (4).

$$\beta = \cos^{-1}\left(\frac{F_m + P\cos\alpha}{\sqrt{P^2 + F_m^2 + 2PF_m\cos\alpha}}\right) \tag{4}$$

**Figure 4b** demonstrates the operational concept of the mechanism, depicting it as a slider-crank mechanism. Point C signifies the position corresponding to the motion of the magnetization frames. Joint A, serving as the cam disc, rotates, causing the length of line segment AC to fluctuate according to the direction of joint A's rotation. This variability plays a critical role in determining the required torque for operating the mechanism. The operational torque T of the mechanism is formulated as Equation (5), contingent upon the tilt angle θ.

$$T = 9.55 \times AB \times BC \times \sin\theta \sqrt{\left(\frac{P^2 + F_m^2 + 2PF_m\cos\alpha}{AB^2 + BC^2 - 2AB \times BC\cos\theta}\right)} \tag{5}$$

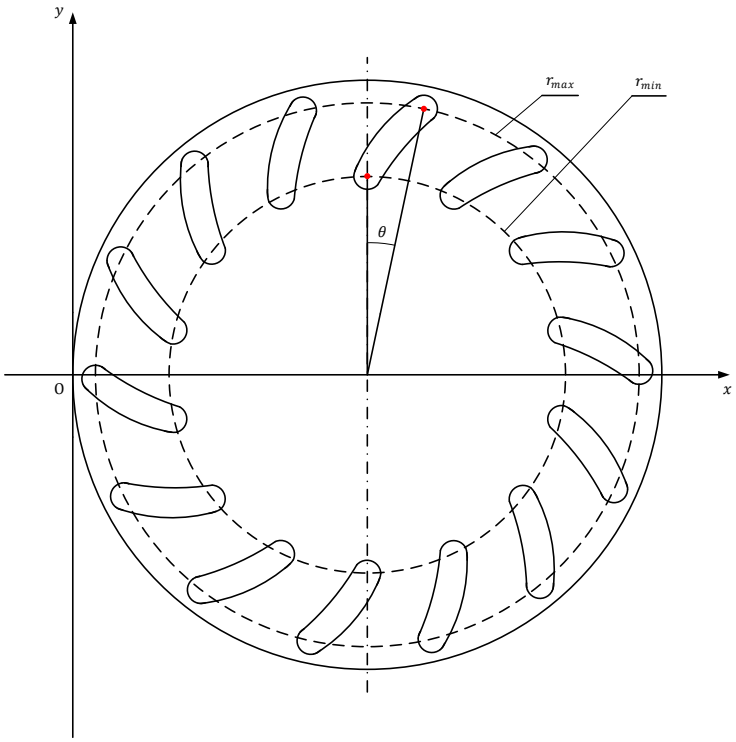



**Figure 4. The coordinate axis projection of the 14 Archimedean spiral cam slots**

## 4. Simulation and result

To ascertain the operational characteristics of the mechanism and evaluate whether the engine parameters align with its requirements, this chapter will elucidate the outcomes of simulating the mechanism using MATLAB and SolidWorks software.

Each MFL module is outfitted with two permanent magnets composed of NdFeB-5214 material, each measuring 50×50×25mm in dimensions and 35N in weight. The magnetic force exerted by each MFL module on a pipe wall with a thickness of 10mm is directly measured at 184N. This magnetic force value will be integrated into the simulation, and the outcomes illustrated in Figure 5.

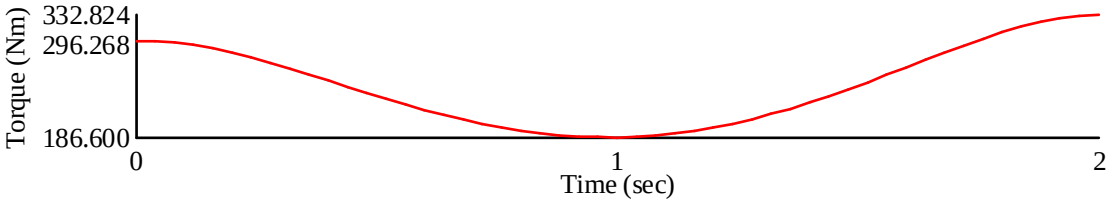



**Figure 5. Mechanism output torque over time**

According to the simulation results, during the initial phase when the MFL modules commence unfolding, the torque gradually diminishes, starting at approximately 296.298Nm due to alignment with the magnetic force direction exerted by the MFL modules. As the MFL modules complete their retraction, the torque stabilizes around 186.6Nm. In the subsequent phase, as the MFL modules retract, the torque experiences a sharp increase, peaking at approximately 332.824Nm, attributed to overcoming the magnetic force exerted by the MFL modules.

Based on the simulation findings, where the maximum output torque reaches approximately 332.824Nm, and considering a transmission ratio of 1:500, the torque at the remaining motor shaft is calculated to be about 0.66Nm. The rated torque of the HF-KP43(B) engine stands at 1.3Nm. Therefore, based on these simulation results, it is evident that the engine satisfactorily meets the specified requirements.

## 5. Conclusion

This study introduces an innovative solution for enhancing PIGs by integrating distance-adjustable Archimedean spiral cam slots. These cam slots address critical limitations in traditional MFL systems by ensuring precise sensor positioning across various pipeline diameters. With each MFL module applying 184N magnetic force exertion on a 10mm-thick pipeline wall, torque analysis reveals stable performance, with values peaking at 332.824Nm during operation. The adaptability of the cam slots enhances detection efficacy and reduces maintenance needs, extending the lifespan of the sensors and improving the versatility and efficiency of PIG technology.

However, this study's limitations include the lack of experimental measurements and the absence of simulations considering mechanical system disturbances. Future research will focus on conducting direct measurements within pipeline environments and acquiring data from hall sensors to empirically validate the effectiveness of this approach compared to traditional methods. Such empirical validation is crucial for confirming and optimizing the expected performance improvements, thereby advancing the reliability and applicability of PIG technology in pipeline maintenance practices.

## Acknowledgments

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number TX2024-20b-01. We acknowledge the support of time and facilities from the National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

## References

[1] API 5CT, "Specification for Casing and Tubing," *American Petroleum Institute*. pp. 1–291, 2005. [Online]. Available: https://www.monogramwebstore.org/publications/item.cgi?d86ba73e-8154-436c-88d0-7ea1ca8b3a33

[2] T. T. Nguyen, S. B. Kim, H. R. Yoo, and Y. W. Rho, "Modeling and simulation for PIG flow control in natural gas pipeline," *KSME Int. J.*, vol. 15, no. 8, pp. 1165–1173, 2001, doi: 10.1007/BF03185096.

[3] J. Okamoto, J. C. Adamowski, M. S. G. Tsuzuki, F. Buiochi, and C. S. Camerini, "Autonomous system for oil pipelines inspection," in *Mechatronics*, 1999, pp. 731–743. doi: 10.1016/s0957-4158(99)00031-8.

[4] L. Guan, Y. Gao, H. Liu, W. An, and A. Noureldin, "A Review on Small-Diameter Pipeline Inspection Gauge Localization Techniques: Problems, Methods and Challenges," in *2019 3rd International Conference on Communications, Signal Processing, and their Applications, ICCSPA 2019*, IEEE, 2019, pp. 1–6. doi: 10.1109/ICCSPA.2019.8713703.

[5] J. Cordell and H. Vanzant, *The Pipeline Pigging Handbook*, Third Edition, 2003.

[6] H. Q. Pham, B. V. Tran, D. T. Doan, V. S. Le, Q. N. Pham, and K. Kim, "Highly Sensitive Planar Hall Magnetoresistive Sensor for Magnetic Flux Leakage Pipeline Inspection," vol. 54, no. 6, pp. 1–5, 2018.

[7] G. Tan, D. Wang, S. Liu, H. Wang, and S. Zhang, "Frictional behaviors of rough soft contact on wet and dry pipeline surfaces: With application to deepwater pipelaying," *Sci. China Technol. Sci.*, vol. 56, no. 12, pp. 3024–3032, 2013, doi: 10.1007/s11431-013-5398-8.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session C: Intelligent Mechanism (Monday, August 12th, Room 720)

Paper ID: C-04

# Enhancing Autonomous Mobile Robot Safety with Camera-Based Object Detection and Tracking

Trinh Tran Vinh An[1], Hwan-Seong Kim[1,*] and Sam-Sang You[2]

[1]*Department of Logistics, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan, Republic of Korea, 49112*

[2]*Northeast-Asia Shipping and Port Logistics Research Center, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan, Republic of Korea, 49112*

[*]Corresponding author. E-mail: kimhs@kmou.ac.kr

## Abstract

In the field of autonomous mobile robots in warehouses, ensuring safe and efficient navigation in dynamic environments is crucial. To enhance the awareness of robots and enable them to distinguish between obstacles and the pallets they are responsible for handling, this presentation proposes a camera-based object detection and tracking method. The data collected from the camera attached to the robot are processed using the YOLO model to detect objects and draw bounding boxes around them. By tracking the movement of the objects through successive frames, the robot gains information about the presence and movement of objects in its view. To ensure safety, a safety zone is defined within the camera view by drawing a straight line on the frame. If the bounding box of an object crosses this zone line, the robot can make decisions to avoid collisions and maintain safe operation. This mechanism not only ensures safety but also provides the robot with crucial information for further processing and decision-making.

**Keywords:** Mobile robot, Object Detection, Object Tracking, Machine Learning, Visual Tracking.

## Acknowledgments

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (MOE)(2023RIS-007)

## References

A. Sarda, S. Dixit, and A. Bhan, "Object Detection for Autonomous Driving using YOLO algorithm," *2021 2nd International Conference on Intelligent Engineering and Management (ICIEM)*, Apr. 2021, doi: 10.1109/iciem51511.2021.9445365.

S. Syntakas, K. Vlachos, and A. Likas, "Object detection and navigation of a mobile robot by fusing laser and camera information," *2022 30th Mediterranean Conference on Control and Automation (MED)*, Jun. 2022, doi: 10.1109/med54222.2022.9837249.

Q. Abdullah *et al.*, "Real-time Autonomous Robot for Object Tracking using Vision System," *arXiv (Cornell University)*, Jan. 2021, doi: 10.48550/arxiv.2105.00852.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session C: Intelligent Mechanism (Monday, August 12th, Room 720)

Paper ID: C-05

# Research on Transporting Anchovy to Salt-Brined Fish Tank in Fish Sauce Factory

Ngoc Hung Nguyen[1,2], Cong Toai Truong[1,2], Minh Triet Huynh[1,2], Van Tu Duong[1,2], Tan Tien Nguyen[1,2,*]

[1] *National Key Laboratory of Digital Control and System Engineering (DCSELab), Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam*

[2] *Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam*

[*]Corresponding author. E-mail: nttien@hcmut.edu.vn

## Abstract

Vietnam is a coastal country with several traditional villages relative to oceanic activities. One of the most popular traditional coastal villages is a fish sauce-making village. Nowadays, based on the demand for producing a large quantity, automating the transportation of a mixture of fish is necessary to enhance efficiency and lower hiring labor costs. To address this problem, this paper provides a comprehensive of the current handicrafts procedures for making fish sauce and the outstanding problems. Secondly, the article analyzes a fish sauce procedure in Phan Thiet, specifically using anchovy to produce fish sauces, to inquire about the factory's structure as well as the characteristics of anchovy-salt mixture specifications, including length, mass density, and the coefficient of friction. Thereby, the article gives the proposed design solution of an automated system for the transportation of the mixture in the factory, which is a line-conveying system with modules for supplying, conveying, and cleaning, such as a pneumatic conveying and a tubular drag-chain system, and analyzes the benefits and drawbacks of each system before choosing the solution of the tubular drag-chain system. Additionally, this paper presents the three-dimension design of a tubular drag chain system, including a screw conveyor, driving and driven sprockets, a set of pulling disks attached to the chain, and discharge valves, along with the calculations to figure out the relationship between the technical specifications. Eventually, the article carries out the experiments and evaluations of two cases: a simple straight-segment pipeline and a scale model of a full system, respectively. With the goal of verifying the possibility of conveying the mixture of fish and salt as well as figuring out the system features that need to be considered, and the latter is to identify the relationships among the design specifications to optimize the system.

**Keywords:** Transportation of anchovy solution, tubular-drag chain conveyor, fish-sauce factory.

## Acknowledgments

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number TX2024-20b-01. We acknowledge the support of time and facilities from the National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session C: Intelligent Mechanism (Monday, August 12th, Room 720)

Paper ID: C-06

# Tower-typed Smart Farm using automatic cultivation machine

Seokhyeon Jeon[1], Jaewon Choi[1] , Taegang Kim[1] , Guenho Do[1] , Minseok Kim[1] and Junghyuk Ko[1,*]

[1]*Department of Mechanical Engineering, Korea Maritime and Ocean University, Busan, Korea*

[*]Corresponding author. E-mail: jko@kmou.ac.kr

## Abstract

Currently, Korea is an aged society where the working age population continues to decrease and the elderly population continues to increase. The appearance of an aging society is more prominent in rural areas. According to the results of the Agriculture, Forestry and Fisheries Survey by the National Statistical Office of Korea, the proportion of the agricultural population in 2023 accounts for 4% of the total population, of which the elderly population is 52.6%. This small proportion of the population and aging problem lead to a decrease in agricultural labor force, and a decrease in agricultural labor force leads to a decrease in crop production. To solve this problem, a smart farm system is introduced. The smart farm system means a farm that can properly maintain and manage the growing environment of crops remotely and automatically by integrating the fourth industrial revolution technologies such as IoT, Big Data, artificial intelligence, and robots into greenhouses. Applying the smart farm system to grow crops has the advantage of reducing the skill level required for agriculture, increasing the inflow of the agricultural population, and reducing the labor required through an automated system. However, existing smart farms cannot grow in order or individually because there is no space separation. So, we propose a tower-typed smart farm that uses an automatic cultivation machine. Our smart farm is designed as a tower type, so it is possible to grow successively by giving different environmental conditions for each layer, and the crops grown by stages can be grown efficiently through the automatic cultivation machine. Environmental conditions are changed for sequential growth, and the elements of environmental conditions include artificial light through LEDs, water level control through pumps, and artificial modification through fans. It is designed to collect separated environmental data and receive data in real time using Bluetooth. In addition, a Husky Lens is used to select criteria for separating environmental conditions. We devised an operation algorithm in which a husky lens is deep learning the color data of the crop, and color-learned Husky Lens measures the color of the crop and distinguishes and transfers the growth state of the crop. Using this algorithm, the environment is automatically classified and crops are grown without human intervention. Electricity is always required during the automatic cultivation process, and the energy cost generated by supplementing electricity by using renewable energy sources such as solar and wind power generators is reduced. Currently, only a part of the smart farm system is manufactured, but if the system is expanded and enlarged, a large number of crops can be grown, which can lead to an increase in agricultural production.

**Keywords:** Smart Farm, Automatic cultivation system, Tower-typed structure

## References

Young-Jae Ryoo (2024). Accurate Plant Parts Recognition for Smart Farm Robot Using Deep Learning. Journal of Korean Institute of Intelligent Systems, 34(1), 89-94, 10.5391/JKIIS.2024.34.1.89

Chul-Hong Park, Soo-Chang Lee, Mi-Jeong Lee, Jin-Young Kim, & Gwang-Hyun Yu (2024). Smart Farm Sensor Data and Deep Learning Prediction Models for Strawberry Growth in All Seasons. Journal of Digital Contents Society, 25(2), 557-565, 10.9728/dcs.2024.25.2.557

Eun-Byul Ko, Il-Woong Jeong, & Chul-Hee Lee (2023). Design and Implementation of Platform for Small-Scale Smart Farm using Deep Learning. Journal of the Korean Society of Manufacturing Process Engineers, 22(11), 59-67.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session C: Intelligent Mechanism (Monday, August 12th, Room 720)

Paper ID: C-07

# Utilizing MFL Signal Mapping Techniques for Defects and Corrosion Detection on Ferromagnetic Surfaces

Quoc Minh Lam[1,2], Cong Toai Truong[1,2], Quang Linh Vo[4], Huy Hung Nguyen[3], Van Tu Duong[1,2*]

[1]*National Key Laboratory of Digital Control and System Engineering (DCSELab), Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam.*

[2]*Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam.*

[3]*Faculty of Electronics and Telecommunication, Sai Gon University, Vietnam.*

[4]*Hanoi – Amsterdam Highschool for the Gifted, Vietnam*

[*]Corresponding author. E-mail: dvtu@hcmut.edu.vn

## Abstract

Detection and assessment of defects on ferromagnetic surfaces are crucial for maintaining the safety and functionality of industrial structures. This paper focuses on the signal processing techniques for Magnetic Flux Leakage (MFL) data to identify and evaluate surface defects. Specifically, we address the transformation of MFL signals into a two-dimensional (2D) mapped representation, which facilitates a detailed analysis of defect characteristics. By employing advanced signal processing algorithms, the MFL data is processed to enhance the detection accuracy and resolution of surface irregularities. The 2D mapping of MFL signals allows for clear visualization of defect locations and sizes, providing a comprehensive method for surface inspection. The process begins with the acquisition of raw MFL signals from the ferromagnetic surface. These signals often contain noise and require preprocessing to remove irrelevant data and enhance features related to defects. Various filtering techniques, such as low-pass and high-pass filters, are employed to clean the data, followed by normalization procedures to standardize the signal for further analysis. Advanced algorithms, including Fourier transforms and wavelet analysis, are utilized to convert the time-domain MFL signals into frequency-domain representations, which are more suitable for identifying characteristic patterns associated with defects. Once the signals are preprocessed, they are mapped onto a 2D grid representing the ferromagnetic surface. This mapping involves spatial interpolation techniques to ensure the signal data accurately corresponds to the physical locations on the surface. The resulting 2D map provides a visual representation of the MFL signals, with different colors and intensities indicating the presence and severity of defects. Experimental results validate the effectiveness of the proposed approach, demonstrating its capability to accurately map and identify various defect types on ferromagnetic surfaces. Tests conducted on sample surfaces with known defects show a high correlation between the detected defects and the actual defect locations and sizes. By transforming raw MFL data into informative 2D maps, the proposed method offers a powerful tool for industrial applications, enabling more efficient and accurate surface inspections. Future work will focus on refining the signal processing algorithms and exploring real-time applications of the technique in various industrial settings. The adoption of this method could lead to significant advancements in the maintenance and safety management of ferromagnetic structures.

**Keywords:** Magnetic Flux Leakage (MFL), Signal Processing Techniques, Two-Dimensional (2D) Mapped Representation, Spatial Interpolation Techniques.

### Acknowledgments

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number TX2024-20b-01. We acknowledge the support of time and facilities from National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session C: Intelligent Mechanism (Monday, August 12th, Room 720)

Paper ID: C-08

# Development of the Automated Multi-Pipette System Using CNC Machine

Minsoo Kang[1], Jonghyuk Im[1], Mingi Kim[1], Minjeong Kim[1], Jiyoung Heo[1], Junghyuk Ko[1,*]

[1]*National Korea Maritime and Ocean University, Busan, Republic of Korea*[1]

[*]Corresponding author. E-mail: jko@kmou.ac.kr

## Abstract

The recent outbreak of infectious diseases, such as COVID-19, has highlighted the need for rapid screening tests for a large number of suspected cases. As of August 2023, the cumulative number of COVID-19 cases in South Korea reached approximately 34,693,890, which accounted for about 67.12% of the total population. On March 17, 2022, the daily maximum number of confirmed cases reached around 621,328, which strained the capacity of screening clinics nationwide due to a shortage of medical personnels. To address the issue, an automated multi-pipette system is required. The system can significantly assist screening efforts by reducing efforts required to process many samples and easing the burden on users. However, for an automated multi-pipette system to be effective, the issues related to pipetting accuracy and efficiency must be solved. W. M. Leung et al. developed a calibration system for multi-pipettes using gravimetric methods. Zeng Huang et al. proposed a high-rigidity screw-type pipette shaft with an automatic centering effect and a disposable tip assembly mechanism to enhance operational efficiency. Despite these achievements, current models still need to develop flexibility for users, making it easier to meet various experiments. We propose a new model capable of 3-axis movement and pipetting many well plates to address the operational range issues of existing pipetting systems. Thus, experiments were conducted to achieve high accuracy in pipette positioning and suction volume relative to the motor speed and specified travel distance. The movement of the pipette is controlled by a Computer Numerical Control (CNC) machine for convenience. Repeated experiments were performed by varying the pipette's travel distance and speed in each direction, as well as by altering both motor speed and target suction volume to measure the suction volume repeatedly through the customized CNC system. The experimental results demonstrated precise movements and suction volumes according to the input parameters, confirming the precision and efficiency of the proposed system. We believe that utilizing the system can enhance the flexibility and efficiency for screening processes.

**Keywords:** CNC machine, Multi-Pipette, Parameter study, Efficiency

## References

Huang, Z. et al. Structure optimization of a pipetting device to improve the insertion effect of tips, Mech. Sci., 12, 501–510

W.M. Leung *et al*. Calibration of multi-channel pipettes using gravimetric method in accordance with the ISO 8655-6, Journal of Physics: Conference Series, Volume 1065, Issue 9

# SESSION D: AI & OPTIMUM (POSTER)

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session D: AI & Optimum (Poster) (Monday, August 12th, Room 718)

Paper ID: D-01

# Indoor mobile robot localization system based on object detection and optical character recognition

Bui Minh Hau[1], Hwan-Seong Kim[1,*]

[1]Department of Logistics, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan 49112, Republic of Korea

[*]Corresponding author. E-mail: kimhs@kmou.ac.kr

## Abstract

The application of mobile robots has become more significant in automated or semi-automated indoor systems due to their ability to perform various tasks effectively. A crucial factor driving the effectiveness of these automated systems is the advancement of computer vision technology. Traditional uses of cameras in robotics include detecting and avoiding obstacles, identifying routes, and reading and analyzing text. As computer vision technologies have progressed, cameras have increasingly assumed the roles of various sensors in automated vehicles, enhancing their overall functionality and efficiency. This paper focuses on the implementation of advanced computer vision techniques to enhance the localization systems of indoor mobile robots. The proposed localization system is designed to detect labels installed on the walls within the environment. Each label contains a unique code representing its specific position, which is an important part of the proposed robot's localization system. By utilizing object detection and optical character recognition (OCR) technologies, the system processes these labels and codes to accurately determine the robot's location. The object detection component identifies the presence of the labels, while the OCR component interprets the encoded positional data of the label. Extensive experiments were conducted to evaluate the performance of the proposed localization system. The results demonstrate the system's operational effectiveness, highlighting its ability to accurately determine the robot's position in various indoor settings. These findings suggest that the implementation of computer vision techniques significantly improves the localization capabilities of indoor mobile robots, enabling them to perform tasks more efficiently and autonomously. The development of computer vision techniques, along with deep learning, has helped cameras gradually assume the roles of many different types of sensors in the field of automation. The study underscores the transformative potential of computer vision in robotic systems, paving the way for more complex applications in indoor environments. By leveraging advanced detection and recognition technologies, mobile robots can achieve higher levels of autonomy and precision, ultimately enhancing their utility in various practical scenarios.

**Keywords:** Autonomous localization system, Mobile robot, Object detection, Optical character recognition

## Acknowledgments

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea (NRF) funded by the Ministry of Education(MOE)(2023RIS-007).

## References

R. Waranusast, P. Riyamongkol and P. Pattanathaburt, "Distance Estimation Between Camera and Vehicles from an Image using YOLO and Machine Learning", 2022 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC), 2022, pp. 482-488.

D.E. Saputra, A.S.M. Senjaya, J. Ivander, and A.W. Chandra. "Experiment on Distance Measurement Using Single Camera", 2021 4th International Conference on Information and Communications Technology (ICOIACT), 2021, pp. 80-85.

L. Seungyoo, H. Kyujin, S. Park and X. Yang. "Vehicle Distance Estimation from a Monocular Camera for Advanced Driver Assistance Systems", Symmetry, 2022, 14, 2657.

K.M. Yang, J. Kwak and K.H. Seo, "Study on Expanding Marker Sensing Range for Robot Localization Using Tilt Camera", 2023 23rd International Conference on Control, Automation and Systems (ICCAS), 2023, pp. 890-894

# Cargo Detection for AGV Support System in Warehouse using Advanced Computer Vision

Ho Van Roi[1], Hwan-Seong Kim[1,*] and Sam-Sang You[2]

[1]*Department of Logistics, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan 49112, Republic of Korea.*

[2]*Northeast-Asia Shipping and Port Logistics Research Center, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan 49112, Republic of Korea*

[*]Corresponding author. E-mail: kimhs@kmou.ac.kr

## Abstract

Efficient and accurate cargo detection is crucial for the operational success of automated guided vehicles (AGVs) in warehouse environments. This paper presents a novel support system for AGVs that leverages advanced computer vision techniques, specifically the YOLOv8 (You Only Look Once version 8) model, to enhance cargo detection capabilities. Our approach involves the development of a comprehensive computer vision pipeline that includes image preprocessing, real-time object detection using YOLOv8, and robust tracking mechanisms. The YOLOv8 model processes visual data and extracts relevant features, enabling the system to handle various cargo types with high accuracy. The proposed system also integrates seamlessly with the warehouse management system (WMS), allowing real-time communication and data exchange. This integration enables the system to accurately count and manage products for pick-up, contributing to inventory control and order fulfillment. Extensive experiments were conducted using a diverse set of warehouse scenarios to evaluate the system's performance. In conclusion, the integration of the YOLOv8 model into autonomous mobile robots offers a promising solution for enhancing warehouse automation. The proposed system not only boosts the accuracy and efficiency of cargo detection but also contributes to the overall productivity and effectiveness of warehouse operations. This comprehensive approach contributes significantly to the realization of a fully automated warehouse system, optimizing productivity and operational effectiveness.

**Keywords:** Cargo Detection, Automated Guided Vehicle, Computer Vision, Machine Learning.

## Acknowledgments

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea (NRF) funded by the Ministry of Education(MOE)(2023RIS-007)

## References

Neetha, S. S., Vijay Kumar Pandey, and Amit Kumar Sharma. "Real-Time Motion Detection for Cargo Tracking and Management in Industrial Warehouses." In 2024 International Conference on Optimization Computing and Wireless Communication (ICOCWC), pp. 1-6. IEEE, 2024.

Syu, Jia-Liang, Hsin-Ting Li, Jen-Shiun Chiang, Chih-Hsien Hsia, Po-Han Wu, Chi-Fang Hsieh, and Shih-An Li. "A computer vision assisted system for autonomous forklift vehicles in real factory environment." Multimedia Tools and Applications 76 (2017): 18387-18407.

Naumann, Alexander, Felix Hertlein, Laura Dörr, Steffen Thoma, and Kai Furmans. "Literature review: Computer vision applications in transportation logistics and warehousing." arXiv preprint arXiv:2304.06009 (2023).

Lei, Bin, Zhaoyuan Jiang, and Haibo Mu. "Integrated optimization of mixed cargo packing and cargo location assignment in automated storage and retrieval systems." Discrete Dynamics in Nature and Society 2019, no. 1 (2019): 9072847.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

# A hybrid MCDM approach for container terminal selection based on cumulative prospect theory

Pham Thi Yen[1], Hwan-Seong Kim[1,*], Truong Ngoc Cuong[1]

[1]*Department of Logistics, Korea Maritime and Ocean University, Busan, Republic of Korea, 49112*

[*]Corresponding author. E-mail: kimhs@kmou.ac.kr

## Abstract

This paper aims to determine the optimal container terminal in Southern Vietnam by using the rough analytic hierarchy process (AHP) and the rough technique for order of preference by similarity to the ideal solution (TOPSIS) based on cumulative prospect theory (CPT). Four container terminals in Southern Vietnam were evaluated as a case study to demonstrate the accuracy of the proposed approach. The findings indicate that the TICT terminal was the optimal container terminal in Southern Vietnam. Furthermore, the sensitive analysis demonstrated the affection prospect parameters of the decision-maker's preferences. The proposed approach, with its practical and effective tools, can significantly enhance the competitiveness of container terminal operators. Moreover, it equips liner shipping companies with reliable tools for their port selection processes, motivating them to make strategic decisions.

**Keywords:** multi-criteria decision-making (MCDM); rough analytic hierarchy process (rough AHP); the rough technique for order of preference by similarity to ideal solution (rough TOPSIS); container terminal selection; cumulative prospect theory (CPT).

## Acknowledgments

## References

e.g. M.T. Capizzi and R. Ferguson, "Loyalty trends for the twenty-first century", Journal of Consumer Marketing 22(2) (2005) pp.72-80.

Ha, M. H., & Yang, Z, "Comparative analysis of port performance indicators: Independency and interdependency", Transportation Research Part A: Policy and Practice 103 (2017), pp. 264-278.

Hsu, W. K. K., Lian, S. J., & Huang, S. H. S, "An assessment model based on a hybrid MCDM approach for the port choice of liner carriers", Research in Transportation Business & Management 34 (2020), pp. 100426.

Song, W., Ming, X., & Wu, Z, "An integrated rough number-based approach to design concept evaluation under subjective environments", Journal of Engineering Design 24(5) (2013), pp. 320-341.

Stević, Ž., Pamučar, D., Vasiljević, M., Stojić, G., & Korica, "Novel integrated multi-criteria model for supplier selection: Case study construction company", Symmetry 9(11) (2017), pp. 279.

Tversky, A. and Kahneman, D, "Advances in prospect theory: Cumulative representation of uncertainty", Journal of Risk and Uncertainty 5 (1992), pp.297-323.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session D: AI & Optimum (Poster) (Monday, August 12th, Room 718)

Paper ID: D-04

# 3D Construction and Object Positioning Support for Autonomous Mobile Robots in Warehouses

Nguyen Duy Tan[1], Hwan-Seong Kim[1,*] and Sam-Sang You[2]

[1]*Department of Logistics, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan, Republic of Korea, 49112*

[2]*Northeast-Asia Shipping and Port Logistics Research Center, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-gu, Busan, Republic of Korea, 49112*

[*]Corresponding author. E-mail: kimhs@kmou.ac.kr

## Abstract

This research proposes a novel approach to 3D construction and object positioning in indoor environments using 2D camera inputs. Coupled with advanced computer vision algorithms and machine learning techniques, the standard 2D camera can reconstruct detailed 3D representations of indoor spaces. Three main tasks are applied: object detection, depth measurement, and positioning in a 3D warehouse environment. These are combined to develop an object recognition and positioning system that identifies and locates objects within the reconstructed 3D space. The proposed system has significant potential applications in fields such as indoor navigation, providing a cost-effective and accessible solution for 3D reconstruction and object positioning, which is applied to a finite number of specific objects. Potential collaborations with augmented reality and robotics industries will also be considered to expand the practical applications of the technology. Ultimately, this research aims to provide a scalable and efficient solution for 3D mapping and object positioning in warehouse, contributing to advancements in automated warehouse navigation and spatial awareness technologies. In future steps, the system should be expanded to handle a larger variety of objects, and the accuracy of the object construction should be enhanced.

**Keywords:** 3D Construction, Object Detection, Warehouse, Computer Vision, Machine Learning.

## Acknowledgments

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea (NRF) funded by the Ministry of Education(MOE)(2023RIS-007)

## References

P. Castro and T.-K. Kim, “PoseMatcher: One-shot 6D object pose estimation by deep feature matching,” *arXiv.org*, Apr. 03, 2023. https://arxiv.org/abs/2304.01382

H. Jiang, Z. Jiang, K. Grauman, and Y. Zhu, “Few-View Object Reconstruction with Unknown Categories and Camera Poses,” *arXiv.org*, Dec. 08, 2022. https://arxiv.org/abs/2212.04492

S. Thalhammer, P. Hönig, J.-B. Weibel, and M. Vincze, “Open challenges for monocular single-shot 6D object pose estimation,” *arXiv.org*, Feb. 23, 2023. https://arxiv.org/abs/2302.11827

B. Wen *et al.*, “BundleSDF: Neural 6-DOF Tracking and 3D Reconstruction of Unknown Objects,” *arXiv (Cornell University)*, Jan. 2023, doi: 10.48550/arxiv.2303.14158.

C. Zhao, Y. Hu, and M. Salzmann, “LoCPoseNet: Robust Location Prior for Unseen Object pose Estimation,” *arXiv.org*, Nov. 29, 2022. https://arxiv.org/abs/2211.16290

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session D: AI & Optimum (Poster) (Monday, August 12th, Room 718)

Paper ID: D-05

# A Study on the Possibility of Construction 3D Printer with Multi-Layer Nozzle

Inwoo Kim[1] and Junghyuk Ko[1,*]

[1]*Department of Mechanical Engineering, National Korea Maritime and Ocean University, Busan, Korea, 49112*

[*]Corresponding author. E-mail: jko@kmou.ac.kr

## Abstract

The global construction industry is transitioning to a smart construction system that incorporates the 4th Industrial Revolution technology. In addition, compared to other industries, the construction industry is often carried out repeatedly and manually, so it is necessary to take measures against population decline and aging. As a result, research on automation and intelligent smart construction-related technologies is actively progressing. 3D printing technology is one of them. 3D printing refers to a technology that manufactures structures designed in three dimensions by layering them using automation equipment. The advantage of 3D printing technology is that it can quickly and accurately construct structures with complex shapes or customized members. In addition, from an economic point of view, it can prevent unnecessary waste of materials and reduce labor costs. However, the 3D printing of the additive method has been confirmed to show reduced physical properties compared to general concrete in terms of the bonding between layers. In addition, it is evaluated as a vulnerable structure in that it is difficult to purchase rebar, which is a representative concrete reinforcement material. To compensate for the shortcomings of 3D printing technology, we have developed a construction 3D printer that incorporates multi-layer nozzle technology. Multi-layer nozzle technology refers to a method in which two or more materials are not mixed and output through a single nozzle. The multi-layer nozzle we made is in the form of epoxy applied to the outside of the concrete layer and output. The epoxy applied on the outside reinforces the joint surface of the layer and improves the bending strength of the concrete-epoxy composite. In the experiment, two types of specimens were made and their flexural strength was compared. Specimens printed only with concrete and specimens with epoxy applied. Two types of specimens were measured in displacement and strain using DIC. As a result of the review of the load displacement curve, it was found that even when epoxy was applied (less than 1.0 vol%), there was a very high rate of improvement in flexural strength (17%). Through this experiment, it was possible to check the improvement in the performance of the structure printed with a construction 3D printer using a multi-layer nozzle. In the next experiment, we will make a construction 3D printer that can print a structure with a width of 1m, a height of 1m, and a height of 1m in order to experiment by creating a structure that is not the size of the specimen, and a nozzle that can use reinforcement materials other than epoxy.

**Keywords:** Construction 3D Printer, Multi-Layer Nozzle, Reinforcement, Epoxy

## Acknowledgments

This research was supported by the Regional Industry-linked University Open-Lab project through Science and Technology Commercialization Agency.

## References

JinYoung. Lee and TaiSik. Lee, "Using In Situ Resources and 3D Printing for Space Exploration Habitat Construction", KSCE Journal of Civil and Environmental Engineering Research 40(3) (2020) pp.337-343.

Jaewook. Lee, Jongho. Lee, Chorong. Park, Soyeon. Kim, "Research Trends in the Construction Field for the Revitalization of Smart Construction Technology", Journal of the Korea Academia-Industrial cooperation Society 23(12) (2022) pp.72-86.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session D: AI & Optimum (Poster) (Monday, August 12th, Room 718)

Paper ID: D-06

# Ammonia Leakage Characteristics in Enclosed Spaces

Jin-Woo Bae[1], Kweon-Ha Park[*2,*]

[1]*Korea Institue of Maritime and Fisheries Technology, Pusan .Korea, 49111*

[2] *National Korea Maritime & Ocean University, Pusan,Korea, 49112*

[*]Corresponding author. E-mail: dbdnltn@naver.com

## Abstract

As the International Maritime Organization strengthens its efforts to reduce greenhouse gases, ammonia is receiving significant attention as an environmentally friendly marine fuel due to its zero carbon dioxide emissions. However, ammonia's high toxicity, explosiveness, and corrosiveness necessitate forced ventilation in confined ship spaces such as Fuel Storage Hold Spaces (FSHS), Tank Connection Spaces (TCS), and Fuel Preparation Rooms (FPR). Research on ventilation performance is essential to mitigate the stagnation and concentration of harmful substances in these confined spaces. This study utilizes FLACS 22.2 to develop 14 scenarios by varying the placement of supply and exhaust ports in the fuel preparation room and analyze ventilation performance. The leakage rate was set to 0.1 kg/s, and the ventilation rate was set to 30 ACH.

Results indicate that when the supply port was located at Aft-Top-Stbd and the exhaust port at Fwd-Top-Stbd (Case 13), the average ammonia concentration was the highest after 100 seconds. Conversely, when the supply port was at Aft-Bottom-Stbd and the exhaust port at Fwd-Bottom-Port (Case 1), the concentration was the lowest. Despite increasing the ventilation time by 100 seconds, ammonia concentrations did not uniformly reduce to safe levels. After 50 seconds, Case 1 showed ammonia concentrations exceeding 1500 ppm towards the Aft, while Case 14 exhibited a stagnant zone along the Fwd wall. The distribution of ammonia concentration and velocity varied by height, influenced by the positioning of supply and exhaust ports as well as the arrangement and size of equipment. Stagnant areas, where velocity was relatively low, resulted in higher ammonia concentrations.

Additionally, when a small amount of ammonia leaked at 0.1 kg/s for 10 seconds, the explosive gas range was confined to approximately 1 meter in height near the leak point, indicating a very low risk of explosion from minor leaks. These findings underscore the importance of strategic port placement and robust ventilation design to enhance safety in ammonia-fueled ships. This research provides valuable insights for developing effective ventilation systems and safety protocols, contributing to the safe and sustainable use of ammonia as a marine fuel.

**Keywords:** Ammonia, Confined ship space, FLACS, Ventilation, Explosive gas range

## References

Shin I. S., Cheon J. M. Lee J. H.(2022), A Study on the Hazard Area of Bunkering for Ammonia Fueled Vessel, Journal of the Korean Society of Marine Environment & Safety, Vol. 29, No. 7, pp. 964-970.

Shin Y. H, Cho Guy Sun(2022), A Study on Response Time Effectiveness of Gas Detector to Prevent Leakage Accidents - Focusing on ammonia and carbon monoxide, Korean Journal of Hazardous Materials, Vol. 10, No. 2, pp. 01-07.

Gexcon AS, 2017, FLACS v10.6 User's Manual.

Yadav, A., & Jeong, B. (2022). Safety evaluation of using ammonia as marine fuel by analysing gas dispersion in a ship engine room using CFD. Journal of international maritime safety, environmental affairs, and shipping, Vol. 6, No. 2-3, pp. 99-116.

Lee C. Y., Cho D. H. (2022). A Numerical Study on Ventilation Characteristics of Factors Affecting Leakages in Hydrogen Ventilation. Journal of the Korean Society of Marine Environment and Safety, Vol. 28 No. 4, pp. 610-619.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session D: AI & Optimum (Poster) (Monday, August 12th, Room 718)

Paper ID: D-07

# Automating container damage detection with YOLOv8 deep learning model

Nguyen Thi Phuong Thanh[1], Gyu Sung Cho[2*] and Indranath Chatterjee[3]

[1,2] *Department of Port Logistics System, Tongmyong University, Busan, South Korea, 48520*

[3]*Department of Computing and Mathematics, Manchester Metropolitan University, Manchester, United Kingdom, M15 6BH*

[*]Corresponding author. E-mail: *gscho@tu.ac.kr*

## Abstract

The integrity of shipping containers is critical to guaranteeing product quality and worldwide logistics efficiency. Container damage can lead to severe economic losses, delays, and safety risks. However, manual inspection of containers is time-consuming, labor-intensive, and prone to human error. This study investigates the application of deep learning-based object detection to automate the detection of damage in shipping containers. Specifically, we employ the You Only Look Once version 8 (YOLOv8) model to identify container damages. The results demonstrate the effectiveness of the YOLOv8 model in detecting container damage, achieving a precision of 1.00 at a confidence threshold of 0.851 and a mean average precision (mAP@0.5) of 0.636 across all classes. These findings suggest that the model can accurately identify damage in shipping containers, enabling timely intervention and reducing the risk of goods damage or loss. The proposed method has several potential applications in container management at ports. It can be integrated into existing inspection processes to save time and money, used for real-time monitoring to prevent damage during transit, and employed for predictive maintenance to identify and prevent future damage. Additionally, it can facilitate the development of smart ports, where containers are equipped with sensors and cameras for real-time monitoring. This can improve port efficiency and safety, reducing the need for manual inspection. The method has far-reaching implications for logistics, transportation, and supply chain management, enabling a more efficient and cost-effective system for managing shipping containers.

**Keywords:** Container damage, Object detection, Computer vision, You Only Look Once version 8 (YOLOv8), Port efficiency, Logistics system

## Acknowledgments

This research was supported by "Regional Innovation Strategy (RIS)" through the National Research Foundation of Korea(NRF) funded by the Ministry of Education(MOE)(2023RIS-007).

## References

1. D. Han and G. Tang, “Damage detection of quayside crane structure based on improved faster R-CNN”, International Journal of New Developments in Engineering and Society 3(1) (2019) pp.284-301.

2. H. Huang, B. Wang, J. Xiao and T. Zhu, “Improved small-object detection using YOLOV8: A comparative study”, Applied and Computational Engineering 41 (2024) pp. 80–88.

3. M. Talib, A.H.Y. Al-Noori and J. Suad, “YOLOV8-CAB: Improved YOLOV8 for real-time object detection”, Karbala International Journal of Modern Science 10(1) (2024).

4. Z. Wang, J. Gao, Q. Zeng and Y. Sun, “Multitype damage detection of containers using CNN based on transfer learning”, Mathematical Problems in Engineering 21(1) (2021) pp.1-12.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session D: AI & Optimum (Poster) (Monday, August 12th, Room 718)

Paper ID: D-08

# Efficient synthesis of zeolite X and calcium carbonate from blast furnace slag

Seonmi Shin[1,2], Myoung-Jin Kim[1,2,*]

*Department of Civil and Environmental Engineering, Korea Maritime and Ocean University ,Busan, Republic of Korea*

[2] *Interdisciplinary Major of Ocean Renewable Energy Engineering, Korea Maritime and Ocean University, Busan, Republic of Korea*

[*]Corresponding author. E-mail: kimmj@kmou.ac.kr

## Abstract

The synthesis of zeolites using industrial by-products has gained significant attention as an effective recycling strategy. Utilizing by-products rich in Si and Al, such as blast furnace slag (BFS), for zeolite synthesis is significantly more cost-effective compared to the use of pure chemicals. Indirect carbonation involves converting calcium extracted from industrial by-products into calcium carbonate through a reaction with carbon dioxide. The residual by-products, post calcium extraction from BFS, are abundant in Si and Al, which are essential for zeolite synthesis. This study aims to develop a method for the efficient extraction of calcium from BFS, its conversion into calcium carbonate, and the simultaneous synthesis of zeolite using the residual by-products. This research investigates the potential of transforming the valuable elements (Ca, Si, Al) present in BFS into high-value-added products. Calcium was extracted from BFS using 0.5-1 M acetic acid at temperatures ranging from 30-70°C. Subsequently, 99.9% $CO_2$ was introduced into the calcium extraction solution to synthesize calcium carbonate. The residual by-products were then mixed with NaOH, fused at 550°C, and subjected to hydrothermal reactions at 90°C for 6 hours to synthesize zeolite. Analyses using XRF, XRD, and SEM confirmed that the synthesized materials were calcite-type calcium carbonate and zeolite X, respectively. The highest strength of synthesized zeolite X was observed when residual by-products obtained after extracting calcium with 1 M acetic acid at 50°C were used. This study demonstrates the feasibility of effectively utilizing Ca, Si, and Al in BFS to synthesize calcium carbonate and zeolite X. It proposes an economical and environmentally friendly method for converting industrial by-products, such as BFS, into high-value-added products.

**Keywords:** Blast furnace slag, Zeolite X, Calcium carbonate, Indirect carbonation

## Acknowledgments

This work was supported by the National Research Foundation (NRF) of Korea grant funded by the Korean government (NRF-NRF-2024RS00337666).

## References

Wang, J., Zhong, M., Wu, P., Wen, S., Huang, L., & Ning, P, “A review of the application of steel slag in CO2 fixation.” ChemBioEng Reviews, 8(3) (2021) pp.189-199.

Hartati, Prasetyoko, D., Santoso, M., Qoniah, I., Leaw, W. L., Firda, P. B., & Nur, H, “A review on synthesis of kaolin-based zeolite and the effect of impurities.” Journal of the Chinese Chemical Society, 67(6) (2020) pp.911-936.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session D: AI & Optimum (Poster) (Monday, August 12th, Room 718)

Paper ID: D-09

# Enhancing economic viability of indirect carbonation: Utilization of $Ca(OH)_2$ as an alkaline additive

Won Jo[1], Myoung-Jin Kim[1, 2*]

[1]*Department of Convergence Study on the Ocean Science and Technology, Korea Maritime and Ocean University, Busan, Republic of Korea, 49112*

[2]*Interdisciplinary Major of Ocean Renewable Energy Engineering, Korea Maritime and Ocean University, Busan, Republic of Korea*

[*]Corresponding author. E-mail: kimmj@kmou.ac.kr

## Abstract

Mineral carbonation technology utilizes natural minerals or industrial by-products to sequester $CO_2$ in the form of carbonates. Indirect carbonation offers the advantage of producing high-purity carbonates, but its commercialization is hindered by the high costs associated with solvents required for calcium leaching and alkaline additives necessary for pH adjustment. This study investigates the potential of using a more cost-effective alkaline additive, $Ca(OH)_2$, in place of the traditionally used, more expensive NaOH, to improve the economic viability of the process. Experiments were conducted to compare the efficacy of these two alkaline additives in adjusting pH and producing vaterite-type $CaCO_3$ during the indirect carbonation process. Cement kiln dust served as the calcium source, while seawater desalination brine was used as the solvent. The results indicated that $Ca(OH)_2$ effectively dissolved during carbonation, generating $OH^-$ ions and thus fulfilling the role of an alkaline additive. When the two different alkaline additives were used, both yielded similar results with vaterite content consistently at 98-99% and particle size below 2 μm. Notably, the yield of $CaCO_3$ was approximately 60% higher when $Ca(OH)_2$ was utilized. This increased yield not only confirms the feasibility of substituting NaOH with $Ca(OH)_2$ as an alkaline additive but also suggests a potential cost reduction of around 58% in alkaline additive expenses. Furthermore, the enhanced yield of $CaCO_3$ with $Ca(OH)_2$ implies a corresponding increase in $CO_2$ storage capacity. These findings have important implications for the accelerated commercialization of indirect carbonation technology.

**Keywords:** $Ca(OH)_2$, Alkaline additive, Indirect carbonation, pH swing, Vaterite

## Acknowledgments

This work was supported by the National Research Foundation (NRF) of Korea grant funded by the Korean government (NRF-NRF-2024RS00337666).

## References

A. Azdarpour, M. Asadullah, E. Mohammadian, H. Hamidi, R. Junin, M.A. Karaei, “A review on carbon dioxide mineral carbonation through pH-swing process”, Chem. Eng. J. 279 (2015) pp. 615–630

J. Jeon, M.J. Kim, “$CO_2$ storage and $CaCO_3$ production using seawater and an alkali industrial by-product”, Chem. Eng. J. 378 (2019)

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session D: AI & Optimum (Poster) (Monday, August 12th, Room 718)

Paper ID: D-10

# Application of 3D techniques in manufacturing orthopedic instruments

Hoang Chieu Le Phan[1,2,3], Minh Khoi Nguyen Tien[2,3]

[1] *Department of Process and Equipment, Department of Chemical Engineering, Ho Chi Minh City University of Technology*

[2] *National key Laboratory of Digital Control and System Engineering, DCSELab*

[3]*Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc District, Ho Chi Minh City, Vietnam;*

## Abstract

**A**nkle **F**oot **O**rthotics (AFO) plays an important role in patient rehabilitation. However, the method of conveying the AFO creation regimen in Vietnam currently does not meet the quality and time requirements for treatment. The manual process is complex and relies heavily on the technician's skills, resulting in a product that requires many revisions and is not suitable for the patient. In this regard, this research describes the process of manufacturing an AFO brace using 3D printing technology, including collecting patient limb data by 3D scanning method, modeling the limb, designing the brace on a computer, and manufacturing the brace using a 3D printer, and finally check product quality. The advantage of this method is shortened production time to 12 hours and products are customized for each patient.

The 3D printed AFO brace has been tested on 30 patients and has improved their walking function. Patients rate this product as comfortable, the right size, and not causing pain or negative effects on the skin. In conclusion, combining 3D scanning and 3D design in the AFO brace manufacturing process has overcome the limitations of traditional methods. This improves production times, product quality and patient comfort, while also guiding the development of technology in this field.

**Keywords:** Process technology, 3D printing, AFO

## 1. Introduction

Ankle foot orthosis (AFO) is widely used in human rehabilitation treatment. The brace applies force to the patient's limbs to help correct and restore range of motion and daily activities, especially to build gaiting of the patients [1].

Currently, domestic ankle braces are made using traditional manual methods, including the following main steps [1]:

*Step 1. Examine the patient*

*Step 2. Apply cast to create mold (negative mold)*

*Step 3. Create positive bones (leg model)*

*Step 4. Correct positive bones*

*Step 5. Absorb plastic (make splint).*

*Step 6. Cut the plastic from the dough*

*Step 7. Try the splint on the patient*

*Step 8. Complete the brace*

*Step 9. Inspect, evaluate and deliver the brace.*

With traditional manual methods, the quality of splints does not fully and promptly meet the doctor's treatment requirements. The measurement process is still manual and inaccurate, resulting to the longer manufacturing time. The process of making manual splints is quite complicated, depending heavily on the skill and experience of the worker to create a product that meets treatment requirements as well as patient satisfaction. Manufacturing time usually lasts from 1 to 2 weeks, productivity is low, and does not respond promptly to treatment requirements. The casting process causes discomfort for the patient, and plaster molding causes environmental pollution. In general, traditional manual production methods do not meet the requirements of production capacity, manufacturing time and product quality for patient treatment in the current period.

On the world, 3D technology has been widely applied in the orthopedic instrument manufacturing industry through 3D scanning tools, design support (CAD), calculation support (CAE), and production support. (CAM) and 3D printing to custom design and manufacture precise products that fit the patient's body.

3D printing technologies such as FDM, SLS, SLA, LOM etc. are gradually being applied in the production of orthopedic devices for rehabilitation needs, a growing and potential technical field in years to come. [2]


**Figure 1. Orthopedic device manufactured using 3D printing technology.**

## 2. Process of manufacturing AFO blanks using 3D printing technology

The following section outlines general (non-formatting) guidelines to follow. These guidelines are applicable to all authors and include information on the policies and practices relevant to the publication of your manuscript.

### 2.1 Technological process

The process of designing and manufacturing ankle braces using 3D printing technology includes the following steps:

**Step 1: Collect detailed data**

- Use 3D scanning tools to collect profiles of the patient's foot area (digital data).

**Step 2: Build the patient's body shape**

- Based on the part number data, construct the part model, ensuring smoothness and accuracy.
- Evaluate errors between 3D scanning models and part models.

**Step 3: Design the brace**

- Check and complete the limb model according to the doctor's treatment requirements.
- Design the shape of the brace.
- Design details on the brace.
- Check geometrical profiles and dimensions according to technical criteria.

**Step 4: Simulate and optimize the brace**

- Analyze and check the technical characteristics and durability of the brace.

Step 5: Making splints

- Fabricate braces using 3D printers with FDM or SLA technology.
- Post-processing of 3D printed splint products includes: heating, drying, sandblasting to smooth the product.
- Strapping and completing the splint.

**Step 6: Check product quality**

- Check the profile, size and structure of the brace with measuring tools.
- Have the patient try on the brace, perform exercises to check the function and evaluate the quality of the brace.

**Step 7: Complete the splint, instruct on how to wear the splint and monitor the patient's treatment process.**

With this process, the time to design and manufacture the ankle brace is shortened to about 3 days. The product is customized to suit the patient's body right during the computer simulation and design stage. The 3D printed ankle brace has high precision, convenience, aesthetics, creating psychological comfort and satisfaction for the patient.

### 2.2 Equipment

Main machinery and equipment in the process of manufacturing AFO braces using 3D printing technology include:

- Handheld 3D scanner, positioning device to support scanning of patient's limbs.
- Software to design and optimize braces.
- FDM or SLA 3D printer.
- Post-processing equipment for 3D printed splints.

- Testing tools.

### 2.3 Manufacturing ankle braces using FDM 3D printing technology

After the ankle brace is designed, the STL file (*.stl) is transferred to the 3D printer to print the product. In case the splint size is larger than the printer size, redesign the splint with 2 parts that can be joined after printing.

The brace is made using an FDM 3D printer. The material used is PP plastic, which is the type of plastic used to make traditional AFO braces.

**Figure 2. The ankle brace is made using 3D printing technology, PP material**

The time to design and manufacture the AFO brace is 12 hours, quickly meeting the doctor's treatment requirements.

**Table 1. Splint fabrication time**

| No | Job | Time |
|---|---|---|
| 1 | Scan the body | 15 min |
| 2 | Brace design | 2 hrs |
| 3 | 3D printing of braces | 6 hrs |
| 4 | Post-treatment of splints | 2 hrs |
| 5 | Complete the splint | 1 hr |
| 6 | Try splinting, check | 45 min |
| | **Total time** | **12 hrs** |

The time the patient participates in the splint making process is shortened to 30 minutes compared to the traditional production process. The problem of wearing a limb cast is replaced by 3D scanning, creating comfort for the patient when making a splint.

The quality of the brace is evaluated through checking the geometric dimensions and usability:

- Check the profile, geometric size, location of adjustment points, and movement at the Manufacturing Workshop.
- Have the patient try on the brace and perform exercises as prescribed by the doctor. The quality of the brace is assessed by the doctor based on the patient's gait and ability to move. Patients evaluate their satisfaction with wearing the brace in terms of size, severity, aesthetics, effects on the skin when wearing the brace, etc.

## 3. 3D printed brace testing

The styles and formats for the ICACE 2024 Template have been incorporated into the structure of this document. If you are using Microsoft Word, please use this template to prepare your manuscript. If you are reading a hard-copy or .pdf version of this document, please download the electronic template file, PAPER_template.dot, from the conference website.

### 3.1 Testing

The 3D printed AFO brace product was tested to treat 30 patients at the Traditional Medicine Hospital and the Rehabilitation and Occupational Disease Treatment Hospital in Ho Chi Minh City.

Splint trial period: 1 month.

Number of times tested and evaluated: 4 times.

The quality of the brace and patient satisfaction are evaluated by the doctor weekly during follow-up visits and the patient is instructed to practice during the first month of treatment.

### 3.2 Test result

The quality of the brace met treatment requirements, and the patient's walking function improved after one month of wearing the brace. Patients feel comfortable wearing the brace: light, airy, suitable size, aesthetic. No patient had pain when wearing the brace, and the skin was not affected.

## 4. Discussion

This research should be considered in the context of the experimental conditions and the potential applications of the findings. The main objective was to investigate the ability to apply 3D scanning and 3D printing for the AFO brace product. Manufacturing AFO braces and other orthopedic devices using traditional methods is still too manual, time consuming, and low productivity. Product quality depends greatly on the technician's experience. The quality control and accuracy of the product is limited, sometimes the splint must be adjusted by hand many times before being used by the patient. Applying a cast to create a mold always creates discomfort for the patient, and requires the use of plaster, which pollutes the environment.

Combining 2 solutions of 3D scanning and 3D design, it is possible to overcome the remaining limitations in the traditional orthopedic device manufacturing process.

3D scanning will replace the casting and molding process. 3D scanning does not cause discomfort to the patient and is not exposed to chemicals that can affect health. In particular, 3D scanning can only be performed once to store digital data of the patient's body. 3D scanning data shows the full geometric dimensions of the part and allows for storage on a computer or in the cloud.

From 3D detailed data, braces are designed on CAD software, ensuring more accuracy than hand-made braces. 3D splint design on software allows technicians and doctors to adjust the splint directly on the computer, creating a suitable product that meets the pressure position requirements for treatment.

Design data is transferred to a 3D printer to create braces with more accurate dimensions than current hand-made products. In addition, 3D printing technology can use a variety of different plastic materials (or mix many types of materials) to create products that are highly aesthetic, most convenient, and meet treatment requirements. for each individual patient.

## 5. Conclusion

The 3D manufacturing process is performed mainly on computer software. The use of CAD and 3D printing technology facilitates the simulation of patient limbs, and the design and manufacture of suitable orthopedic devices has many advantages over traditional methods in applied research. Using new materials, custom designs, virtual testing, etc. The application of 3D techniques can lead to significant improvements in the orthotic manufacturing process because of lower manufacturing times, faster and more comfortable sizing for the patient, and molds. plaster is suppressed and manufacturing errors are minimized.

Therefore, the application of 3D technology and 3D printing to manufacture products is really necessary, serving technological innovation in orthopedic instrument factories to improve productivity, product quality, and digitalization. data, improving treatment effectiveness, in line with world development trends.

References

[1] Ministry of Health, "Guidelines for specialized technical procedures for rehabilitation (Phase 3)", issued together with Decision No. 2520/QD-BYT dated June 18, 2019, of the Minister of Health.

[2] Yong Ho Cha et. al., Ankle-Foot Orthosis Made by 3D Printing Technique and Automated Design Software, Applied Bionics and Biomechanics, Vol. 2017, pp. 1-6, 2017.

## References

[1] Ministry of Health, "Guidelines for specialized technical procedures for rehabilitation (Phase 3)", issued together with Decision No. 2520/QD-BYT dated June 18, 2019, of the Minister of Health.

[2] Yong Ho Cha et. al., *Ankle-Foot Orthosis Made by 3D Printing Technique and Automated Design Software*, Applied Bionics and Biomechanics, Vol. 2017, pp. 1-6, 2017.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session D: AI & Optimum (Poster) (Monday, August 12th, Room 718)

Paper ID: D-11

# Design and Control of a Testing Machine for Fire Sprinkler K-factor Evaluation

Hai Dang Ho[1,2], Huu Nhan Nguyen[1,2], Cong Toai Truong[1,2], Huy Hung Nguyen[3], Van Tu Duong[1,2*]

[1] *National Key Laboratory of Digital Control and System Engineering (DCSELab), Faculty of Mechanical Engineering, Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam*

[2] *Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam*

[3] *Faculty of Electronics and Telecommunication, Sai Gon University*

[*]Corresponding author. E-mail: dvtu@hcmut.edu.vn

## Abstract

Fire sprinklers are crucial devices for preventing fires, and one important statistic that captures these systems' operational properties is the K-factor. The efficacy of fire suppression and compliance with safety regulations depend on precise K-factor measurement. According to fire sprinkler standard, which also details the design and testing procedures for such systems, mandates that the K-factor for sprinkler systems be verified. In order to meet the strict requirements of the fire sprinkler standard, an advanced sprinkler K-factor test system that satisfies this demand is presented in this work along with its design and control. The standard rules are adhered to by the experimental setup. First, the water pump is turned on and the sprinkler head is attached. The pressure sensor measures the desired pressure, which is 0.5 bar, and the pump speed is adjusted accordingly. After a predetermined amount of time, this pressure is maintained, and the K-factor is computed in accordance with the standard guidelines to confirm that the sprinkler satisfies the requirements. Next, the pressure is raised by 1 bar at a time, recalculating the K-factor at each level, and so on, until the pressure reaches 6.5 bar. The pressure is then reduced by 1 bar increments once it reaches 6.5 bar, recalculating the K-factor at each step, until it reaches 0.5 bar again. This last measurement marks the end of the experiment. The sprinkler diameter determines the K-factor, which needs to be within the range given in the standard. The sprinkler head is considered to comply with the standard if the test results indicate that the K-factor is within this range. A user-friendly interface is also included with the control system to enable real-time parameter monitoring. The interface lets operators quickly assess system operation by showing the flow rate and current pressure. Additionally, the interface includes graphical representations to help with data visualization, allowing users to spot patterns and decide on course during testing. Moreover, a PID controller is made to efficiently control the system's pressure. In order to maintain the appropriate pressure level, the PID controller continuously checks the pressure and modifies the pump speed. This guarantees steady and accurate pressure management, which enhances the precision and dependability of the K-factor readings.

**Keywords**: Fire sprinkler, K-factors, Fire-safety standard, flow control

## Acknowledgments

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number TX2024-20b-01. We acknowledge the support of time and facilities from the National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

The 5th International Conference on Applied Convergence Engineering (ICACE 2024)

August 12-13, 2024, National Korea Maritime and Ocean University, Busan, Republic of Korea

Session D: AI & Optimum (Poster) (Monday, August 12th, Room 718)

Paper ID: D-12

# Design and Control of Pressure Exposure Testing Machine for Fire Extinguishers

Huu Nhan Nguyen[1,2], Cong Toai Truong[1,2], Van Tu Duong[1,2], Huy Hung Nguyen[3], Tan Tien Nguyen [1,2,*]

[1]*National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), 268 Ly Thuong Kiet Street, District 10, Ho Chi Minh City, Vietnam.*

[2]*Vietnam National University Ho Chi Minh City, Linh Trung Ward, Thu Duc City, Ho Chi Minh City, Vietnam.*

[3]*Faculty of Electronics and Telecommunication, Sai Gon University.*

[*]*Corresponding author. E-mail: nttien@hcmut.edu.vn*

## Abstract

In numerous countries, the mandatory testing of firefighting equipment, specifically fire extinguishers, is imperative to ensure quality commercial in the market. In Vietnam and several other nations, fire extinguisher testing adheres to the ISO 11601:2008 standard, which encompasses burst pressure testing to assess the quality of fire extinguishers. To create the fire extinguisher explosion pressure, single-fluid systems, such as water or oil, are frequently utilized. However, these systems have drawbacks when applied to the fire extinguisher explosion test. Specifically, the control of pressure in an only-water system is complex due to its nearly incompressible nature, and in the case of an only-oil system, waste cleanup following a fire extinguisher explosion presents a challenge. To surmount these disadvantages, this paper proposes a fire extinguisher explosion test method in accordance with the ISO 11601:2008 standard. This method depicts a pressure-boosting system utilizing a cylinder with water in one chamber and oil in the remaining chamber, a hydraulic circuit and simulation for the corresponding circuit are also presented. Additionally, the experiment test with extinguishers is conducted to re-test the efficiency of the pressure-boosting system. The extinguisher is drained out to fill the water until pressure-increasing. The pressure-increasing factor would raise the pressure at a rate specified by the standard, and this increase is kept continuously until the extinguishers explode. In this study, three types of fire extinguisher containers were tested, corresponding to 4 kg, 6 kg, and 8 kg, with pressure explosion extinguisher ratings of 48 bar, 51 bar, and 54 bar, respectively. The resulting data and images of the explosion extinguishers are thoroughly documented and presented specifically in the experiment test and result sections of the research paper.

**Keywords:** fire prevention and fire protection, fire extinguishers, hydraulic cylinder, burst pressure.

## Acknowledgment

This research is funded by Vietnam National University Ho Chi Minh City (VNU-HCM) under grant number TX2024-20b-01. We acknowledge the support of time and facilities from the National Key Laboratory of Digital Control and System Engineering (DCSELab), Ho Chi Minh City University of Technology (HCMUT), VNU-HCM for this study.

Hosted and Organized by

KOSME

DCSELAB

한국해양대학교

BK21

Global R&E Program for Interdisciplinary Technologies of Ocean Renewable Energy

93530

9 788955 627817

ISBN 978-89-5562-781-7