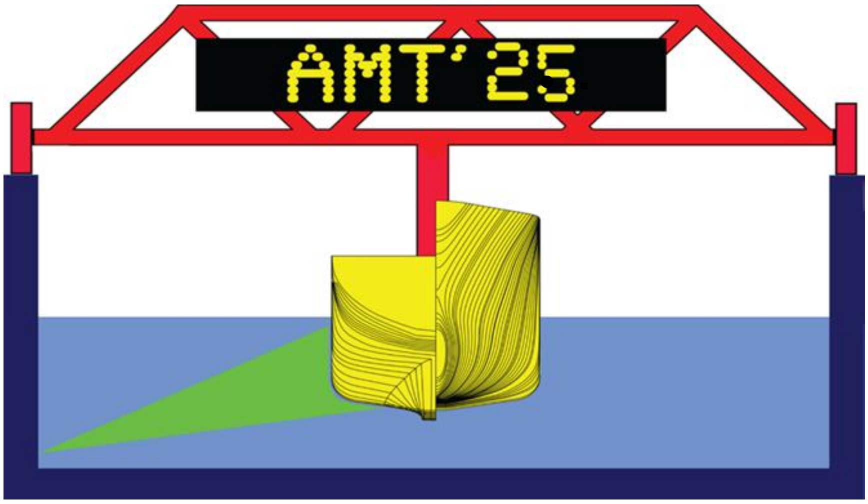
The 8th International Conference on Advanced Model Measurement Technology for the Maritime Industry (AMT'25)



29-31 October 2025, Daejeon, Republic of Korea

AMT'25 is organised by the Hydro-Testing Forum (HTF) members and hosted by the Korea Research Institute of Ships and Ocean (KRISO) in Daejeon

Conference Programme

&

Book of Abstracts

University of Strathclyde

HYDRO-TESTING FORUM

KRISO
KOREA RESEARCH INSTITUTE OF SHIPS & OCEAN ENGINEERING

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1952

Introduction

AMT'25 is the 8th international meeting of "*The Advanced Model Measurement Technology for the Maritime Industry*" conference series hosted at Daejeon in the Republic of Korea from 29th to 31st October 2025.

AMT'25 is hosted in the Daejeon Convention Centre in collaboration with the Korea Research Institute of Ships and Ocean (KRISO) as the host and the University of Strathclyde (UoS) as the organiser representing the HTF partners. The conference is organised and sponsored by the Hydro Testing Forum (HTF) members in collaboration with KRISO and UoS as the conference chair. This booklet contains the "*Conference Programme and Abstracts*" of the papers presented at AMT'25, which can also be downloaded from the conference website at https://www.amt2025.com/.

The AMT'25 conference features 40 technical paper presentations from 15 different countries, covering contemporary experimental topics, as well as two keynote presentations on the first and second days of the conference. The technical papers cover diverse state-of-the-art measurement technologies and testing facilities for the marine environment, including model-scale and full-scale measurements, supported by computational prediction and analysis methods. The presentations include: smart methods and facilities for underwater Radiated Noise (URN) and cavitation erosion measurements and observations; SPIV/LDA based measurement and imaging technologies; smart free running model and propulsor tests; wind assisted propulsion and air lubrication tests; biomimetic application tests involving tubercles and flapping foils to provide basis for novel energy saving devices (ESDs) and frictional drag reduction technologies; the full-scale performance of autonomous vessels; novel ESDs, including the gate rudder system and associated power prediction uncertainties as well as the uncertainty analysis involving other model tests; some special vessel designs including the hydrogen and electric propulsion are also part of the presentations.

The third and final morning of AMT'25 is dedicated to visiting the model testing facilities of the host institution, the Korea Research Institute of Ships and Ocean (KRISO), which is celebrating its 51st anniversary. The visit, conducted in split groups, involves guided tours of their large cavitation tunnel, ocean basin, towing tank, and ice tank.

In addition to the dissemination from the Hydro Testing Forum (HTF) members and other participants, AMT'25 provides an excellent networking opportunity, with delegates and invited equipment manufacturers displaying their products in the exhibition area during the conference.

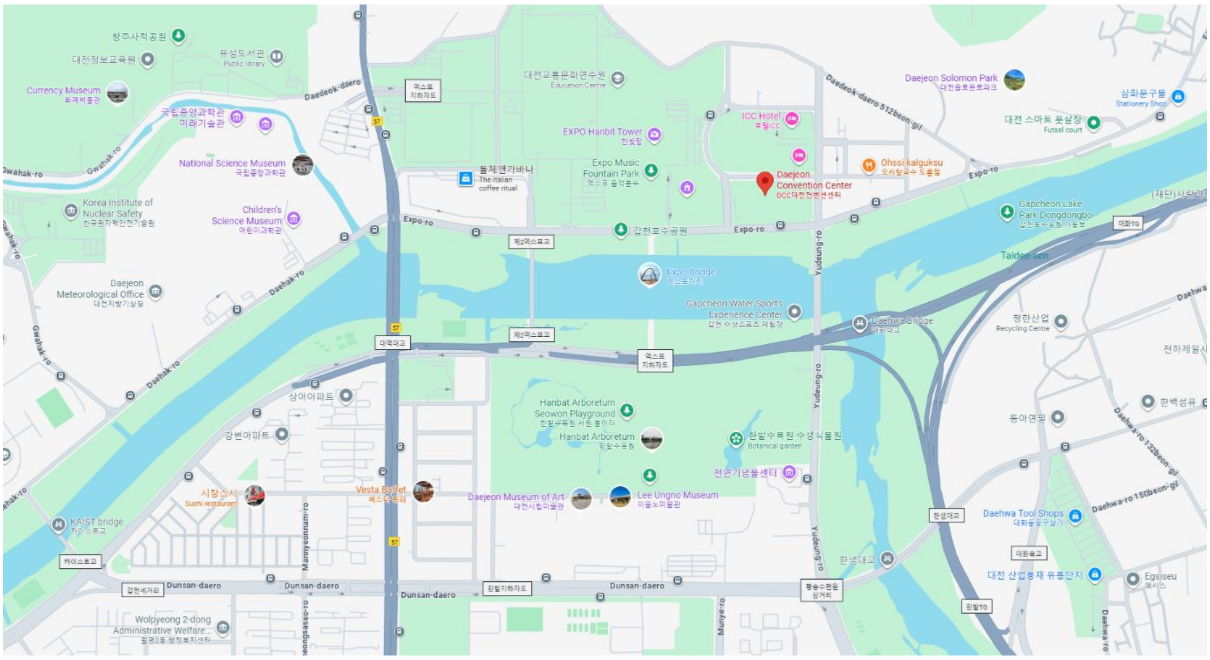
The first social function of the AMT'25 includes a reception with canapés and drinks, as well as a Korean cultural movie displayed in the background at the end of the first day's technical sessions in the conference venue. The second and primary social function is the Conference banquet at the exclusive restaurant of the Lotte City Hotel, including an exceptional live performance of Korean traditional music (Gugak) in orchestra style.

The AMT'25 Organising Committee

Contents

Dates & Venue

The 8th International Conference on Advanced Model Measurement Technology for the Maritime Industry (AMT’25) will be held from the 29th to the 31st of October 2025 at Daejeon Conference Centre (DCC) of Daejeon City, Republic of Korea, which is located on the map below:



Preface

Welcome to the 8th International Meeting of "*The Advanced Model Measurement Technology for the Maritime Industry*" Conference series, AMT'25, at Daejeon, the Republic of Korea.

The AMT'25 meeting coincides with the 17th Anniversary of the biannually held AMT Conference Series. The 1st through the 8th AMT conferences were held, respectively, at Nantes in 2009, Newcastle upon Tyne in 2011, Gdansk in 2013, Istanbul in 2015, Glasgow in 2017, Rome in 2019 and Istanbul in 2023 as part of the external dissemination of the Hydro Testing Alliance (HTA) Network of Excellence (NoE) which was sponsored under the umbrella of the 6th EU Framework Programme (FP) and the Hydro Testing Forum (HTF). All of the AMT conferences were excellent platforms for introducing the activities of HTA and HTF to conference delegates outside the NoE and for sharing the knowledge gained in the field of model measurement technologies in the marine environment by HTA and HTF.

The root of the AMT Conference Series is related to the HTA Network of Excellence (HTA-NoE), which introduced the 1st and 2nd conferences as the major dissemination platforms for this network. The five years for the HTA-NoE were successfully concluded in 2011, leaving the AMT Conference Series as its legacy. In the meantime, one of the missions of the HTA project was to establish the HTA as a formal and long-lasting forum to sustain the scientific activities of the HTA. Therefore, the members of the HTA-NoE established the "Hydro Testing Forum" (HTF) in 2012.

The vision of the HTF is to achieve reliable and validated hydro-testing services with advanced measurement techniques for maritime technologies. The mission of HTF is to establish a formal and lasting international network to coordinate the definition and introduction of novel measurement, observation, and analysis technologies for the hydrodynamic model testing environment.

In HTF, any interesting topic can be agreed upon as a Community of Practice (CoP) and investigated by interested HTF members, based on the agreed-upon framework. In the HTF network, maritime research institutes, measurement equipment providers and universities share their experiences in measurement technologies. Expert members meet in forum events through workshops on specific subjects and plenary discussions on new ideas and achievements. The membership of the HTF network is open to all hydro-testing organisations, universities, measurement systems providers and end-users. To become a member of the HTF network, a membership agreement must be signed. Detailed information on the HTF and membership application can be found on the official website of the HTF at www.hydrotestingforum.org

All the AMT Conference Proceedings are also freely accessible on the HTF website, including the AMT'25.

On behalf of the AMT'25 Organising Committee and HTF Standing Committee, we wish you a pleasant stay in Daejeon and a fruitful conference.

The AMT'25 Conference Co-Chairs

Prof Mehmet Atlar
(HTF & University of Strathclyde, UK)

Dr Jin Kim
(KRISO, Republic of Korea)

The AMT'25 Organising Committee

Name	***Affiliation***	***Mail***
Prof Mehmet Atlar	University of Strathclyde	mehmet.atlar@strath.ac.uk
Dr Noriyuki Sasaki (Hon Prof)	University of Strathclyde	noriyuki.sasaki@strath.ac.uk
Dr Cagatay Koksal	University of Strathclyde	cagatay.koksal@strath.ac.uk
Dr Saishuai Dai	University of Strathclyde	saishuai.dai@strath.ac.uk
Dr Ahmet Gurkan	University of Strathclyde	ahmet.gurkan@strath.ac.uk
Assoc Prof Serkan Turkmen	Tallinn University of Technology	serkan.turkmen@taltech.ee
Dr Jin Kim	KRISO	jkim@kriso.re.kr
Dr Hanshin Seol	KRISO	seol@kriso.re.kr
Dr Hongseok Jeong	KRISO	hsj@kriso.re.kr
Dr Dongwook Kim	KRISO	dwkim@kriso.re.kr

Conference Programme

AMT'25 Conference Programme

	(Day 1) 29th of October 2025
Time	Events & Locations
8:00-9:00	**Registry & Coffee/Tea** (Daejeon Conference Centre [DCC] – Lobby)
9:00-9:15	**Opening Ceremony:** Welcome speeches Chair: TBC (Daejeon Conference Centre [DCC] – Room 101-102)
9:15-10:15	**KEYNOTE PRESENTATION 1 –** Hydrodynamic Model Testing: Where we stand and where we are headed? *Dr Hyun-ho Lee, Executive Vice President & Research Director, Hyundai Maritime Research Institute, Republic of Korea* Chair: TBC (DCC – Room 101-102)
10:15-10:45	**Refreshments** (DCC – Lobby)

10:45-12:15	**Session 1A – Cavitation, Erosion and Underwater Radiated Noise Model Tests and Numerical Modelling** Chair: TBC (DCC - Room 101-102)	**Session 1B – Special Vessel Operations** Chair: TBC (DCC - Room 103-104)
10:45-11:15	PAPER 1 - Aspects of Source Level Estimation from Sound Measurements In MARIN's Depressurised Wave Basin *dos Santos, FL et al., Maritime Research Institute Netherlands (MARIN), The Netherlands.*	PAPER 44 - Development of Manoeuvring Models of a Korea Autonomous Surface Ship 'Haeyang Nuri' Based on Model- and Full-Scale Tests *Kim, D-J et al., Korea Research Institute of Ships and Ocean Engineering, Republic of Korea*
11:15-11:45	PAPER 20 - Computer Vision Analysis of Cavitation Erosion at the Propeller Blade Root *Franzosi, G. et al., University of Genoa, Italy.*	PAPER 48 - Numerical Study of a Crew Transfer Vessel (CTV) – Wind Turbine Interaction under Moderate Sea Conditions *Gurkan, A.Y. et al., The University of Strathclyde, Glasgow, UK.*
11:45-12:15	PAPER 37 - Numerical and Experimental Investigation of Vortex Structures on Hydrofoils. *Ozsayan, S. et al., Istanbul Technical University, Turkey.*	PAPER 27 - Operational Speed Trial for Full-Load Performance Assessment: A Case Study of a Large Container Vessel *Lee, J-H et al., Korea Research Institute of Ships and Ocean, Daejeon, Korea*
12:15-13:30	**Lunch** (DCC – Lobby)	

13:30-15:00	**Session 2A – Smart Model Testing Technologies for Propulsion** Chair: TBC (DCC - Room 101-102)	**Session 2B – Miscellaneous Smart Model Testing Technologies** Chair: TBC (DCC - Room 103-104)
13:30-14:00	PAPER 4 - Development and Assessment of a Propeller Shaft Load Measurement System *Islam, A. et al., National Research Council of Canada, Canada*	PAPER 3 - Development of an Omni-Directional Hydrodynamic Model for Offshore Wind Turbine Platform Based on Singular Value Decomposition *Huang, PY et al., National Taiwan University, Taipei, Taiwan.*
14:00-14:30	PAPER 11 - Experimental Investigation of a Model-Scale Rim-Driven Thruster: Open Water Performance Estimation *Joo S. et al., Seoul National University, Korea*	PAPER 28 - High-Speed Towing Tank Experiments for Air Bubble Drag Reduction in Ships *Lee, KU et al. Hyundai Maritime Research Institute (HMRI), South Korea.*
14:30-15:00	PAPER 25 - Towing Tank Experiment for Full-Scale Performance Prediction of Complicated Energy Saving Device using Boundary Layer Similarity Model *Katayama, S. et al., Imabari Shipbuilding Co., Ltd., Japan*	PAPER 35 - Impact of UVC Exposure on Hydrodynamic Performance of Antifouling Paint in Wave and Tidal Energy Generators *Ryan, E. et al., Newcastle University, UK.*
15:00-15:30	**Refreshments** (DCC – Lobby)	
15:30-17:30	**Session 3A – LDA / (S)PIV Applications with Propellers in Model Tests** Chair: TBC (DCC - Room 101-102)	**Session 3B – Uncertainty in Model Tests** Chair: TBC (DCC - Room 103-104)
15:30-16:00	PAPER 15 - Tip-vortex interaction in a contra-rotating propeller via LDV *Alves Pereira, F. et al., CNR-INM, Rome, Italy*	PAPER 9 - Comparison of Two Tracking Systems Under Manoeuvring Conditions *Rzeszutko J. et al., Development Centre for Ship Technology and Transport Systems (DST), Duisburg, Germany*
16:00-16:30	PAPER 10 - SPIV and Acoustic Measurements for Examining Effects of Propeller Boss Cap Fins (PBCF) on Hub Vortex Suppression *Kao, H-C, National Taiwan Ocean University, R.O.C.*	PAPER 23 - A Monte-Carlo Approach to Using Uncertainties in Hydrodynamic Model Testing *Kimber, N and Thompson, N., QinetiQ, United Kingdom*
16:30-17:00	PAPER 16 - Experimental Investigation of Propeller Near-Wake Topology Under Wind-Assisted Conditions using Stereo PIV and Shake-The-Box *Jacobi, G., Delft University of Technology, Netherlands*	PAPER 31 - Characterization of Residual Effects in a Shallow Water Towing Tank *Roettig, F. et al., Development Centre for Ship Technology and Transport Systems (DST), Duisburg, Germany*
17:00-17:30	PAPER 38 - Experimental Investigation of Propeller Hydrodynamics and Cavitation Performance in a Cavitation Tunnel *Foley, B., et al., Memorial University of Newfoundland, St. John's, Canada*	PAPER 50 - Uncertainty Assessment in Fully Turbulent Flow Channel Tests of Panels Coated with Marine Coatings *Koksal, S.C. et al., The University of Strathclyde, Glasgow, UK.*
17:30 -19:00	**Reception with Canapes & Drinks** (DCC – Lobby)	
19:00	**END OF FIRST DAY**	

	(Day 2) 30th of October 2025
Time	Events & Locations
8:00-9:00	**Registry & Coffee/Tea** (Daejeon Conference Centre [DCC] – Lobby)
9:00-10:00	**KEYNOTE PRESENTATION 2 –** The Gate Rudder System: A Game Changer for Ship Propulsion and Steering *Prof (Hon) Noriyuki Sasaki, University of Strathclyde, Glasgow, UK* Chair: TBC (DCC – Room 101-102)
10:00-10:30	**Refreshments** (DCC – Lobby)

10:30-12:30	**Session 4A – Wind Assisted Propulsion Model Tests & Numerical Modelling Technologies** Chair: TBC (DCC - Room 101-102)	**Session 4B – Biomimetic Applications with Model Tests & Numerical Modelling** Chair: TBC (DCC - Room 103-104)
10:30-11:00	PAPER 2 - Wind Tunnel Tests of a Wind-Powered Car Carrier *Blackert, E. et al. KTH Royal Institute of Technology, Wallenius Marine, Sweden*	PAPER 6 - Numerical Investigation of the Effect of Biomimetic Tubercles on the Hydrodynamic Resistance of a Flat Plate. *Marino, A. et al., Fincantieri S.p.A., Italy & University of Strathclyde, UK*
11:00-11:30	PAPER 30 - Experimental analysis of resistance performance and roll motion characteristics of wind-assisted wing sail vessels using SIL system *Min, G. et al. Department of Naval Architecture & Ocean Engineering, Inha University, Republic of Korea.*	PAPER 8 - Systematic Hydrodynamic, Performance, and Acoustic Analysis of Biomimetic Solutions for Marine Propellers *Felli, M. et al., Institute of Marine Engineering, National Research Council, Italy*
11:30-12:00	PAPER 33 - A CFD-Based Performance Assessment of Roller Wing Sail For Wind Assisted Ship Propulsion *Lee, I. et al, Pusan National University, Republic of Korea*	PAPER 43 - An Improved Experimental Workflow to Evaluate Performance of Passive Drag Reduction Methods. *Fiedoruk, A. et al., University of Strathclyde, UK*
12:00-12:30	PAPER 29 - Evaluation of Manoeuvring Performance Under External Forces Using a Duct Fan-Type Auxiliary Thruster In Free-Running Model Tests *Lee, K.-M. et al., HD Hyundai Heavy Industries, Republic of Korea*	PAPER 17 - Numerical and Experimental Investigation on the Behaviour of Biomimetic Tubercles In A Fully Turbulent Flow Channel at High Reynolds Numbers *Marino, A. and Atlar, M, The University of Strathclyde, Glasgow, UK*
12:30-13:30	**Lunch** (DCC – Room 107-108)	

13:30-15:00	**Session 5A – Gate Rudder Systems: Design Applications** Chair: TBC (DCC - Room 101-102)	**Session 5B - Further Biomimetics, Wave-Drone and Mini-Submarine Applications** Chair: TBC (DCC - Room 103-104)
13:30-14:00	PAPER 39- Exploration of Propulsion Performance of a Gate Rudder Retrofitted Vessel with a Tunnel Stern *Gurkan, A.Y., et al., The University of Strathclyde, Glasgow, UK.*	PAPER 19 - Research on The Effect of Ship Swing Foil on Reducing Resistance and Increasing Thrust *Zhou, J. et al., Harbin Institute of Technology (Weihai), Republic of China.*
14:00-14:30	PAPER 5 - Gate Rudder System Application to Wide Area of Ocean-going vessels *Sasaki, N. and Atlar, M., The University of Strathclyde, Glasgow, UK*	PAPER 47 – Wave Drone: Feasibility Study on A Short-term Wave Elevation Measurement Method. *Song, F. et al. The University of Strathclyde, Glasgow, UK.*
14:30-15:00	PAPER 40 - Gate Rudder System Performance Prediction for Different Rudder Modes: A Comparative Study of Sliding Mesh and Actuator Disk CFD Models *Gurkan, A.Y. et al., The University of Strathclyde, Glasgow, UK.*	PAPER 7 - Design and Construction of a Large-Scale Underwater Test Vehicle Multi-Purpose Mini Submarine *Ozden, C., Istanbul Technical University, Istanbul, Turkey*
15:00-15:30	**Refreshments** (DCC – Lobby)	
15:30-17:30	**Session 6A – Hydrogen and Electric Ship Propulsion Technologies** Chair: TBC (DCC - Room 101-102)	**Session 6B – Further SPIV Applications and Smart Biofilm Farm Development** Chair: TBC (DCC - Room 103-104)
15:30-16:00	PAPER 41 - Hydrogen-Powered Research Vessel Design *Koksal, S.K. et al., The university of Strathclyde, Glasgow, UK.*	PAPER 46 – Experimental Study on the Hydrodynamic Performance of a Pump-Jet Propulsor Compared to a Conventional Propeller *Felli, M. CNR, Rome, Italy*
16:00-16:30	PAPER 34 - Energy, Emissions and Economics: A Measured Approach to Electric Tug Design *Nugent, L., et al., The University of Strathclyde, Glasgow, UK.*	PAPER 32 – Practical Issues in Stereoscopic-PIV Measurements for The Nominal Wake Fields in Regular Head Waves *Lee, J. et al., Korea Research Institute of Ships and Ocean, Daejeon, Korea*
16:30-17:00	PAPER 36 - Innovative solution for retrofitting diesel to electric CTVs with H2 as a range extender *Turkmen, S., et al., Tallinn University of Technology, Estonia*	PAPER 12 - Evaluation of Stereo PIV for Towing Tank Investigation of Hull-Propeller-Rudder Interaction in Waves *Sin, T.D. et al., Southampton University, Southampton, UK.*
17:00-17:30	PAPER 42 - Multi-Element Gas Container Failure Scenario-Based Hydrogen Dispersion Modelling *Koksal, S.K. et al., The University of Strathclyde, Glasgow, UK.*	PAPER 45 - Design and Commissioning of an Effective Biofilm Cultivating Farm for Drag Reduction and Coating Performance Investigations *Atlar, M., et al., The University of Strathclyde, Glasgow, UK*
18:30-22:00	**Conference Banquette** (Lotte City Hotel - Crystal Ball Room) (one-minute walk from DCC)	
22:00	**END OF TECHNICAL PRESENTATIONS & SECOND DAY**	

	(Day 3) 31st of October 2025	
Time	Events & Location	
09:00–12:00	**Coffee/Tea** (Daejeon Conference Centre [DCC] – Room 101-102)	
09:30 -12:00	**GUIDED VISIT TO THE KRISO TESTING FACILITIES**	
Group 1	09:30 – 09:50	DCC to KRISO by bus
	10:00 – 10:30	Ice Tank
	10:30 – 11:00	Large Cavitation Tunnel
	11:00 – 11:30	Ocean Engineering Basin
	11:30 – 11:50	KRISO to DCC by bus
Group 2	10:10 – 10:30	DCC to KRISO by bus
	10:30 – 11:00	Ice Tank
	11:00 – 11:30	Large Cavitation Tunnel
	11:30 – 12:00	Ocean Engineering Basin
	12:00 – 12:30	KRISO to DCC by bus
12:30	**END OF THE CONFERENCE**	

List of Abstract

(in Session Order)

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Abstracts

ASPECTS OF SOURCE LEVEL ESTIMATION FROM SOUND MEASUREMENTS IN MARIN'S DEPRESSURISED WAVE BASIN

Fernanda Leticia dos Santos, Maritime Research Institute Netherlands (MARIN), The Netherlands
Thomas Lloyd, Maritime Research Institute Netherlands (MARIN), The Netherlands
Johan Bosschers, Maritime Research Institute Netherlands (MARIN), The Netherlands
Frans Hendrik Lafeber, Maritime Research Institute Netherlands (MARIN), The Netherlands

Propeller cavitation noise at full scale can be estimated from model-scale tests conducted in the Depressurised Wave Basin (DWB) at MARIN. Accurate analysis and interpretation of the measured sound levels require knowledge of the facility's reverberation characteristics. In the current study, the reverberation radius for the DWB was determined experimentally for both stationary and moving sound sources. Additionally, the effect of the free surface, i.e. Lloyd's mirror correction, in the determination of source levels is investigated, as this correction is not entirely valid when a ship model is present. To conduct these analyses, tests were performed in the DWB using a sound projector placed within the propeller disc of a ship model for both stationary and forward-speed conditions. The average reverberation radius was found to be 4.9 m for both conditions, aligning with previous findings [1] and indicating that the presence of the ship model has a negligible influence on the reverberation radius. The reverberation radius is used in the analysis of the cavitation noise measurements to ensure that the free field assumption is valid when analysing the selected time windows; thus, no correction of the measured pressure for the facility reverberation is needed. For a stationary source, the Lloyd's mirror correction was not sufficient to accurately estimate the source levels for hydrophones located under the ship model because of the reflections from the hull. Therefore, care must be taken when performing stationary calibration measurements with a ship model present. In contrast, in the moving source case, the influence of the ship model on the estimated source levels was found to be negligible. Applying the same processing method used for cavitation noise measurements yielded source level estimates within 2 dB of the expected values.

COMPUTER VISION ANALYSIS OF CAVITATION EROSION AT THE PROPELLER BLADE ROOT

Giovanni Franzosi, University of Genoa, Department of Naval Architecture, Electric, Electronic and Telecommunication Engineering, Italy
Afaq Amhed Abbasi, University of Genoa, Department of Naval Architecture, Electric, Electronic and Telecommunication Engineering, Italy
Michele Viviani, University of Genoa, Department of Naval Architecture, Electric, Electronic and Telecommunication Engineering, Italy
Daniele Bertetta, Fincantieri S.p.A. Naval Vessel Business Unit, Italy
Giorgio Tani, University of Genoa, Department of Naval Architecture, Electric, Electronic and Telecommunication Engineering, Italy

This paper presents an experimental approach for investigating erosive cavitation phenomena occurring at the blade root of marine propellers.

The primary objective of this work is to develop a method that provides quantitative measurements of the size and dynamics of cavitating structures occurring at the blade root of marine propellers.

The selected case study is a four-bladed, controllable-pitch model propeller tested under specific loading and flow conditions.

The proposed method combines high-speed video recordings with advanced computer vision techniques to quantify the evolution of the cavitating area as a function of the blade's angular position. The resulting data provides valuable information on the unsteady behavior of erosive cavitation.

Future developments will integrate these measurements with data on the extent and growth rate of surface damage obtained through computer vision and the soft paint technique.

By correlating the cavitation flow characteristics with the erosion patterns, the proposed approach will enable a more comprehensive understanding of the mechanisms driving cavitation damage.

The integration of traditional experimental tools with automated vision-based analysis demonstrates strong potential for achieving more detailed, localized, and quantitative assessments of erosive cavitation, paving the way for improved prediction and mitigation strategies.

Keywords: Cavitation erosion, marine propeller, soft paint, computer vision, cavitation collapse dynamics.

NUMERICAL AND EXPERIMENTAL INVESTIGATION OF VORTEX STRUCTURES ON HYDROFOILS

S. Özsayan, Faculty of Naval Architecture and Ocean Engineering, Istanbul Technical University (ITU), Türkiye
F. Ertarhanacı, Faculty of Naval Architecture and Ocean Engineering, Istanbul Technical University (ITU), Türkiye
E. Korkut, Faculty of Naval Architecture and Ocean Engineering, Istanbul Technical University (ITU), Türkiye

The lower pressure in the vortex core compared to its surroundings often leads to cavitation inception, typically observed in vortex cavitation. Flows around lifting surfaces such as rudders, propellers, and fins inherently contain vortical structures of various scales and strengths, making them highly prone to cavitation. Ships are rich in such flows, and consequently, unexpected performance losses, noise, and vibrations may occur even at moderate speeds. In vortex-vortex interactions, weaker vortices may cavitate earlier than stronger ones due to the stretching effect imposed by the latter, contrary to common expectation. In this study, vortex-vortex interactions were investigated numerically using two hydrofoils capable of generating vortex pairs with varying sizes and strengths. An experimental setup was designed to validate the findings. Vortex-vortex interactions depend on the vortex diameter, circulation ratio, and separation distance. For this reason, a simple experimental mechanism allowing variation of the hydrofoils' angle of attack and distance was designed to study vortex interactions in detail. The experimental campaign will be conducted at the Istanbul Technical University Cavitation Tunnel (ITUKAT). In the numerical analyses, the Delayed Detached Eddy Simulation (DDES) method with the SST (Menter) k-ω turbulence model was employed. The two-phase flow solution was carried out using the Volume of Fraction (VOF) method, and cavitation was modeled with the Schnerr–Sauer cavitation model. The results indicate that not only the weaker vortex is influenced by the stronger one, but the stronger vortex is also affected by the weaker vortex.

Keywords: Vortex-vortex interaction, cavitation observations, cavitation inception, DDES method, cavitation tunnel.

DEVELOPMENT OF MANOEUVRING MODELS OF A KOREA AUTONOMOUS SURFACE SHIP 'HAEYANG NURI' BASED ON MODEL- AND FULL-SCALE TESTS

Dong-Jin Kim, Korea Research Institute of Ships and Ocean Engineering, Republic of Korea
Kunhang Yun, Korea Research Institute of Ships and Ocean Engineering, Republic of Korea
Dong Jin Yeo, Korea Research Institute of Ships and Ocean Engineering, Republic of Korea

In recent, maritime autonomous surface ships (MASS) have become major issues in the maritime industry and research fields. Relevant technologies are developing rapidly, it is expected that MASS will operate with minimum or no human intervention in the future. For the development of intelligent navigation features such as route planning/optimization, obstacle recognition and avoidance, it is necessary to predict the manoeuvring performance of MASS accurately. In line with such a global trend, 'Korea Autonomous Surface Ship Project ('20~'25)' was conducted for the last six years in Korea. 26 m testbed vessel, 'Haeyang Nuri' was built for autonomous system developments and verifications. In this study, manoeuvring simulation models of the 'Haeyang Nuri' are developed based on model tests and full-scale trials. 2- and 4-meter-long models are built in order to predict testbed vessel's hydrodynamic performance at the early design stage. Through captive model tests of the 4-meter model which are carried out in a towing tank of Korea Research Institute of Ships and Ocean Engineering (KRISO), standard manoeuvring models are established. IMO standard manoeuvring simulations in model-scale show good agreements with free-running model test results. Present simulation models are also verified by comparison with low speed free-running test results of the 2-meter-long model with arbitrary steering scenarios. In a harbor, the speed of the ship is usually extremely low, sometimes the ship moves laterally or goes backward during berthing manoeuvres. For reliable low speed manoeuvring simulations, manoeuvring models are further improved based on additional captive model tests with large drift angles, yaw rotations, and four quadrant open water tests of the propeller. It is confirmed that astern manoeuvre simulations by the improved models show good agreements with full-scale trials as well as free-running model tests. Sea margins on the hull resistances are additionally considered in the present manoeuvring models so that manoeuvring performance of 'Haeyang Nuri' at sea can be predicted by full-scale simulations with higher accuracy.

NUMERICAL STUDY OF A CREW TRANSFER VESSEL (CTV) – WIND TURBINE INTERACTION UNDER MODERATE SEA CONDITIONS

Ahmet Yusuf Gurkan, University of Strathclyde, UK
Saishuai Dai, University of Strathclyde, UK
Sol Judah, University of Strathclyde, UK
Osman Turan, University of Strathclyde, UK

The accurate prediction of relative motions between Crew Transfer Vessels (CTVs) and offshore wind turbines is essential for ensuring safe personnel transfer operations in moderate seas. This study focuses on computational fluid dynamics (CFD) simulations to investigate the hydrodynamic interactions between a CTV and a turbine platform during landing conditions. Experimental data from model-scale tests of a platform conducted at the Kelvin Hydrodynamics Laboratory (KHL) were used primarily for validation purposes.

Validated CFD models were then applied at full scale to analyze the coupled motion behavior under irregular wave conditions. A representative 13.5 m-long CTV was simulated at sea state 4, corresponding to a significant wave height of 1.5 m and a wave period of 6.4 s. Systematic simulations were performed to assess the influence of propeller bollard-push levels (10, 20, and 40 kN) and fender–platform friction coefficients (0.12 and 0.35) on the relative motions during landing.

The CFD results show strong agreement with experimental trends and highlight key operational dependencies: increasing propeller thrust amplifies relative displacements, while lower fender friction coefficients effectively reduce motion amplitudes. These findings demonstrate the capability of CFD as a predictive tool for assessing and optimizing the safety of CTV landing operations under challenging sea conditions.

OPERATIONAL SPEED TRIAL FOR FULL-LOAD PERFORMANCE ASSESSMENT: A CASE STUDY OF A LARGE CONTAINER VESSEL

Joon-Hyoung Lee, Korea Research Institute of Ships and Ocean, Daejeon, Korea
Ho Kim, Korea Autonomous Surface Ship Project Office, Daejeon, Korea
Suak Ho Van, CIIZ R&D Team, Busan, Korea
Jinho Jang, Korea Research Institute of Ships and Ocean, Daejeon, Korea
Haesung Ahn, Korea Research Institute of Ships and Ocean, Daejeon, Korea

This study investigates the propulsion performance of a large container vessel under full-load draft condition through an operational speed trial conducted during a commercial voyage. Traditionally, full-scale speed trials are performed at ballast condition due to loading limitations during shipyard acceptance testing. Consequently, direct performance data at full-load condition are scarce, and performance assessments rely on extrapolations from model tests and ballast condition trials. This limits the ability to validate model–ship correlation and hampers accurate propulsion performance evaluation.

To address these limitations, a speed trial under full-load conditions was planned and executed in a segment of the ship's operational route selected for its relatively calm sea state. Key propulsion-related quantities, including shaft power, revolutions per minute, and speed over ground, were measured using onboard sensors and GPS. A speed log was also installed to measure speed through the water. Sea state data from a weather service were incorporated to account for environmental conditions. Bidirectional runs were performed and averaged to minimize the influence of asymmetrical external forces. Performance analysis was conducted according to the ISO 15016:2015 standard, enabling a direct comparison with results from the ship's model test results. The comparison reveals discrepancies attributable to changes in hull and propeller condition due to fouling and aging, as well as the impact of real-world environmental conditions. The study emphasizes the importance of full-scale propulsion performance monitoring, especially in the context of Maritime Autonomous Surface Ships (MASS), where continuous onboard data acquisition is essential for operational efficiency and performance optimization. Recommendations are provided regarding required measurements, sensor deployment, and future challenges in real-time data interpretation for full-load performance evaluation.

DEVELOPMENT AND ASSESSMENT OF A PROPELLER SHAFT LOAD MEASUREMENT SYSTEM

Mohammed Islam, National Research Council of Canada, Canada
Moqin He, National Research Council of Canada, Canada
Edward Kennedy, National Research Council of Canada, Canada
James Sweeny, National Research Council of Canada, Canada
Heather Peng, Memorial University of Newfoundland, Canada
Lorenzo Moro, Memorial University of Newfoundland, Canada

Accurate model-scale measurement of dynamic shaft loads remains a significant challenge in characterizing propeller-induced noise and vibration. Conventional test methods lack the ability to directly capture high-frequency, multi-axis forces at the propeller shaft, limiting the fidelity of validation data for predictive models. To address this gap, a novel shafting system has been developed to measure six-component propeller loads directly, facilitating high-frequency shaft vibration characterizations in a model-scale test setup. This is a unique sensory system to capture high-frequency propeller-induced vibration forces directly at the hub.

At its core is an AMTI SP1-500 load sensor integrated into a custom-designed shaft assembly capable of resolving axial thrust, torque, and lateral loads induced by the propeller. The system was qualified through in-situ testing, with data cross-compared to conventional propeller dynamometry, pressure sensors, and accelerometers. Frequency-domain analysis showed strong alignment of load and vibration signatures at propeller blade harmonics, primarily below 200 Hz. These direct shaft load measurements at the propeller hub provide critical insights into the dynamic forcing mechanisms that contribute to propeller noise and hull-excited vibrations, offering a powerful tool for validating computational fluid dynamics (CFD) models and improving quiet ship design.

EXPERIMENTAL INVESTIGATION OF A MODEL-SCALE RIM-DRIVEN THRUSTER: OPEN WATER PERFORMANCE ESTIMATION

Sunghoon Joo, Department of Naval Architecture & Ocean Engineering, Seoul National University, Korea
Jeongsoo Ha, Department of Naval Architecture & Ocean Engineering, Seoul National University, Korea
Jeonghwa Seo, Department of Autonomous Vehicle System Engineering, Chungnam National University, Korea
Shin Hyung Rhee, Research Institute of Marine Systems Engineering, Seoul National University, Department of Naval Architecture & Ocean Engineering, Seoul National University

In this study, an experimental approach is presented to establish an experimental method for evaluating the open water performance of a model-scale hubless rim-driven thruster. As rim-driven thruster gain attention for their compact form and electric-drive compatibility, there remains a lack of standard and quantitative experimental procedures, particularly for small-scale systems. Previous investigations have been mostly limited to computational fluid dynamics, and experimental validation—especially under controlled towing tank conditions—has been sparse. To address this gap, a practical experimental methodology is presented for evaluating the open water performance of a model-scale hubless rim-driven thruster. This involved testing the thruster in a controlled towing tank environment, where it was operated at multiple rotational speeds and a range of towing velocities. For each test condition, a custom-designed setup allowed for the simultaneous measurement of thrust and torque, providing a reliable basis for quantifying the thruster's open water performance. From the collected data, thrust and torque coefficients were calculated to represent the standalone performance of the rim-driven thruster. The main contribution of this study lies not in providing complete performance curves, but in proposing a validated experimental methodology tailored to model-scale rim-driven thrusters. Ultimately, this method is expected to serve as a foundation for the establishment of standardized testing protocols for rim-driven thruster and support further design, development, and performance optimization of rim-driven thruster for marine applications.

TOWING TANK EXPERIMENT FOR FULL-SCALE PERFORMANCE PREDICTION OF COMPLICATED ENERGY SAVING DEVICE USING BOUNDARY LAYER SIMILARITY MODEL

S. Katayama, Imabari Ship Model Basin, Imabari Shipbuilding Co., Ltd., Japan
W. Narita, Imabari Ship Model Basin, Imabari Shipbuilding Co., Ltd., Japan
T. Ikebuchi, Imabari Ship Model Basin, Imabari Shipbuilding Co., Ltd., Japan
N. Shimizu, Imabari Ship Model Basin, Imabari Shipbuilding Co., Ltd., Japan
Y. Idomoto, Hydrodynamics Group, Basic Design Department, Nihon Shipyard Co., Ltd., Japan
A. Nakata, Hydrodynamics Group, Basic Design Department, Nihon Shipyard Co., Ltd., Japan
Y. Toda, Imabari Ship Model Basin, Imabari Shipbuilding Co., Ltd., Japan

Towing tank experiments using boundary layer similarity (BLS) model are presented in this paper. BLS model is originally proposed by Prof. Hino's group to know the full-scale performance of various energy saving devices in usual self-propulsion test by designing the shorter BLS model which has the similar mean flow field around propeller as the full-scale ship. The concepts were investigated using computation and the tank tests has not been done. In this paper, to achieve this objective in real towing tank, the BLS models are designed by using bare hull computation around full-scale ship and BLS model as well as the model scale computation. The computed mean wake distribution, limiting streamlines and pressure field around propeller of final designed BLS were similar as the full scale results. although the boundary layer development to the axial direction was different. The usual model (around 7.5m) and designed BLS model were used for the experiment in 212m towing tank to investigate the full-scale performance of the ship. The propulsion tests were done using BLS and various ESD. The loading of the propeller is adjusted using the corrected full scale thrust from model experiment due to the difference of BLS resistance from usual model. The results show the scale effect for wake fraction and the results agreed with the usual full-scale prediction from model scale experiment for bare hull. The results of BLS with ESD show the effect of a thin boundary layer on the self-propulsion factors. The flow field around the stern of BLS model was also measured using stereo-PIV system as well as PIV measurements for usual model ship. The PIV results show the thinning of boundary layer and longitudinal vorticity fields in mean velocity field around BLS model as similar as the full-scale ship.

DEVELOPMENT OF AN OMNI-DIRECTIONAL HYDRODYNAMIC MODEL FOR OFFSHORE WIND TURBINE PLATFORM BASED ON SINGULAR VALUE DECOMPOSITION

P.Y. Huang, Department of Engineering Science and Ocean Engineering, National Taiwan University, Taipei, Taiwan
F.E. Lee, Department of Engineering Science and Ocean Engineering, National Taiwan University, Taipei, Taiwan
T.Y. Lin, Department of Engineering Science and Ocean Engineering, National Taiwan University, Taipei, Taiwan
H.E. Wu, National Academy of Marine Research, Kaohsiung, Taiwan
H.Y. Chen, National Academy of Marine Research, Kaohsiung, Taiwan

The growing demand for green energy has led to the development of increasingly large wind turbines, which in turn require stable and reliable floating platforms. In engineering practice, the force exerts on an offshore platform could be easily estimated with the Morison equation. However, it may overlook the contribution of the actual geometric design, which can sometimes greatly influence its load condition. We seek an omni-directional description of hydrodynamic behavior for more practical applications. In this study, the steady state resistance of multiple angles is firstly simulated. The resulting pressure field is processed via singular value decomposition, expressing them as combinations of several dominant components. The corresponding weightings are represented as a function of inflow angle to construct an omni-directional mathematical model. To find a solution for the model, model tests under sinusoidally oscillation flow (SOF) are conducted in multiple directions. The added mass and drag coefficients are greatly influenced by Keulegan-Carpenter number, as well as the accuracy of the experiment. The model was applied to the experimental results; however, its performance was unsatisfactory, suggesting that future refinements are needed.

Keywords: Singular value decomposition, omni-directional model, offshore platform.

HIGH-SPEED TOWING TANK EXPERIMENTS FOR AIR BUBBLE DRAG REDUCTION IN SHIPS

Kyoungun Lee, HD Hyundai Heavy Industries, Republic of Korea
Younmo Lee, HD Hyundai Heavy Industries, Republic of Korea
Seokcheon Go, HD Hyundai Heavy Industries, Republic of Korea
Seonhyeong Lee, Research Institute of Medium & small Shipbuilding, Republic of Korea

The Air Lubrication System (ALS) reduces frictional resistance by injecting air along the hull bottom. Its potential has been demonstrated in model-scale studies. However, reproducing the actual behaviour of the air layer under full-scale operation conditions remains a challenge due to its sensitivity to flow velocity. Accordingly, high-speed towing experiments are required, but facilities that allow such testing are limited. In this study, towing experiments were conducted in the Research Institute of Medium & Small Shipbuilding (RIMS) high-speed towing tank using a 14 m-long, 0.7 m-beam ship model fitted with a full-scale Air Dispense Unit (ADU). The ship model was designed with detachable bottom segments, and underwater cameras were employed to observe air-layer behaviour directly. This approach, combining large-scale modelling, high-speed conditions, full-scale ADU, and flow visualisation, constitutes a key feature of the present work. It was observed that air discharged from the ADU initially formed a film-type layer, which at higher flow velocities rapidly transformed into a bubbly layer. For quantitative evaluation, a segmented model and a defined performance indicator were applied, allowing the drag-reduction contribution of the bubbly layer to be identified. In parallel, the configurations of both film and bubbly layers were clearly distinguished through underwater camera images. Taken together, these findings provide quantitative resistance data and qualitative insight into air-layer behaviour under realistic conditions, offering a reliable basis for scaling ALS performance towards full-scale applications.

IMPACT OF UVC EXPOSURE ON HYDRODYNAMIC PERFORMANCE OF ANTIFOULING PAINT IN WAVE AND TIDAL ENERGY GENERATORS

Emmet Ryan, Newcastle University
Serkan Turkmen, Tallinn University of Technology
Nick Baker, Newcastle University
Alasdair Charles, Newcastle University

Marine biofouling is a major risk for submerged and splash-zone surfaces and structures, posing significant operational and economic challenges across the marine industry. Consequently, effective biofouling mitigation strategies must be integrated into both the design and lifecycle of marine systems. Conventional antifouling methods rely on chemical coatings which contaminate marine ecosystems and require regular surface cleaning and periodic reapplication to maintain antifouling protection and system performance. Therefore, the development of sustainable antifouling alternatives which can prolong system in-service time and operational performance is desirable. Previous research has demonstrated that exposure to low doses of UVC ultraviolet irradiation using LEDs can inhibit biofouling microorganisms and keep surfaces clean. This paper investigates the use of this UVC method in conjunction with conventional chemical coatings to improve biofouling control and extend the in-service operation of marine systems. Experimental tests to assess the long-term impact of UVC exposure on antifouling paint are presented. Initial results suggest that the application of ultraviolet irradiation can adversely affect existing antifouling coatings and their hydrodynamic performance, indicating that potential combined UVC and chemical solutions to enhance biofouling prevention should consider maximum UVC dosage levels to avoid surface degradation.

TIP-VORTEX INTERACTION IN A CONTRA-ROTATING PROPELLER VIA LDV

Francisco Alves Pereira, CNR-INM, Italy
Alessandro Capone, CNR-INM, Italy
Fabio Di Felice, CNR-INM, Italy

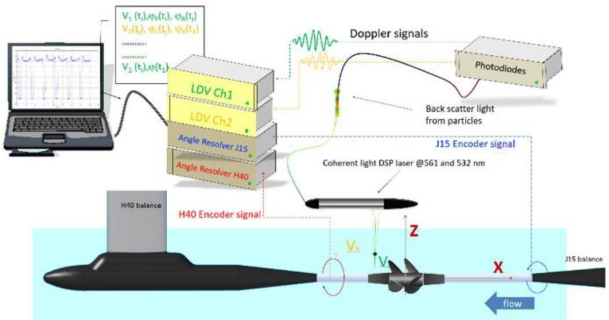

Figure 1:experimental setup

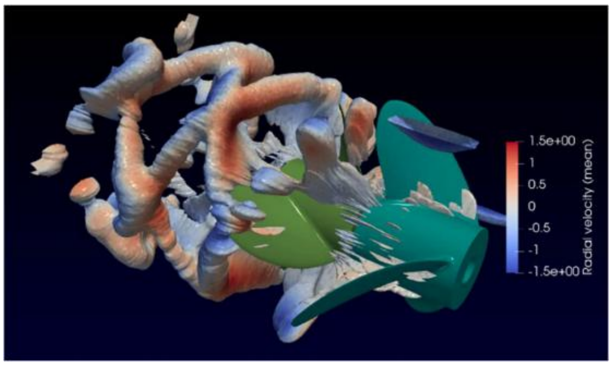

Figure 2: CRP tip vortex system. Color coded by

Efficient propulsion systems have become crucial in addressing global challenges like fuel consumption and environmental impact. Among the most promising advancements are contra-rotating propellers (CRPs), which feature two coaxial propellers rotating in opposite directions. This design maximizes thrust efficiency by recovering energy typically lost in single-rotating propellers, making CRPs particularly valuable in marine and aviation applications. However, careful attention must be paid to the interaction between the two propellers to prevent detrimental effects such as cavitation and noise. The interaction is complex and is evident in the dynamics of the tip vortex system. This study presents insights into the flow complexity of the CRP system. The current CRP system has been previously investigated using Particle Image Velocimetry (PIV), focusing on the wake due to limited optical access between the propellers and the limited relative phase angles of the front and rear propellers. In this study, we employ Laser Doppler Velocimetry, which, due to its superior optical access and time-resolving capabilities, allows for a detailed examination of the interblade flow and tip vortex wake dynamics. By utilizing phase-lock techniques, we can simultaneously resolve velocity measurements concerning the relative angular position of the front and rear propellers. The experimental setup is illustrated in Figure 1, where the propellers are mounted on two distinct dynamometric balances within the cavitation tunnel, enabling the measurement of thrust and torque for each propeller. Two encoders provide data on the angular position of each propeller. In post-processing, we can reconstruct the flow field phase-locked to either the front or rear propeller. For instance, the flow field phase-locked with the CRP is depicted in Figure 2.

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SPIV AND ACOUSTIC MEASUREMENTS FOR EXAMINING EFFECTS OF PROPELLER BOSS CAP FINS (PBCF) ON HUB VORTEX SUPPRESSION

Hao-Chun Kao, Dept. Systems Engineering & Naval Architecture, National Taiwan Ocean University, R.O.C.
Wei-Che Tseng, Dept. Systems Engineering & Naval Architecture, National Taiwan Ocean University, R.O.C.
Yaw-Huei Lee, Dept. Systems Engineering & Naval Architecture, National Taiwan Ocean University, R.O.C.
Ching-Yeh Hsin, Dept. Systems Engineering & Naval Architecture, National Taiwan Ocean University, R.O.C.
Yi-Chih Chow, Dept. Systems Engineering & Naval Architecture, National Taiwan Ocean University, R.O.C.

According to the 2023 IMO GHG Strategy, international shipping must reduce its carbon intensity by at least 40% by 2030, making improvements in propeller efficiency a key measure for energy conservation and carbon reduction (ECCR). Among available technologies, the Propeller Boss Cap Fins (PBCF) has been proven capable of suppressing hub vortex (HV) and improving propeller performance, although the flow characteristics yielded that effect HV suppression, as well as its acoustic effect, have rarely been examined. In this work, two model propellers (The Princess Royal and KP505) with or without PBCF installed were tested in a cavitation tunnel using the setup of Reverse Propeller Open-water Test (R-POT). Three kinds of measurements have been done: (1) dynamometry for the propellers' dynamic performances (thrust and torque), (2) Stereoscopic Particle Image Velocimetry (SPIV) for the flow field in the near wake of propeller's hub and the evolution of the HV's strength, and (3) acoustic measurement for the noise generated by the propeller. In addition, a high-speed camera was used to capture images of cavitation induced by vortices under low ambient pressure to visualize vortical flow structures. The dynamometry results show that both propellers with PBCF installed improve their efficiencies by approximately 0.4%–6.6%, along with the SPIV results of the HV's strength confirming effective suppressions of their HVs. The SPIV results of the hub's near wake further reveal that the propeller with PBCF would generate behind the boss a stagnation point, which implies a recirculation zone upstream of it that seems to act as a fairwater cap to straighten outer swirling streams when the PBCF has an optimized pitch angle. However, acoustic measurements indicate an unexpected increase of over 5 dB in sound pressure level at blade frequency with PBCF installed. Based on the SPIV results, this elevated noise can be attributed to PBCF's tip vortices.

EXPERIMENTAL INVESTIGATION OF PROPELLER NEAR-WAKE TOPOLOGY UNDER WIND-ASSISTED CONDITIONS USING STEREO PIV AND SHAKE-THE-BOX

Gunnar Jacobi, Delft University of Technology, Netherlands

The wake dynamics of marine propellers operating under off-design conditions are highly three-dimensional and sensitive to inflow perturbations. In the context of wind-assisted propulsion, aerodynamic thrust from sails reduces propeller loading and introduces oblique inflow due to leeway, altering the helical wake structure. In this study, the near-wake topology of a four-bladed fixed-pitch propeller was investigated experimentally in the towing tank at Delft University of Technology using two different flow measurement techniques: Stereo Particle Image Velocimetry (PIV) and volumetric Lagrangian particle tracking with the Shake-the-Box (STB) method. Stereo PIV provided phase- and time-averaged three-component velocity fields in a cross-plane downstream of the propeller, while STB enabled volumetric reconstruction of particle trajectories and access to the full velocity gradient tensor. The methodological comparison demonstrates the strengths of both approaches: Stereo PIV yields robust planar data but is limited in resolving out-of-plane dynamics, whereas STB captures the full three-dimensional vortex system, allowing reconstruction of derived flow quantities such as vorticity and eventually pressure. The analysis of the near wake shows that even small oblique inflow angles induce pronounced asymmetries in tip vortex trajectories and strength distribution, with effects amplified at higher advance ratios corresponding to reduced loading.

EXPERIMENTAL INVESTIGATION OF PROPELLER HYDRODYNAMICS AND CAVITATION PERFORMANCE IN A CAVITATION TUNNEL

Benedict Foley, Department of Ocean and Naval Architectural Engineering, Memorial University of Newfoundland, St. John's, Canada
Shameem Islam, Ocean, Coastal and River Engineering, National Research Council Canada, St. John's, Canada
Heather Peng, Department of Ocean and Naval Architectural Engineering, Memorial University of Newfoundland, St. John's, Canada

The overall research aims to develop physical model test procedures and analysis techniques for detailed studies of hydrodynamic and cavitation characteristics, such as cavitation inception behaviour, performance deterioration due to cavitation, and local flow fields using a Laser Doppler Anemometer under uniform inflow and simulated ship-wake and in non-cavitating and cavitating conditions utilizing the National Research Council Canada's Cavitation Tunnel facility. This paper presents a comparative evaluation of the performance data obtained from cavitation tunnel tests and corresponding atmospheric CWT tests conducted under equivalent propeller loading conditions. Also presented is a baseline experimental investigation into the hydrodynamic and cavitation performance of model-scale marine propellers. The findings demonstrate that the cavitation tunnel can provide accurate assessments of hydrodynamic performance and reliable insights into cavitation phenomena for the subject propeller. Future work will extend this campaign with Laser Doppler Anemometer measurements of local flow fields and ship-wake simulation to further understand propeller-wake interactions under heavily cavitating conditions.

COMPARISON OF TWO TRACKING SYSTEMS UNDER MANOEUVRING CONDITIONS

Jakob Rzeszutko, University of Duisburg-Essen, Duisburg, Germany
Felix Roettig, Development Centre for Ship Technology and Transport Systems, Duisburg, Germany
Justin Jasa, Development Centre for Ship Technology and Transport Systems, Duisburg, Germany
Erwin Schoonderwaldt, Qualisys AB, Gothenburg, Sweden
Jonathan Frey, Federal Waterways Engineering and Research Institute, Hamburg, Germany
Hanne Jansch, Federal Waterways Engineering and Research Institute, Hamburg, Germany
Matthias Tenzer , Development Centre for Ship Technology and Transport Systems, Duisburg, Germany

Accurate measurement of model ship trajectories is essential for deriving high-fidelity mathematical manoeuvring models for simulators, particularly in confined and shallow waters. This study presents a comprehensive analysis of the trajectory of an inland waterway ship (IWS) in shallow water, using two optical tracking systems: a camera-based motion system and a position-based system. The IWS was fitted with active markers for the Arqus A12 camera-based tracking system by Qualisys Aktiebolag (AB) and a Trimble Active Track 360 target for the SPS930 DR+ Total Station position-based tracking system by Trimble Incorporation. The ship's trajectories were recorded simultaneously in a shallow water basin during two manoeuvring situations: quasi-steady states and free manoeuvres. The IWS was controlled remotely via a local wireless local area network (WLAN) during the recording process. The quasi-steady cases were measured at seven distinct positions in the basin. The free manoeuvres covered the entire basin. An uncertainty analysis of the Euclidean distance was conducted, and the measured lengths were compared with ship speeds taken into account. Due to the different measurement frequencies, the ship speeds derived from the Qualisys system were characterised by high resolution, whereas those from the Total Station system exhibited increased noise. Applying Kalman filters to both signals, as in previous studies, yielded smoother and physically more reliable estimates of model speed. Results showed that both optical tracking systems were capable of reproducing the ship's trajectories. The comparison revealed that the distance differences between the two systems were speed-dependent: accuracy improved at higher speeds, while deviations increased at lower speeds, up to a Euclidean distance of 8 mm. These findings confirm that both optical tracking systems can reliably capture the trajectories of inland waterway ships in shallow water basins, strengthening the methodological foundation for the future use of indoor motion tracking in maritime applications.

A MONTE-CARLO APPROACH TO USING UNCERTAINTIES IN HYDRODYNAMIC MODEL TESTING

Nick Kimber, QinetiQ, United Kingdom
Neil Thompson, QinetiQ, United Kingdom

Estimating uncertainties of individual measurements is a well discussed topic in the field of hydrodynamic model testing. In a large experimental set-up such as a captive submarine model test, uncertainties can arise from many sources, such as model build tolerances, rigging alignment, force sensor calibrations, environmental factors in the facility, as well is in the data reduction and analysis processes. The output from this type of experiment is typically a set of hydrodynamic coefficients which may then be used to predict manoeuvring performance by way of time-domain simulation tools. A reasonable question to ask is, how do the individual uncertainties combine to provide an overall uncertainty of predicted manoeuvring performance. Classical procedures for combining multiple uncertainties can be cumbersome to work through this entire process, and so this paper adopts a Monte-Carlo approach. Each individual parameter is assigned a random value within its uncertainty range, and the derivation process is conducted from the source measurement through to the time-domain simulation of a particular manoeuvre, in this example a turning circle. This is repeated a large number of times, using random uncertainties, to generate a distribution of the predicted circle diameter, and therefore gain an insight into the impact of the source uncertainties on the uncertainty in the resulting prediction output.

Related to this is where the hydrodynamic model is used as a basis for controller design. Here the question may be asked, what are the uncertainties in the individual hydrodynamic coefficients, such that the controller can be tested for robustness over a realistic range. The same Monte-Carlo technique can be used to derive the uncertainties in the linear derivatives typically used in controller design, and thus provide the control designer with the overall uncertainty in the linear mathematical model.

CHARACTERIZATION OF RESIDUAL EFFECTS IN A SHALLOW WATER TOWING TANK

Felix Roettig, Development Centre for Ship Technology and Transport Systems, Germany
Justin Jasa, Development Centre for Ship Technology and Transport Systems, Germany
Jens Henße, General Acoustics e. K. (GA), Germany
Björn Niehaus, General Acoustics e. K. (GA), Germany
Leander Schütt, General Acoustics e. K. (GA), Germany
Benjamin Friedhoff, Development Centre for Ship Technology and Transport Systems, Germany

The measurement accuracy of experimental investigations with ship models in towing tanks is significantly affected by the disturbances from previous test runs, so-called basin residues. In order to reduce this uncertainty, waiting times of an hour or more are required in some cases, particularly for test campaigns in shallow water conditions, which limits productivity and drives up costs and effort. The root cause is considered to be the soliton wave generated during the acceleration of the model, which can only be dampened very slowly with the commonly used artificial beaches.

In order to analyse the influence of the water level deflection and the associated currents more precisely, waves and current velocities were measured simultaneously using a novel measurement setup. Acoustic wave probes were combined with a radar-based wave sensor and an electro-magnetic flow sensor to assess residual waves and currents in the shallow water towing tank at the Development Centre for Ship Technology and Transport Systems (DST). Each experiment was initiated by a self-propulsion test, allowing for the detection of small-amplitude wave components that persist after the main event.

Experiments were performed across two water depths and varying speed to evaluate the influence of these factors. The analysis employed both time-domain and frequency-domain methods, facilitating the identification of dominant frequencies and decay characteristics of the basin residues. By correlating measurement patterns, the study indirectly derived basin-specific properties such as reflection behaviour and modal responses. The results provide practical insights for optimising waiting times between test runs.

UNCERTAINTY ASSESSMENT IN FULLY TURBULENT FLOW CHANNEL TESTS OF PANELS COATED WITH MARINE COATINGS

Çağatay Sabri Köksal, University of Strathclyde, UK
Antoni Fiedoruk, University of Strathclyde, UK
Ahmet Yusuf Gurkan, University of Strathclyde, UK
Osman Turan, University of Strathclyde, UK
Mehmet Atlar, University of Strathclyde, UK

The uncertainty associated with Fully Turbulent Flow Channel (FTFC) tests performed on acrylic test panels coated with marine coatings comprising primer, tie-coat, and topcoat layers is assessed. The coatings include two antifouling (AF), two foul-release (FRC), and one hybrid (AF–FRC) type, tested with commercial brand names omitted for confidentiality. Prior to coating application, all test panels were blasted to replicate an actual ship hull surface, and surface roughness measurements were then conducted across all panels to verify that the target roughness values had been achieved before coating. A total of sixteen panels were prepared, four coated with one coating type and three panels for each of the remaining four coating types. The four panels coated with the same coating were used to quantify the bias error associated with coating application, based on surface roughness measurements taken using a laser scanner (UNISCAN OSP100 profilometer) and verified with a portable surface finish meter (Surtronic 25) as a complementary check. Statistical analyses of the surface roughness measurements were performed to assess variability along each test panel individually and to evaluate the distribution of mean roughness values across panels coated with the same coating. Furthermore, complementary comparisons were made based on the FTFC test results. The analysis quantifies both precision and bias components of uncertainty, incorporating contributions from repeatability, instrumentation, manufacturing, and coating application. The overall uncertainty level is within acceptable limits, with results demonstrating strong agreement between roughness-based and flow-based measurements for panels coated with the same coating, which were also used to determine precision error. The outcomes indicate that although surface roughness is one of the major contributors to indirect drag measurements, comparisons of the skin-friction coefficient (CF) reveal that roughness alone is insufficient to explain the differences among coating types, hence, FTFC tests are essential for a comprehensive evaluation. This represents the first comprehensive uncertainty assessment of FTFC testing that incorporates coating application effects alongside experimental and measurement-standard-related sources of uncertainty.

WIND TUNNEL TESTS OF A WIND-POWERED CAR CARRIER

Erik Blackert, KTH Royal Institute of Technology, Wallenius Marine, Sweden
Ulysse Dhomé, KTH Royal Institute of Technology, Wallenius Marine, Sweden
Antonia Hillenbrand, KTH Royal Institute of Technology, Oceanbird, Sweden
Carl Fagergren, Wallenius Marine, Sweden
Jakob Kuttenkeuler, KTH Royal Institute of Technology, Sweden
Frederik Gerhardt, RISE, Sweden

To further improve the design and operation of modern sailing cargo vessels, additional knowledge of the interaction between multiple sails in combination with the hull is needed. This study investigates the aerodynamic performance of a fully sailing car carrier through an experimental test campaign with a large, fully instrumented model of the complete ship at the Volvo Cars Wind Tunnel in Gothenburg. The ship design is based on the latest version of the Orcelle vessel deigned by Wallenius Marine, which is a 217 m long car-carrier, equipped with six two element wingsails. The campaign focuses on evaluating multiple sail trims under varying apparent wind angles and different hull configurations. All tests are done at a chord based Reynolds number of approximately 0.9×10^6*. The evaluation involves measuring the aerodynamic forces through individual force measurements for each wingsail, combined with the overall force generated by the integrated hull and wingsail system, all measured in six degrees of freedom. The results highlight the importance of the sail trim and demonstrate how hull design influences wingsail performance. For apparent wind angles below 30°, reduced flap angles, a slender bridge, and trimming strategies that maximize forward thrust while minimizing yaw moment are favorable. At apparent wind angles closer to 90°, larger flap angles are preferred, bridge design becomes less critical, and maximizing forward thrust remains the primary trimming objective.*

EXPERIMENTAL ANALYSIS OF RESISTANCE PERFORMANCE AND ROLL MOTION CHARACTERISTICS OF WIND-ASSISTED WING SAIL VESSELS USING SIL SYSTEM

Gyeongseo Min, Department of Naval Architecture & Ocean Engineering, Inha University, Republic of Korea
Hyeongseok Yoon, Department of Naval Architecture & Ocean Engineering, Inha University, Republic of Korea
Jaeyoon Jeon, Department of Naval Architecture & Ocean Engineering, Inha University, Republic of Korea
Saishuai Dai, Department of Naval Architecture, Ocean and Marine Engineering, University of Strathcylde, United Kingdom
Jisoo Han, Hanwha Ocean Co., Ltd., Republic of Korea
Soonseok Song, Department of Naval Architecture & Ocean Engineering, Inha University, Republic of Korea
Sanghyun Kim*, Department of Naval Architecture & Ocean Engineering, Inha University, Republic of Korea
*corresponding author email: kimsh@inha.ac.kr

In response to the recently strengthened regulations by the International Maritime Organization (IMO) concerning the Carbon Intensity Index (CII), there is a growing need to adopt alternative propulsion technologies to reduce fuel consumption and carbon emissions. In this context, wing sails, as one of the wind-assisted propulsion systems, are gaining attention as an eco-friendly solution to enhance ship fuel efficiency. However, their practical implementation requires thorough performance verification under diverse sea conditions and a comprehensive assessment of their influence on ship stability. To address this gap, this study evaluates the resistance reduction and roll motion characteristics of wing sail vessels under various marine environmental conditions using the Software-in-the Loop (SIL) method. The SIL method, previously employed in Floating Offshore Wind Turbine (FOWT) experimental studies, measures the motion of floating structures by applying real-time varying aerodynamic forces through virtual force simulation systems. In this study, a similar approach is applied to wing sail vessels, where the aerodynamic forces generated by wing sails are simulated using rotating motor fans. This enables real-time measurement of ship roll motion and resistance reduction rates corresponding to instantaneous posture changes under various environmental conditions, with wing sail forces dynamically adjusted based on the vessel's real-time motion response.

Keywords: Software-in-the Loop (SIL), Wind-assisted ship propulsion (WSAP), Wing sail

A CFD-BASED PERFORMANCE ASSESSMENT OF ROLLER WING SAIL FOR WINDASSISTED SHIP PROPULSION

Inwon Lee, Pusan National University, Republic of Korea
Vivar Levakova Armando Ernesto1, Pusan National University, Republic of Korea
Jin-Won Yu, Pusan National University, Republic of Korea

The International Maritime Organization's (IMO) Green House Gas (GHG) strategy sets out the target to reduce the total annual GHG emissions by at least 50% compared to 2008 by 2050. To achieve this ambitious target, IMO has suggested the implementation of various innovative energy efficiency technologies in the existing and new ships. These technologies include the Wind Assisted Ship Propulsion system (WASP), among others. In this study, a parametric study on the characteristics of a plain wingsail was carried out using numerical calculations. Later, the plain wing was modified, fitting a rotary cylinder on the suction side, which improved its performance, providing a higher lift coefficient and delaying considerably the stall angle. Finally, the EEDI calculation was performed for the ship KVLCC2. Concluding that the optimized wingsail considerably reduces the power delivered by the main engine of the ship.

EVALUATION OF MANOEUVRING PERFORMANCE UNDER EXTERNAL FORCES USING A DUCT FAN-TYPE AUXILIARY THRUSTER IN FREE-RUNNING MODEL TESTS

Kwang-min Lee, HD Hyundai Heavy Industries, Republic of Korea
Ho-tak Ok, HD Hyundai Heavy Industries, Republic of Korea
Young-min Kang, HD Hyundai Heavy Industries, Republic of Korea

This study presents the development of a free-running model test system equipped with a duct fan arrangement to emulate external forces acting on ships. The system comprised an optical motion tracking system for real-time measurement of the model ship's position and attitude, a self-propulsion system, a wireless control and data acquisition system, and an auxiliary thruster unit for applying external forces. A control framework was established to calculate target forces and yaw moments in real time as functions of ship velocity and heading, and to distribute the corresponding inputs to multiple fans. Using this setup, external loads associated with wind-assisted propulsion system (WAPS) were reproduced and applied directly to the model ship during free-running model tests. Turning tests were conducted under WAPS-on and WAPS-off conditions, and the trajectories responded in a reasonable manner to the applied external loads.

NUMERICAL INVESTIGATION OF THE EFFECT OF BIOMIMETIC TUBERCLES ON THE HYDRODYNAMIC RESISTANCE OF A FLAT PLATE

Alessandro Marino, Fincantieri S.p.A., Italy & University of Strathclyde, UK
Roberto Ravenna, University of Strathclyde, UK
Momchil Terziev, University of Strathclyde, UK
Mehmet Atlar, University of Strathclyde, UK

Mimicking the features of living animals or plants is often an efficient solution for engineering problems. In the marine world, humpback whales (Megaptera Novaeangliae) are well known for their remarkable agility, despite their bulky bodies, and biologists, as well as engineers, have studied them to uncover their secret. While the tubercles on the leading edge of their pectoral fins have been successfully applied to wing profiles in aeronautics [1, 2] and marine technology [3–5], the present work presents the application of the circular-base tubercles located on the head of these whales to a flat surface. In fact, the circular-base tubercles proved to be effective in manipulating the flow over the flat plate [6–8]and in some cases, also reduced the total drag. In the present study, Computational Fluid Dynamics (CFD) simulations were performed in order to expand the investigation in [6] and replicate the experimental results obtained in [7, 8]. Simulations were run with both RANS and DES solvers, and the results were analysed and compared. The results confirmed the trend observed during the previous experimental campaign, showing that biomimetic tubercles can modify, and in some instances improve, the performance of a flat plate by reducing its drag.

SYSTEMATIC HYDRODYNAMIC, PERFORMANCE, AND ACOUSTIC ANALYSIS OF BIOMIMETIC SOLUTIONS FOR MARINE PROPELLERS

Mario Felli*, Institute of Marine Engineering, National Research Council, Italy
Giaime Paradiso, Institute of Marine Engineering, National Research Council, Italy
Ivan Santic, Institute of Marine Engineering, National Research Council, Italy

* Corresponding author e-mail: mario.felli@cnr.it

Tubercle-based solutions, inspired by the unique morphology of humpback whale flippers, have gained significant attention in naval propulsion and aerodynamics for their performance-enhancing capabilities. These biomimetic designs employ sinusoidal leading-edge modifications that generate streamwise vortices, improving flow attachment and increasing resistance to flow separation. Additionally, the literature reports advantages of tubercle-assisted propellers (TAP) in mitigating cavitation phenomena and underwater radiated noise by promoting improved flow uniformity, delaying cavitation inception, and reducing erosion effects, which ultimately contribute to quieter, more efficient, and durable propulsion systems. The present study presents the results of a systematic experimental investigation into the hydrodynamic and hydroacoustic performance of various configurations of a tubercle-assisted ducted propeller, compared to a conventional ducted propeller in behind-ship conditions. Conducted as part of the Horizon Europe Research Project "RESHIP" this survey included propulsion tests, detailed flow measurements, cavitation tests, and acoustic measurements using a scaled model of a supply vessel. The paper reports a description of the experimental survey as well as a critical analysis of the most relevant findings.

Keywords: Tubercle assisted propeller, SPIV, sound measurements, efficiency

AN IMPROVED EXPERIMENTAL WORKFLOW TO EVALUATE PERFORMANCE OF PASSIVE DRAG REDUCTION METHODS

Antoni Fiedoruk, University of Strathclyde, UK
Çağatay Sabri Köksal, University of Strathclyde, UK
Fernando Gamboa, BAE Systems, UK
Osman Turan, University of Strathclyde, UK
Mehmet Atlar, University of Strathclyde, UK

The Fully Turbulent Flow Channel (FTFC) at the University of Strathclyde is designed for indirect measurement of friction drag on test plates with varied surface characteristics. Beyond evaluating coatings, the facility enables the assessment of energy-saving surface patterns. Previous test campaigns revealed that such patterns introduce a three-dimensional component into an otherwise two-dimensional flow. This effect necessitates data correction due to its influence on pressure measurements and potential for misleading drag evaluation. Furthermore, literature indicates that some energy-saving surface patterns perform better in channel flow than in open flow, implying an additional free-stream interaction component that arises only in open flow testing. The complex effects of the energy-saving surface patterns are difficult to capture with RANS turbulence models, often requiring the use of higher-fidelity approaches. Consequently, obtaining the necessary data correction or accounting for the open-flow effects becomes computationally expensive and impractical for extensive campaigns.

This paper presents a proposed testing facility designed to complement FTFC investigations through parallel open-flow testing. The rig, designed for towing tank use, enables direct force measurements on FTFC plates in open flow, providing both the necessary pressure-data correction and a means of capturing the open-flow effect through direct comparison with channel-flow results. The paper outlines the design rationale, proposed experimental methodology, boundary layer measurement approach and further presents numerical simulations of the open-flow experiment, highlighting predicted behaviour and associated uncertainties. In doing so, the project aims to expand the experimental dataset of energy-saving surface patterns in water and to introduce a new framework for their open-flow testing, thereby advancing current understanding of their hydrodynamic behaviour with special focus on the open flow effects.

NUMERICAL AND EXPERIMENTAL INVESTIGATION ON THE BEHAVIOUR OF BIOMIMETIC TUBERCLES IN A FULLY TURBULENT FLOW CHANNEL AT HIGH REYNOLDS NUMBERS

Alessandro Marino, Fincantieri S.p.A., Italy & University of Strathclyde, UK
Mehmet Atlar, University of Strathclyde, UK

Biomimetic tubercles, inspired by those on humpback whales (Megaptera Novaeangliae), have been shown to have a remarkable effect on the flow feature around a foil structure when applied to its leading edge.

The effect of biomimetic tubercles on marine vessels is addressed in the present study through their capacity to manipulate the flow characteristics on the flat surfaces to which they are attached. A numerical investigation was conducted to identify the most relevant combinations and configurations of tubercles for physical testing in the Fully Turbulent Flow Channel (FTFC) at the University of Strathclyde. The CFD simulations were conducted using a commercial RANS code to determine the behaviour of tubercles on a flat panel and their interactions in various configurations.

The tubercles configurations were subsequently tested at high Reynolds numbers in an extensive experimental campaign in the FTFC. The results were corrected for the 3D effect of tubercles in the channel's measuring section, with the correction factors being extrapolated from the CFD simulations.

The tubercles' effect on the friction coefficients of the panels was studied and compared to the numerical predictions. The EFD and CFD results could not be directly compared, due to the intrinsic differences between the two models, however, the consistency of results allows the use of RANS simulations to calculate the correction factors to be applied to the EFD results.

The physical tests proved that the tubercles have a generally positive effect on the flat panels, with their distribution and combination affecting the results more than their total number.

EXPLORATION OF PROPULSION PERFORMANCE OF A GATE RUDDER RETROFITTED VESSEL WITH A STERN TUNNEL

Ahmet Yusuf Gurkan, University of Strathclyde, UK
Çağatay Sabri Köksal, University of Strathclyde, UK
Osman Turan, University of Strathclyde, UK
Mehmet Atlar, University of Strathclyde, UK

In the short sea shipping market, characterized by smaller, older vessels and a fragmented operator base, the adoption of low- and zero-carbon technologies faces significant barriers. This study investigates the feasibility of retrofitting a novel gate rudder system, combined with a stern tunnel, to enhance energy efficiency in alternative fuel-powered vessels, specifically methanol-fuelled ships. The proposed system is designed with future adaptability in mind, enabling potential application to existing vessels.

The objective was to replace a conventional rudder and ducted propeller system with a gate rudder design, while incorporating the constraints imposed by an existing stern tunnel. Two design alternatives were developed: one involving a direct replacement of the propulsion system without altering the propeller position, and another shifting the propeller aft to accommodate a more optimal gate rudder geometry. The gate rudder design process employed an enhanced optimization methodology previously developed under the GATERS project.

Design and validation were carried out using full-scale Computational Fluid Dynamics (CFD) simulations. The full-scale CFD results demonstrated approximately a 22% reduction in delivered power with the retrofitted gate rudder system.

This study confirms that the integration of a gate rudder system with a stern tunnel can significantly improve propulsion efficiency, offering a viable retrofit solution for short sea shipping vessels to meet International Maritime Organization (IMO) emissions targets, even for ships already equipped with energy-saving devices like ducted propellers.

GATE RUDDER APPLICATION TO WIDE AREA OF OCEAN-GOING VESSELS

Noriyuki Sasaki, University of Strathclyde, United Kingdom
Mehmet Atlar, University of Strathclyde, United Kingdom

This paper introduces recent gate rudder system applications to the wide range of ocean-going vessels, including large container ships, tankers, and bulk carriers. All the target ships have been tested in the same towing tank to minimise any noise and scatter that may be introduced by the so-called facility bias, which can occur when tests are conducted in different facilities.

The paper also describes the difference of design principles for the ocean going ships and coastal ships by introducing two ships which were delivered very recently.

The study implies that the fuel savings appers on the ocean going ships strongly depends on the sea margin which is larger than before due to slow steaming.

Keywords: Gate rudder System, Gate rudder model test, the standard model test procedure, facility bias

GATE RUDDER SYSTEM PERFORMANCE PREDICTION FOR DIFFERENT RUDDER MODES: A COMPARATIVE STUDY OF SLIDING MESH AND ACTUATOR DISK CFD MODELS

Ahmet Yusuf Gurkan, University of Strathclyde, UK
Uğur Oral Ünal, Istanbul Technical University (ITU), Turkey
Mehmet Atlar, University of Strathclyde, UK

The Gate Rudder System (GRS) is a recently introduced innovative energy-saving device (ESD) that integrates steering and propulsion control, thereby providing attractive savings in propulsive efficiency and favourable manoeuvring behaviours in both newbuild ships and retrofit applications. Despite the increasing application of this ESD, accurately predicting its full-scale performance using Computational Fluid Dynamics (CFD) remains challenging due to the complex interactions among the rudder, propeller, and hull.

This study presents a detailed investigation into the accuracy of propulsion performance predictions, including extreme rudder configuration, by comparing sea trial measurements with various CFD-based propulsion modelling approaches for a GRS retrofitted on a 90-meter general cargo vessel with a high block coefficient. The investigation includes high-fidelity discrete propeller modelling using a Sliding Mesh (SM) approach with rigid body motion, compared against more computationally efficient, low-fidelity methods, specifically, actuator disk models represented by the Virtual Disk (VD) approach. The study also includes the investigation of the different propeller modelling approaches for manoeuvring performance, focusing on the GRS' unique rudder capabilities during a turning circle manoeuvre, where each rudder blade assumes a different rudder angle.

The comparative analyses of the powering performance predictions for the trial condition showed that high-fidelity CFD simulations using the SM approach can predict delivered power within 5% of sea trial measurements. In contrast, the modified VD modelling with calibrated thrust and swirl distributions achieves acceptable accuracy within 8%. In the turning circle manoeuvre rudder configuration, the propulsion performance predictions remain similar for delivered power; however, the VD method underestimates the propeller thrust by approximately 6%, with more significant discrepancies observed in rudder forces, especially at higher rudder angles.

These findings highlight the trade-off between computational cost and prediction accuracy when selecting propeller modelling approaches. While the SM approach provides superior accuracy, which can be particularly important, e.g., for securing a class certification for the structural design of the GRS, the VD approach offers a practical alternative for early-stage design studies or parametric analyses requiring faster turnaround times. This study provides valuable guidance for naval architects and CFD practitioners seeking efficient and reliable evaluation methods for GRS performance, including invaluable full-scale powering and manoeuvring data.

RESEARCH ON THE EFFECT OF SHIP SWING FOIL ON REDUCING RESISTANCE AND INCREASING THRUST

Junwei Zhou, School of Ocean Engineering, Harbin Institute of Technology (Weihai), China
Letong Li, School of Ocean Engineering, Harbin Institute of Technology (Weihai), China
Lei Mei*, School of Ocean Engineering, Harbin Institute of Technology (Weihai), China
Yiyan Zhang, School of Ocean Engineering, Harbin Institute of Technology (Weihai), China
Liping Shi, National key laboratory of science and technology on advanced composites in special environments, Harbin Institute of Technology, China

Correspondence: Meilei@hit.edu.cn

Flapping-foil thruster arranged at the bow of the ship could convert the energy from wave motions to useful propulsive power directly, and reducing the added wave resistance of ship by offering dynamic stability at the same time. In addition to the key parameters of the flapping foils (spring stiffness, dimensions), the motion of water particles in waves also has a significant impact on the performance of the flapping foils. Therefore, the encounter phase optimization is also crucial for the performance of the flapping foils. Based on the preliminary exploration of the drag reduction mechanism of elastic bow foil on ship hull in waves, this paper further compares the effects of flapping foil system on the resistance and motion response of different ship types under similar operating conditions, using three classic ship types (DTMB 5415, KCS, and Wigley) as research objects. In the present work, joint simulation of a ship with semi-active elastic flapping foil in head waves is realized by the ISIS-CFD solver based on NUMECA software, the effects of spring stiffness, flapping foil dimensions, and encounter phase on the performance of flapping foil thruster system are also assessed. Numerical results concerning the thrust production and resistance reduction have been presented, indicating significant energy extraction from the waves for the augmentation of ship's overall propulsion and enhancement of dynamic stability. Under optimized parameters, the system can significantly reduce the pitch and heave amplitude of ship in wave, with a maximum reduction of 20.14%, and the resistance reduction ratio can reach up to 9.60%. For the DTMB 5415 ship, the comprehensive effect ratio of reducing resistance and increasing thrust could reach 31.39%. Further more,by analyzing the coupling effect between the ship and the flapping foil, it's found that the thrust increasing performance of the swing foil is not positively correlated with the spring stiffness, while the resistance reducing and roll reducing performance of the swing foil will be enhanced with the increase of spring stiffness. And under the condition of a wavelength to length ratio of 1.2, when the encounter phase of the flapping foil is -90 °, the effect of system is optimal. The research could support us in optimizing the system by designing the parameters according to the application scenario and applicable requirements.

Keywords： Swing foil thruster, Numerical simulation, Ship's sea-keeping, Spring stiffness.

WAVE DRONE: FEASIBILITY STUDY ON A SHORT-TERM WAVE ELEVATION MEASUREMENT METHOD

Fukai Song, The University of Strathclyde, UK
Qirui You, The University of Strathclyde, UK
Patrick Fitzsimmons, The University of Strathclyde, UK
Mehmet Atlar, The University of Strathclyde, UK
Saishuai Dai*, The University of Strathclyde, UK

* Corresponding author e-mail: saishuai.dai@strathc.ac.uk

Field wave elevation measurements can be obtained using various methods, including wave buoys (wave riders), radar systems, seabed-mounted pressure gauges, satellites, and altimeters for high spatial resolution. However, most of these approaches require substantial setup and logistics, for example, mooring a wave buoy at the desired location. While they can provide long-term datasets, often spanning multiple years, such methods may not be practical when only short-term data is needed, such as during a prototype sea trial lasting a few days at a location with no existing metocean data.

This study proposes a short-term wave elevation monitoring method using a drone equipped with a wave rider processor card. The method aims to provide a rapid and deployable solution for temporary wave measurements. The concept was tested in the towing tank at the Kelvin Hydrodynamics Laboratory. Results were compared against measurements from a traditional wave rider buoy under the same wave, to evaluate the feasibility and accuracy of the proposed method. Preliminary results indicate that the proposed method yields measurement results comparable to those obtained by the wave rider, offering a viable mobile solution for short-term field wave elevation monitoring.

DESIGN AND CONSTRUCTION OF A LARGE SCALE UNDERWATER TEST VEHICLE MULTI-PURPOSE MINI SUBMARINE

Cansın Özden, Istanbul Technical University, Faculty of Naval Architecture and Ocean Engineering
&
Datum Denizaltı Teknolojileri Uygulama ve Müh. AŞ, Turkey

Within the framework of a recent research development programme (Çok Amaçlı Mini Denizaltı Geliştirme Projesi supported by Presidency of Defence Industries of Turkey), a manned mini submarine has been designed and constructed. Within the scope of the project, the design, construction and testing of a multi-purpose mini submarine that can dive to a depth of 300 meters, has a crew of four and can be easily transported by land thanks to its length of 12 meters is carrying out.

With ÇAMD, Turkiye will contribute to some extent to the accumulation of knowledge and development for all submarine design/production/integration processes. In this context, the ÇAMD development R&D Project to be delivered has five main objectives;

1. *Enabling the theoretical studies of commercial/military submarine design and verification/improvement activities to be applied on a vehicle that can be manufactured and tested in a short time,*
2. *Providing Türk Loydu with experience in submarine plan approval, material certification and classification activities for national military submarine projects,*
3. *Bringing the systems developed by Turkish defence industry companies for submarines into inventory as a platform that can be integrated for testing purposes or as a test aid in its entirety.*
4. *The vehicle will be served as a large scale hydrodynamics test system which will assist computational simulations.*
5. *The vehicle will be used as a test platform for XLUUV unmaned underwater vehicle software developments.*

The configuration of ÇAMD includes a seven-blade submarine propeller and hydraulically controlled steering gear arranged in a cross shape. The submarine is equipped with main diving, trim and compensation tanks systems and associated pumps and compressed air circuits. There is a specially designed electrical and control system and type approved control systems connected to this system, as well as pressure, various gas, level and fire systems, especially sensor groups. The navigation of the mini-submarine, which has forward-looking sonar, altimeter and radar systems, is ensured by a special inertial navigation system with integrated GPS on the surface and Dopler velocity log underwater. ÇAMD has two retractable masts with antennas for various communication and navigation systems and an electro-optical camera with a 360-degree view. There are emergency rescue systems, a life buoy and an anchor winch.

Within the scope of the project, a water-cooled electric motor, which will also be used in manned/unmanned submarine studies to be developed indigenously in Turkey, was developed indigenously and nationally by Femsan DC motor factory and certified by Türk Loydu.

Keywords: submarine, underwater, test vehicle, lsv, large scale vehicle, XLUUV

HYDROGEN-POWERED RESEARCH VESSEL DESIGN

Çağatay Sabri Köksal, University of Strathclyde, UK
Ahmet Yusuf Gürkan, University of Strathclyde, UK
Nicholas Owens, Scottish Association for Marine Science (SAMS), UK
Osman Turan, University of Strathclyde, UK
Mehmet Atlar, University of Strathclyde, UK

The Scottish Association for Marine Science (SAMS) and the University of Strathclyde are collaborating on the design of a next-generation, hydrogen-powered research vessel (RV), supported by the National Environmental Research Council (NERC). The project is to address the replacement of SAMS' decommissioned RV Calanus with a state-of-the-art, zero-emission platform to support clean oceanographic research, aligned with the UK's Clean Oceanography initiative and the International Maritime Organization's decarbonisation strategy. The vessel design is based on a Deep-V hull concept, drawing on experience with Newcastle University's RV The Princess Royal, and further enhanced through parametric analysis and optimisation. A systematic design study demonstrated that hydrodynamic optimisation, including bow shape, side bulb integration, and stern tunnel geometry, achieved a remarkable reduction in wave-making resistance at the 12 knots service speed compared to the baseline hull. This improvement reduces hydrogen storage capacity and enhances available onboard space. In parallel to hull form optimisation, the feasibility of integrating hydrogen-based propulsion systems was explored. Both compressed gaseous hydrogen (CGH_2) and liquid hydrogen (LH_2) storage concepts were assessed, though challenges remain regarding underdeck storage and compliance with safety regulations. Engagement with classification societies (DNV and Lloyd's Register) and industry stakeholders provided practical pathways to address certification and safety requirements. The study outlines the vessel's main particulars and establishes a validated baseline design. The work is still in progress, with remaining tasks including hydrogen safety integration, model-scale testing at the Kelvin Hydrodynamics Laboratory, and preparation of tender specifications for shipyard commissioning. This project represents a critical step towards the UK's first hydrogen-powered research vessel, providing a demonstrator platform for zero-emission marine science and sustainable ship design.

ENERGY, EMISSIONS AND ECONOMICS: A MEASURED APPROACH TO ELECTRIC TUG DESIGN

Liam Nugent, University of Strathclyde, UK
Stefans Grants, University of Strathclyde, UK
Wilson Beer, University of Strathclyde, UK
Aidan Armory, University of Strathclyde, UK
Henry Lapslie, University of Strathclyde, UK

To achieve global climate targets, the maritime industry must capitalise on improvements in battery chemistry and energy transmission and lead the transition from conventional fuel dependence, to thinking outside the box. This paper presents a computationally driven techno-economic analysis of a methanol-fuel-cell–battery hybrid tugboat intended for harbour and short-range towage operations in a renewable's rich environment. The study evaluates the hydrodynamic performance, energy consumption, and lifecycle costs of the proposed ECO-Tug design using numerical simulations and scenario-based operational modelling. Hydrodynamic resistance and propulsive performance are estimated through CFD simulations. The power and energy requirements derived from the simulations inform a comparative lifecycle cost and emissions model, benchmarked against a conventional diesel tug. The ECO-Tug design shows promising results that indicate significant financial and environmental savings.

INNOVATIVE SOLUTION FOR RETROFITTING DIESEL TO ELECTRIC CTVs WITH H_2 AS A RANGE EXTENDER

Serkan Turkmen*, Tallinn University of Technology, Estonia
Yi Zhou, Newcastle University, Newcastle upon Tyne, United Kingdom
Musa Bashir, Liverpool University, Liverpool, United Kingdom

To address the urgent need for reducing greenhouse gas (GHG) emissions in the maritime sector, retrofitting existing vessels with clean propulsion technologies has emerged as a critical and increasingly viable solution. However, significant challenges persist regarding the practical implementation and real-world application of these innovative technologies within the conservative maritime industry, including technical integration complexities, economic feasibility concerns, and operational reliability requirements. This comprehensive study presents a groundbreaking real-world demonstration of an advanced clean maritime solution, consisting of a fully retrofitted hybrid propulsion system that strategically combines battery-electric power with hydrogen as a range extender. The innovative system was successfully applied to an operational crew transfer vessel (CTV) that previously relied entirely on conventional diesel fuel to power its existing internal combustion engines, representing a typical maritime decarbonisation challenge. The retrofitted propulsion architecture consists of several integrated components, namely, a podded propulsion unit featuring a high-efficiency electric motor strategically attached to the vessel's moonpool plug, advanced lithium-ion battery systems for primary power storage, a purpose-built hydrogen internal combustion engine (HICE) serving as a range extender for extended operations, and specialised high-pressure hydrogen storage tubes designed for marine environments. Furthermore, this research introduces a cost-effective, comprehensive performance monitoring system using Internet of Things (IoT) technologies to enable real-time system optimisation and remote diagnostics. Despite addressing the technical, economic and operational challenges, this work also highlights the successful retrieval of UK maritime certification using the integrated hydrogen and battery systems onboard, which offers both a pathway and valuable insights for ongoing or future projects of a similar scope. The study conclusively demonstrates the substantial potential for GHG emission mitigation through strategic electrification of marine propulsion systems, with hydrogen range extension capabilities maximising sustainable operational capacity whilst maintaining commercial viability.

Keywords: Electrification, hydrogen, retrofitting, maritime

MULTI-ELEMENT GAS CONTAINER FAILURE SCENARIO-BASED HYDROGEN DISPERSION MODELLING

Çağatay Sabri Köksal, University of Strathclyde, UK
Osman Turan, University of Strathclyde, UK
Mehmet Atlar, University of Strathclyde, UK

Hydrogen dispersion caused by multi-element gas container (MEGC) failure scenarios within a confined below-deck void is analysed, focusing on gaseous hydrogen leakage and subsequent accumulation that may give rise to flammable or explosive zones. The aim is to characterise hydrogen dispersion, accumulation, and ventilation under various leak scenarios to facilitate the safe adoption of hydrogen as a deep-sea shipping fuel and to inform safer vessel design strategies for hydrogen-fuelled vessels. Computational Fluid Dynamics (CFD) simulations based on Reynolds-Averaged Navier–Stokes (RANS) models were carried out in relation to various leakage cases, including small apertures (2 mm and 5 mm), a large aperture (50 mm), and full endcap failures of a MEGC at a reference storage pressure. The numerical methods applied were validated against the benchmark experimental study of Swain et al. (1998), which investigated hydrogen release in a semi-closed space. The geometric features of the confined below-deck void, comprising structural components and natural ventilation openings, were incorporated in stages to represent a realistic storage compartment and coupled with external flow regions to enable realistic mass exchange. The results indicate that larger leaks cause rapid and extensive hydrogen dispersion, as expected, forming flammable hydrogen concentrations earlier, whereas smaller leaks result in slower but still hazardous local accumulation zones. Persistent gas pockets were identified beneath the ceiling and adjacent to natural ventilation openings, indicating that natural ventilation alone cannot ensure complete or safe removal of hydrogen. The outcomes provide insight into the effectiveness of compartment arrangement and ventilation strategies, supporting the development of risk mitigation measures and safety standards for hydrogen storage systems located within a below-deck void.

EXPERIMENTAL STUDY ON THE HYDRODYNAMIC PERFORMANCE OF A PUMP-JET PROPULSOR COMPARED TO A CONVENTIONAL PROPELLER

Mario Felli*, Institute of Marine Engineering, National Research Council, Italy
Davide Grassi, CETENA, Italy

* Corresponding author e-mail: mario.felli@cnr.it

Pump-jet propulsors represent an advanced alternative to conventional open propellers, increasingly employed in naval and underwater applications where hydrodynamic efficiency and acoustic performance are critical.

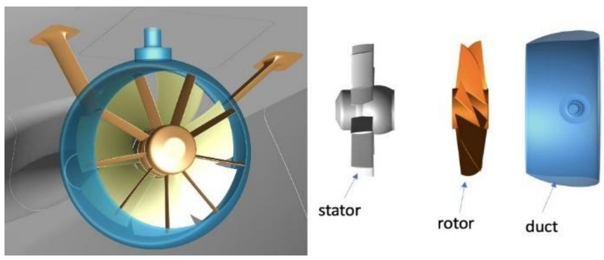

Figure 1: Pump-jet propulsor.

A pump-jet consists of a ducted rotor–stator assembly that enables controlled flow distribution and improved pressure recovery downstream of the rotor. The duct reduces tip vortex losses and delays cavitation inception, while a convergent geometry allows the same thrust as an open propeller to be achieved at lower rotational speeds, thereby enhancing efficiency and further mitigating cavitation. Downstream stator blades recover residual swirl energy, contributing additional thrust and improving overall performance. From an acoustic standpoint, the duct acts as a partial acoustic shield, attenuating pressure fluctuations and broadband noise. These hydrodynamic and acoustic advantages make pump-jet propulsors a promising solution for both new designs and retrofit applications, combining improved efficiency with effective noise mitigation.

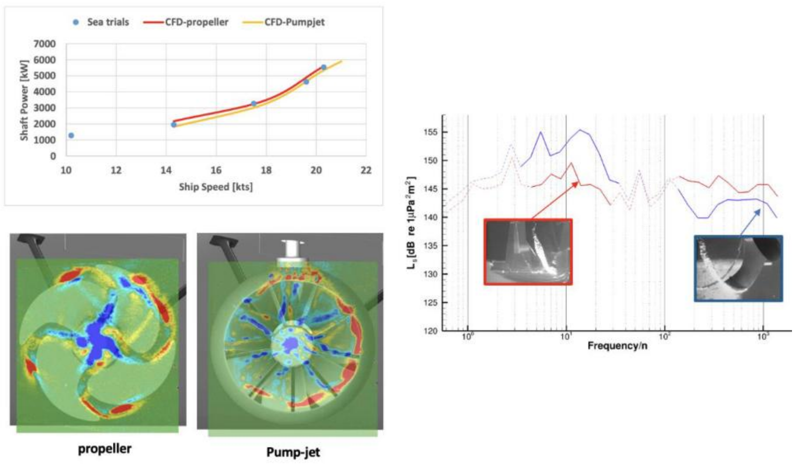

Figure 2: illustrative results comparing the performance of the original propeller and the pump-jet.

This paper presents the results of a comprehensive experimental campaign in which the propulsive, hydrodynamic, and acoustic performance of a ferry model retrofitted with a pump-jet propulsor were evaluated and compared with those of the original open propeller. The investigation covered a wide range of operating conditions, including variations in vessel speed and propulsive load, to provide a detailed assessment of the pump-jet's performance relative to the conventional configuration. The results offer valuable insights into efficiency gains, cavitation behavior, and noise reduction achievable through the adoption of pump-jet technology in ferry applications. These aspects are analyzed in detail through an exhaustive description of the experimental campaign and a critical discussion of the most significant findings. Representative results of the flow-field characteristics behind both the pump-jet and the baseline propeller are reported in Figure 2.

PRACTICAL ISSUES IN STEREOSCOPIC-PIV MEASUREMENTS FOR THE NOMINAL WAKE FIELDS IN REGULAR HEAD WAVES

Jaehoon Lee, Korea Research Institute of Ships and Ocean Engineering (KRISO), Republic of Korea
Seung-Hyun Hwang, Korea Research Institute of Ships and Ocean Engineering (KRISO), Republic of Korea
Young-Yeon Lee, Korea Research Institute of Ships and Ocean Engineering (KRISO), Republic of Korea

Using Stereoscopic Particle Image Velocimetry (Stereo-PIV, 2D-3C), the nominal wake flow fields under head wave conditions were measured in the KRISO towing tank. The system now includes upgraded two 25-megapixel CMOS cameras and a 300mJ-30Hz dual Nd:YAG laser. An enhanced underwater PIV system, with a larger field of view (300x400mm2), higher frame rate (30fps), and improved spatial resolution, replaces the previous system in the KRISO Towing Tank. This study was conducted in the KRISO towing tank to measure the nominal wake field of the tanker ship moving forward with vertical plane motion freedom during regular head waves. In regular head waves (H/L=0.01, λ/L=0.3-2.0, Vs=15.5kts), the target vessel is the KRISO tanker (KVLCC2). In order to identify the relationship between the phase of the incident wave, the motion of the hull in waves, and the change in the flow field at the stern, a time-synchronized measurement system was configured between the wave height meter, the motion displacement meter, and the Nd:YAG laser emission signal. Under the linear wave condition (λ/Lpp=1.2, H/λ=1/120) where the relative motion between the hull and the wave is large and the wave slope is small, approximately 40,000 images were acquired at 29Hz. From this, 2D- 3C velocity field results were obtained and the change in hull attitude and the nominal wake flow change at the stern were analyzed according to the phase of the incident wave. This experimental analysis determines the nominal fluctuation in wake from vertical movement of the ship within waves. Harmonic analysis and velocity component decomposition illustrate the influence of the oscillating component on ship propulsion performance.

Key words: Underwater Stereoscopic Particle Image Velocimetry, Unsteady Nominal Wake Fields in Waves, KRISO Towing Tank

EVALUATION OF STEREO PIV FOR TOWING TANK INVESTIGATION OF HULL-PROPELLER-RUDDER INTERACTION IN WAVES

Dixon T. Sin, University of Southampton, UK
Tahsin Tezdogan, University of Southampton, UK
Melike Kurt, University of Southampton, UK
Joseph Banks, University of Southampton, UK
Stephen Turnock University of Southampton, UK

Accurately predicting hull–propeller–rudder flow interactions is essential for designing energy-efficient marine vessels. However, due to historical limitations in experimental techniques, these complex flow phenomena have primarily been studied using computational fluid dynamics (CFD), with limited high-fidelity physical validation. This gap in validation can lead to discrepancies between CFD predictions and actual vessel performance, particularly in the stern region wake influenced by unsteady turbulence and sometimes flow separation along with ship motions and free surface waves.

An investigation has been made into the data quality possible with an advanced underwater stereoscopic particle image velocimetry (Stereo-PIV) system deployed at the University of Southampton's Boldrewood Towing Tank (138 m × 6 m × 3.5 m), equipped with twelve 0.5 m wave makers. The system enables high-resolution, multi-plane measurements of all three velocity components, allowing derivation of critical flow parameters such as vorticity and flow angles. It facilitates detailed in situ flow-field mapping around towed model hulls with operating propellers and rudders.

Experiments were conducted on two self-propelled ship models: a 3.8 m KRISO Container Ship (KCS) and a 3.2 m twin-screw cargo carrier. The Stereo-PIV setup employed a Litron NANO L200-15PIV dual-cavity laser, two Imager Pro SX 5M cameras operating at 7 Hz, and 55 µm polyamide seeding particles (LaVision, ρ = 1.2 kg/m³). Measurements were made across a series of transverse planes in the stern region. The resulting datasets provide high spatial and temporal resolution of the propeller-induced flow, delivering essential validation for CFD simulations. These works support the development of more accurate hydrodynamic models and contribute to the design of next-generation energy-efficient vessels.

DESIGN AND COMMISSIONING OF AN EFFECTIVE BIOFILM (SLIME) FARM FOR DRAG REDUCTION AND COATING PERFORMANCE INVESTIGATIONS

Mehmet Atlar, The University of Strathclyde, UK.
Kaan Ilter, Brooks-Bell, UK.
Çağatay Sabri Köksal, The University of Strathclyde, UK.
Ahmet Yusuf Gurkan, The University of Strathclyde, UK.
Osman Turan, The University of Strathclyde, UK.

The impact of biofouling on the survival of any marine surfaces, including the drag performance of moving types such as ship hulls, has always been of prime interest to the maritime world. While sophisticated testing facilities (e.g., fully turbulent flow channels) and complementary numerical methods (primarily CFD-based) have been introduced to investigate the effects of biofouling on the performance of these surfaces, the modelling of biofouling is complex; hence, there is a need for a practical and empirical way of including them in prediction and analysis methods. This, in turn, requires easy access and production of various types of biofoulings, particularly of biofilm (slime), under dynamic conditions and controlling their growth. Within the framework of drag reduction surfaces (e.g., riblets, dimples, compliant surfaces, etc.) and different types of marine coatings, the rapid and controlled growth of biofilm on test panels in laboratory conditions necessitates the development of practical and cost-effective slime farms, as the one recently designed and commissioned at the University of Strathclyde.

An octagonal rotating rotor structure, capable of carrying 16 (600x250mm) flat test panels that represent different surface finishes or coated surfaces, is designed and placed vertically in a rectangular tank filled with artificial or natural seawater to grow slime on these surfaces. An electric motor with variable speeds is selected to drive the rotor, simulating the dynamic movement of these panels in the natural sea environment. Meanwhile, the desired seeding specimen of any slime or other type of biofouling to be collected from nature can be planted in the tank solution and is fed systematically with nutrients to grow the biofouling rapidly on the rotating test panels under the effect of submerged LED-lighting and controlled temperature. At the same time, their growth is closely monitored by a dedicated camera.

This paper presents the concept and detailed engineering design of the above-described slime farm, including CFD-based performance analysis and its commissioning, as well as discussing the pros and cons of this unique testing facility compared to other types of biofilm farms, which complements the Strathclyde University's Fully Turbulent Flow Channel to support the ongoing drag/coating research activities

AMT'25 Conference Programme

<table>
<tr><td></td><td colspan="2">(Day 1) 29th of October</td><td></td><td colspan="2">(Day 2) 30th of October</td><td colspan="3">(Day 3) 31st of October</td></tr>
<tr><td>Time</td><td colspan="2">Events & Locations</td><td>Time</td><td colspan="2">Events & Locations</td><td>Time</td><td colspan="2">Events & Locations</td></tr>
<tr><td>8:00-9:00</td><td colspan="2">Registry & Coffee/Tea
DCC – Lobby</td><td>8:00-9:00</td><td colspan="2">Registry & Coffee/Tea
DCC – Lobby</td><td>9:00-12:00</td><td colspan="2">Coffee/Tea
DCC – Room 101-102</td></tr>
<tr><td>9:00-9:15</td><td colspan="2">Opening Ceremony
DCC – Room 101-102</td><td rowspan="2">9:00-10:00</td><td colspan="2" rowspan="2">KEYNOTE PRESENTATION 2
DCC – Room 101-102</td><td>09:30 -12:00</td><td colspan="2">GUIDED VISIT TO THE KRISO TESTING FACILITIES</td></tr>
<tr><td>9:15-10:15</td><td colspan="2">KEYNOTE PRESENTATION 1
DCC – Room 101-102</td><td rowspan="3">Group 1</td><td rowspan="3">09:30 – 09:50
10:00 – 10:30
10:30 – 11:00
11:00 – 11:30
11:30 – 11:50</td><td rowspan="3">DCC to KRISO by bus
Ice Tank
Large Cavitation Tunnel
Ocean Engineering Basin
KRISO to DCC by bus</td></tr>
<tr><td>10:15-10:45</td><td colspan="2">Refreshments (DCC – Lobby)</td><td>10:00-10:30</td><td colspan="2">Refreshments (DCC – Lobby)</td></tr>
<tr><td>10:45-12:15</td><td>Session 1A
DCC
Room 101-102</td><td>Session 1B
DCC
Room 103-104</td><td>10:30-12:30</td><td>Session 4A
DCC
Room 101-102</td><td>Session 4B
DCC
Room 103-104</td></tr>
<tr><td>12:15-13:30</td><td colspan="2">Lunch (DCC – Lobby)</td><td>12:30-13:30</td><td colspan="2">Lunch (DCC – Room 107-108)</td><td rowspan="3">Group 2</td><td rowspan="3">10:10 – 10:30
10:30 – 11:00
11:00 – 11:30
11:30 – 12:00
12:00 – 12:30</td><td rowspan="3">DCC to KRISO by bus
Ice Tank
Large Cavitation Tunnel
Ocean Engineering Basin
KRISO to DCC by bus</td></tr>
<tr><td>13:30-15:00</td><td>Session 2A
DCC
Room 101-102</td><td>Session 2B
DCC
Room 103-104</td><td>13:30-15:00</td><td>Session 5A
DCC
Room 101-102</td><td>Session 5B
DCC
Room 103-104</td></tr>
<tr><td>15:00-15:30</td><td colspan="2">Refreshments
(DCC – Lobby)</td><td>15:00-15:30</td><td colspan="2">Refreshments
(DCC – Lobby)</td></tr>
<tr><td>15:30-17:30</td><td>Session 3A
DCC
Room 101-102</td><td>Session 3B
DCC
Room 103-104</td><td>15:30-17:30</td><td>Session 6A
DCC
Room 101-102</td><td>Session 6B
DCC
Room 103-104</td><td colspan="3" rowspan="2"></td></tr>
<tr><td>17:30 -19:00</td><td colspan="2">Reception with Canapes & Drinks
(DCC – Lobby)</td><td>18:30-22:00</td><td colspan="2">Conference Banquette
(Lotte City Hotel - Crystal Ball Room)</td></tr>
<tr><td>19:00</td><td colspan="2">END OF FIRST DAY</td><td>22:00</td><td colspan="2">END OF TECHNICAL PRESENTATIONS & SECOND DAY</td><td>12:30</td><td colspan="2">END OF THE CONFERENCE</td></tr>
</table>