PRADS 2022
Book of Abstracts

15th International Symposium on Practical Design of Ships and Other Floating Structures

09 - 13 OCTOBER 2022 - DUBROVNIK - CROATIA

EDITORS
Nikola Vladimir Šime Malenica Ivo Senjanović

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2022 PRADS 15th TRIENNIAL

15th International Symposium on Practical Design of Ships and Other Floating Structures

PRADS 2022

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Under the auspices of
the Croatian Academy of Sciences and Arts
Department of Technical Sciences

Organizers:

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Faculty of Mechanical Engineering and Naval Architecture,
University of Zagreb
Zagreb, Croatia

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CONTENT

Zagreb / Paris, September 22, 2022

The 15th PRADS (International Symposium on Practical Design of Ships and Other Floating Structures) is jointly organized by the Faculty of Mechanical Engineering and Naval Architecture (UNIZAG FSB), of the University of Zagreb, Croatia, and Bureau Veritas, Paris, France, from 9th to 13th October 2022 in Dubrovnik, Croatia. Also, PRADS 2022 is organized under the auspices of the Croatian Academy of Sciences and Arts, Department of Technical Sciences, as a highest scientific and artistic institution in the Republic of Croatia.

Since the last PRADS in 2019 in Yokohama, Japan, the world has been completely transformed by COVID-19 pandemic. Besides the extensive change to both our professional and private lives, the pandemic has confirmed that the reliability of transportation chains is one of the key aspects of our existence. The maritime industry has therefore probably never been as important as it is now. On the other hand, the new challenges over the last decade, for instance environmental concerns and fluctuations in energy prices, have contributed to the current highly complex design and operation framework in the maritime sector. Emission reduction targets push all parties involved in ship and offshore business to offer highly competitive products, simultaneously considering safety, functionality and economy.

In spite of the described challenging framework both for marine sector and organization of scientific conferences in general, PRADS 2022 follows the excellence and success of previous conferences and is being held as a conference with 190 in-person and 20 online attendees.

More than 230 abstracts were accepted from authors all over the world, and all received papers have been reviewed by at least two recognized experts. Beside 145 technical papers, that have been accepted, the conference programme includes general presentation of Croatian shipbuilding over the time, prepared by Ivo Senjanović and Neven Hadžić from UNIZAG FSB, as well as 4 plenary lectures given by leading researchers in the field: Odd Magnus Faltinsen, Milovan Perić, Jørgen Juncher Jensen and Quentin Derbanne. The conference programme indicates that all above mentioned challenging issues related to the maritime sector are nowadays being considered by leading institutions in the world and confirms PRADS 2022 as an excellent event to discuss new ideas and future research directions.

Finally, we would like to express our gratitude to all plenary speakers, authors, co-authors, reviewers and session chairs for their valuable contributions to the excellence and success of PRADS 2022.

Nikola Vladimir
Šime Malenica
PRADS 2022

GENERAL SCHEDULE

9 Oct 2022	WELCOME RECEPTION
10 Oct 2022	OPENING CEREMONY
	Nikola Vladimir University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, Croatia
	Šime Malenica Bureau Veritas, Paris, France
	PLENARY LECTURES TECHNICAL SESSIONS
11 Oct 2022	TECHNICAL SESSIONS SC MEETING
12 Oct 2022	TECHNICAL SESSIONS CONFERENCE DINNER
13 Oct 2022	TECHNICAL SESSIONS GUIDED CITY TOUR

CONFERENCE DINNER

Dinner is taking place at **Sunset Beach Dubrovnik Restaurant**
Šetalište kralja Zvonimira 17, 20000, Dubrovnik, Croatia
The Sunset Beach Dubrovnik is a restaurant at a walking distance (10-15 minutes) from the conference venue.

CONFERENCE VENUE & TRAVEL INFO

PRADS 2022 is being held in Hotel Dubrovnik Palace, Dubrovnik Croatia.
https://www.adriaticluxuryhotels.com/hoteldubrovnik-palace/

If you are arriving by airplane, you are going to arrive to **Dubrovnik Airport**. A taxi service is available during the operating hours of the airport directly taking you to the venue for about 40.00 EUR. Cheaper transfers by shuttle or bus are also available. **Dubrovnik airport shuttle** which runs to and from Dubrovnik will take you from Dubrovnik Airport and make stop at the Pile Gate bus stop - about 5 EUR. There you can take the **bus No. 4 (Pile - Hotel Palace)** which will take you directly to the venue (last stop) - about 2 EUR. The bus is departing every 15 minutes.

The currency of Croatia is currently the Croatian Kuna (HRK), with approximate exchange rate: 1.00 EUR = 7.5345 HRK.

SUNDAY, 09 OCTOBER 2022

17:30 - 19:00	REGISTRATION
19:00 - 20:00	WELCOME RECEPTION

MONDAY, 10 OCTOBER 2022

08:00 - Onwards	REGISTRATION
08:30 - 08:40	OPENING CEREMONY **Mare I**
08:40 - 09:00	**Mare I** I. Senjanović, N. Hadžić: **Croatian Shipbuilding - Past, Current Situation & Perspectives**
09:00 - 09:45	PLENARY LECTURE 1 **Mare I** O.M. Faltinsen: **Slamming Load Effects on Ships and Marine Structures**
09:45 - 10:30	PLENARY LECTURE 2 **Mare I** M. Perić: **The Role of CFD in Ship Design and Optimization**
10:30 - 11:00	Coffee break
11:00 - 12:40	TECHNICAL SESSIONS
12:40 - 14:10	Lunch
14:10 - 15:50	TECHNICAL SESSIONS
15:50 - 16:20	Coffee break
16:20 - 18:00	TECHNICAL SESSIONS

TUESDAY, 11 OCTOBER 2022

08:30 - Onwards	REGISTRATION
09:00 - 09:45	PLENARY LECTURE 3 - MARE I J.J. Jensen: **Extreme Value Predictions and Critical Wave Episodes for Marine Structures**
09:45 - 10:30	PLENARY LECTURE 4 - MARE I Q. Derbanne: **Brief History of Rule Loads and Longitudinal Strength of Ships**
10:30 - 11:00	Coffee break
11:00 - 12:40	TECHNICAL SESSIONS
12:40 - 14:10	Lunch
14:10 - 15:50	TECHNICAL SESSIONS
15:50 - 16:20	Coffee break
16:20 - 18:00	TECHNICAL SESSIONS
18:10 - 18:20	GROUP PHOTO
18:30 - 20:00	STANDING COMMITTEE MEETING

WEDNESDAY, 12 OCTOBER 2022

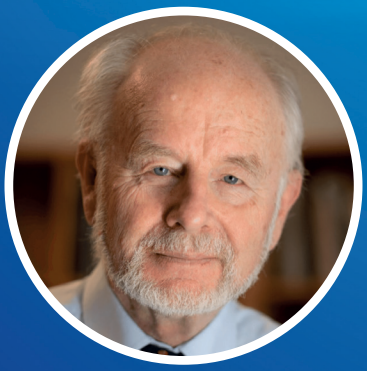
08:30 - Onwards	REGISTRATION
09:00 - 10:40	TECHNICAL SESSIONS
10:40 - 11:10	Coffee break
11:10 - 12:50	TECHNICAL SESSIONS
12:50 - 14:20	Lunch
14:20 - 16:00	TECHNICAL SESSIONS
19:30 - Onwards	CONFERENCE DINNER

THURSDAY, 13 OCTOBER 2022

08:30 - Onwards	REGISTRATION
09:00 - 10:40	TECHNICAL SESSIONS
10:40 - 11:10	Coffee break
11:10 - 12:50	TECHNICAL SESSIONS
12:50 - 14:20	Lunch
14:20 - 16:00	TECHNICAL SESSIONS
16:00 - 18:00	GUIDED CITY TOUR

08:00 - Onwards	REGISTRATION			
08:30 - 08:40	OPENING CEREMONY Mare I			
08:40 - 09:00	Mare I I. Senjanović, N. Hadžić: **Croatian Shipbuilding - Past, Current Situation & Perspectives**			
09:00 - 09:45	PLENARY LECTURE 1 / Mare I O.M. Faltinsen: **Slamming Load Effects on Ships and Marine Structures**			
09:45 - 10:30	PLENARY LECTURE 2 / Mare I M. Perić: **The Role of CFD in Ship Design and Optimization**			
10:30 - 11:00	Coffee break			
11:00 - 12:40	01. TECHNICAL SESSIONS Dubrava I **CFD** T. Katayama , K. Yamaguchi, T. Nanami, J. Umeda, S. Ozeki, M. Soga, T. Watanabe: **Calculation of Hydrodynamics Forces acting on Prismatic Planing Surface by CFD** S.H. Lee, K.J. Paik, J.H. Cho, G.H. Kim, H.S. Kim: **A study on the Added Resistance Performance in Various Regular Waves and Irregular Waves using URANS Solver** L. Perez-Rojas, A. Portillo-Juan: **Study of the Propeller Effect on the Sinkage of Ships** Y.J. Kim, D.H. Kim: **Study of Wind Resistance Reducing Methods for Commercial Vessels**	02. TECHNICAL SESSIONS Mare II **Design I** O.T. Gudmestad: **Modern Ship Design** J. le Poole, N. Charisi, K. Droste, A. Habben Jansen, A.A. Kana: **The Design Knowledge Management Square - a Framework for Early Stage Complex Ship Design** J. Ha, M.I. Roh, K.S. Kim, M.C. Kong: **Integrated Method for the Arrangement Design of a Ship for Implementing Digital Twin in Design** I. Bačkalov, M. Kalajdžić, N. Momčilović, S. Rudaković, M. Vidić: **Shallow-Draught Vessels for the Vessel Train**	03. TECHNICAL SESSIONS Mare III **Structures, Structural analysis I** M. Deul, P. van Lieshout, N. Werter: **On the Validity of using Small-Scale Fatigue Data to Design Full-Scale Steel Welded Structures: Testing Assumptions on Residual Stress Relief** L.N.B. Zacharias, M.I.L. de Souza, I.P. Pasqualino, P.W. dos Reis: **Buckling Analysis of FPSO Panel under Pitting Corrosion** M. Yamada, T. Okada, Y. Naruse, Y.Kawamura, G. Hayakawa, K. Ishibashi, H. Koyama: **Influence of Plate Aspect Ratio on the Axial Load Effect on the Plate Strength against Lateral Pressure** T. Zheng, N.Z. Chen: **Identification and Fatigue Life Prediction for Critical Blade Root Bolts of a Floating Offshore Wind Turbine (FOWT)**	04. TECHNICAL SESSIONS Mare IV **Meteocean** U.D. Nielsen, A. Ikonomakis, J. Dietz: **Sea States Encountered by Ships in the Maersk Fleet - An Assessment based on Reanalysis data (ERA5)** G. de Hauteclocque, M. Lasbleis: **Extreme Seastate Parametrization and its Consequences on Ship Responses** W. Fujimoto, T. Fukui: **Modelling Storm Avoidance Behaviour based on AIS Data of Container Ships in the North Atlantic Ocean** Y.H. Kim, S.K. Cho, H.J. Kang: **Development of Practical Sea State Now-casting System with Optical Images using Machine Learning**
12:40 - 14:10	Lunch			

	05. TECHNICAL SESSIONS Dubrava I **Maneuvering I**	06. TECHNICAL SESSIONS Mare II **Design II**	07. TECHNICAL SESSIONS Mare III **Structures, Structural analysis II**	08. TECHNICAL SESSIONS Mare IV **Monitoring**
14:10 - 15:50	R. Suzuki, Y. Tsukada, M. Ueno: **Effects of Steady Wave Forces for Oblique Motion on Estimation of Manoeuvers of Full-Scale Ships** Ø. Rabliås, T. Kristiansen, R. Skejic: **Sensitivity Study of Wave Height Variation during Turning Circles in Regular Waves** T. Ohmori, K. Ohashi: **Numerical Study to Improve the Estimation of Manoeuvring Fluid Force for a Container Ship in Deep and Restricted Water** M. Kuroda, S. Yokota, M. Tsujimoto, R. Fukasawa: **Effect of Hydrodynamic Forces due to Drift Motion on Ship performance in Actual Seas at Low Speed**	C. Veldhuis, A. Grasman, J. Willemsen, U. Shipurkar: **Systematic Design of Future Marine Power & Energy Systems** R. Gafter, N. Drimer: **A Feasibility Study of a New Concept of VLFS** H.J. Son, J.S. Kim, Y.C. Lee, H.J. Kim: **On Prediction of Drillship Transit Speed under Various Propulsion Modes and Optimization of Power Distribution for Bow and Stern Thrusters** Y.C. Hung, H.J. Tang, C.T. Lee, R.Y. Yang: **Feasibility Study on Different Layouts of Power Cable for Floating Offshore Substation**	J. Andrić, B. Haraminčić, M. Tomičić, P. Prebeg: **Influence of Large Shell Openings Geometry in Ship Superstructure on Stress Concentration Reduction** T. Lindemann, P. Kaeding, A. La Ferlita, N. Schenk, D. Aleksashin: **Determination of Ultimate Strength for a Bulk Carrier under Combined Loads** G. Jagite, D. Coache, Š. Malenica: **On the Modeling of the Nonlinear Dynamic Response of Composite Wind Turbine Blades** J.C. Petiteau, S. Paboeuf: **Fatigue Assessment of Composites Parts for Marine Renewable Energy Converters**	R. Hageman, I. Drummen, I. Thompson, K. Stambaugh: **Fleet Structural Integrity through Monitoring and Data Fusion** K. Toh, Y. Kurisaki, S. Hirakawa, Y. Kawajiri, K. Furukawa, H. Murayama, D. Yanagihara: **Fundamental Investigation on Measuring Procedure of Ship Motion and Hull Girder Deformation by Using Global Navigation Satellite System** R. Miratsu, W. Fujimoto, T. Fukui, H. Ochi: **Evaluation of Ship Motions and Hull Structural Strength for Container Ships based on AIS Data and Wave Hindcast** S. Ivosevic, N. Kovac, G. Vastag: **The Analysis of the Corrosion-Induced Failures of the Inner Bottom Plating of Fuel Oil Tanks**
15:50 - 16:20	**Coffee break**			
	09. TECHNICAL SESSIONS Dubrava I **Maneuvering II**	10. TECHNICAL SESSIONS Mare II **Design III**	11. TECHNICAL SESSIONS Mare III **Structures, Structural analysis III**	12. TECHNICAL SESSIONS Mare IV **Risk Assessment**
16:20 - 18:00	S. Bielicki: **Modified MMG Mathematical Model for Manoeuvring Simulations of Ships driven by Azimuth Thrusters** P. Krata, T. Hinz, S.A. Dugan, M. Marley, J. Montewka: **Prediction and Evaluation of an Angle of Heel due to Turning Maneuver of Small Training Ships: Comparison of Dynamic Analysis and Static Design Criteria** X. Mao, X. Zhan: **Course-keeping Ability and Minimum Propulsion Power Assessment in Adverse Weather Conditions Using a Manoeuvring-Seakeeping Unified Model** R. Skejić, O.M. Faltinsen: **Maneuvering of Submarines at Periscope Depths in a Seaway**	J. Van Houten, D. Singer, M.D. Collette: **Balancing Designer Influence with Rework for Design Paths of a Simple Polynomial Model** T. Takami, U.D. Nielsen, J.J. Jensen: **Application of Prolate Spheroidal Wave Functions for Assessment and Prediction of Ship Responses** E. Scheffers, P. de Vos: **An Improved Approach for On-Board Distribution System Robustness Estimation in Early-Stage Ship Design** I. Gypa, M. Jansson, R. Gustafsson, S. Werner, R. Bensow: **Propeller Design Procedure for aWind-Assisted KVLCC2**	Š. Malenica, T. Novaes, J. de Lauzon, F. Bigot, I. Senjanović, N. Vladimir, B.K. Choi: **Accounting for the Nonlinearities of Tank Supports in Structural Assessment of the Vessels Equipped with Independent Tanks** M. Radon, S. Küster: **Comparative Global Strength Assessment Study for Mega Yachts** D. Dessi, F. Passacantilli: **Application of Modal Strain Energy Analysis to Damage Identification in Marine Structures** J. Yang, B.S. Jang: **The Hull Structural Response Prediction Method using Distortion Base Mode for Various Loading Conditions of Container Ship**	K.S. Kim, M.I. Roh, S.H. Ham, S. Ha: **Evacuation Analysis of Passenger Ships Considering Intermediate Flooding** Y. Yanagi: **Grounding Accident Analysis Using Classified Factors** S. Ahmed, T. Li, S. Huang: **An Integrated FMECA Study of Cruise Ship Propulsion Module Shafting System using Interval Type-2 Fuzzy Expert System** Á. Marrero, F. Rodero: **Application of a Risk Analysis based on Historical Data to Prevent Cargo Ignition on Ro-Ro, Ro-Pax and Car-Carrier Ships**



Odd Magnus Faltinsen
Centre For Autonomous Marine Operations And Systems (AMOS), Norwegian University Of Science And Technology, Trondheim, Norway

LECTURE

SLAMMING LOAD EFFECTS ON SHIPS AND MARINE STRUCTURES

Slamming is of concern for structural design of ships, offshore platforms, lowering of subsea structures through the splash zone, accidentally dropped objects and launching of free-fall lifeboats from offshore platforms. Slamming on ships and sea structures causes both local and global structural response and ought to be coupled with structural mechanics to find important time scales of the many physical effects associated with slamming. Hydroelastic slamming has an analogy to transient response of a mass-spring system. Important factors are the ratio between slamming duration, and important structural natural periods, the time history of loading, added mass and slam damping. If the time scale of a fluid mechanic effect such as liquid compressibility or gas cavity oscillations is very small relative to the structural natural periods associated with maximum structural stress, the details of the fluid mechanic effect do not matter. Hydroelasticity of concrete shells, horizontal plates, and wedge-shaped cross-sections during drop tests are theoretically discussed and partly compared with experiments. Both the water-entry and water-exit phase matter in describing the global load effect due to wetdeck slamming on catamarans and offshore platforms. Bow slamming and whipping of ships are discussed with emphasis on modelling of slamming in an engineering context. Sloshing-induced slamming in prismatic LNG tanks is perhaps the most complicated slamming problem because many fluid-mechanic and thermodynamic parameters as well as hydroelasticity may matter. Further, complicated in-flow scenarios of slamming may appear due to violent sloshing. The consequence is that both computational tools and model test scaling are limited.

BIOGRAPHY

Odd Magnus Faltinsen has worked on broad aspects of hydrodynamics of displacement ships, high-speed craft, offshore structures, and fish farms. Faltinsen was born in 1944 in Stavanger, Norway, and obtained a cand. real. degree in applied mathematics at the University of Bergen in 1968 and a PhD degree in Naval Architecture and Marine Engineering in 1971 at the University of Michigan. He was employed by DNV from 1968 to 1974, was dosent in marine technology from 1974 to 1976, and professor of Marine Hydrodynamics from 1976 at NTNU. Faltinsen is the author of the three textbooks published by Cambridge University Press. He has authored more than 500 publications in scientific journals, conferences, and books, and given about 50 keynote and honours lectures. He gave the 15th Georg Weinblum Lecture, 1992-1993. He received the Fridtjof Nansen's award for outstanding research in science and medicine in 2011. The 26th International Workshop on Water Waves and Floating Bodies held in Athens on April 17-20, 2011, was dedicated to Professor Odd M. Faltinsen. The "Professor Odd Faltinsen Honoring Symposium on Marine Hydrodynamics" was arranged at OMAE 2013, Nantes, France on June 9-14, 2013. He received the OOAE Division-ASME Lifetime Achievement Award in June 2013 and the Council of the Confederation of European Maritime Technology Societies Award in 2017. Faltinsen is elected member of the Norwegian Academy of Science and Letters, The Royal Norwegian Society of Sciences and Letters, corresponding member of Croatian Academy of Sciences and Arts, foreign member of the National Academy of Engineering, USA, and the Chinese Academy of Engineering.

Milovan Perić
Institute Of Ship Technology, Ocean Engineering And Transport Systems (ISMT), Faculty Of Engineering, University Of Duisburg-Essen, Germany

LECTURE

THE ROLE OF CFD IN SHIP DESIGN AND OPTIMIZATION

In this presentation, the growing role of Computational Fluid Dynamics (CFD) in the process of ship design and optimization will be addressed. In early stages, CFD was used to predict resistance of bare hulls, but due to rapid development of CFD techniques, it is nowadays used for more complex tasks. The major milestones in CFD development include: (i) moving grids, which allow for accounting of propeller and rudder motion relative to hull; (ii) interface-capturing methods for free surface flows, allowing to account for wave breaking, ventilation and trapped air; (iii) dynamic fluid-body interaction, allowing for a simultaneous computation of flow and flow-induced motion of floating bodies; (iv) automatic generation of computational grids made of arbitrary polyhedral control volumes, allowing handling of complex geometry without simplification, etc. In addition to advances in computational methods, physics models (in particular to account for turbulence and cavitation) and increasing computing power allowed stepping up from component analysis to simulations at system level. It is nowadays possible to account in a single simulation for interactions between water flow, wind, ship motion, propeller rotation and rudder motion relative to moving hull, cavitation on propeller blades and rudder, ventilation, wave impact etc. The use of CFD will increase further in future, with major trends including (i) improvement of computing performance by using GPUs, (ii) automatic solution-adaptive grid refinement for an optimal use of resources, (iii) automatic multi-objective optimization of geometry and process parameters, and (iv) ever advancing physics models (especially scale-resolving turbulence and cavitation models). Examples from recent simulations will be used to highlight some topics.

BIOGRAPHY

Milovan Perić studied mechanical engineering in Sarajevo and obtained PhD degree at Imperial College in London in 1985 for his work on CFD methods for complex geometries. He worked as research assistant and lecturer at the University of Erlangen from 1986 to 1991, spent one year (1992) as a visiting scholar at Stanford University, and in 1993 became professor of fluid dynamics at the Institute of Shipbuilding in Hamburg. In 1997, he founded with co-workers a private company which developed and marketed a state-of-the-art CFD-code "Comet", which had many features dedicated to naval hydrodynamics. The company and the code were sold to CD-adapco in 2002 and Milovan with most of his team left university to work on further software development. At CD-adapco Milovan held positions of the director of software development, director of technology and lastly vice president of technology. In 2014, he started an independent consulting business but continued to work mostly for CD-adapco and, after it was taken over by Siemens in 2016, for the new owner. In 2016 he was elected member of the Faculty of Engineering at the University of Duisburg-Essen (without employment), teaching applied CFD and supporting professor Bettar el Moctar at the Institute of Ship Technology, Ocean Engineering and Transport Systems. He has published with J.H. Ferziger and R.L. Street a popular book on CFD and is author or co-author of over 200 papers and chapters in edited books.

CALCULATION OF HYDRODYNAMICS FORCES ACTING ON PRISMATIC PLANING SURFACE BY CFD

Toru Katayama[1], Kohei Yamaguchi[2], Tatsuki Nanami[1], Jun Umeda[3], Shohei Ozeki[4], Masatsugu Soga[4], Toshio Watanabe[5]

[1] Osaka Metropolitan University, Graduate School of Engineering Department of Marine System Engineering, Japan
[2] Osaka Prefecture University, Graduate School of Engineering Department of Marine System Engineering, Japan
[3] National Maritime Research Institute, Japan
[4] Siemens PLM Software Computational Dynamics, K.K, Japan
[5] Suzuki Motor Corporation, Japan

Abstract. The purpose of this study is to propose an adequate procedure based on an existing commercial CFD code (STAR-CCM+) to calculate the flow field around different size prismatic planing surfaces accurately and investigate scale effects on their hydrodynamic forces. First, according to ITTC Recommended Procedure, the hydrodynamic forces acting on the prismatic planing surfaces are calculated and compared with measured results. As a result, it is found that the accuracy of calculated frictional force is poor by appearance of Numerical Ventilation. In order to obtain highly accurate calculation, the resolution of partial mesh around stagnation line are made higher and surface tension model is considered. The above-mesh generation procedure is applied for the 10 times large prismatic planing surface and the scale effects are investigated, and it is shown that calculated pressure coefficient on hull is the same regardless of model size and calculated frictional resistance coefficient is close the frictional coefficient in turbulent for equivalent flat plate.

Keywords: CFD, Prismatic planing surface, Hydrodynamic forces, Scale effect, Numerical Ventilation.

A STUDY ON THE ADDED RESISTANCE PERFORMANCE IN VARIOUS REGULAR WAVES AND IRREGULAR WAVES USING URANS SOLVER

Soon-Hyun Lee[1], Kwang-Jun Paik[1]*, Jun-Hui Cho[1], Gu-Hyeon Kim[1], Hwi-Su Kim[1]

[1] Department of Naval Architecture and Ocean Engineering, Inha University, Incheon, South Korea

Abstract. The commercial ship usually operates in irregular sea conditions, and the performance of the ship should be estimated through the simulations in a more realistic environment. So far, to estimate the added resistance, experiments and numerical studies have been conducted in regular waves. In this study, the added resistance performance of the KVLCC2 hull was evaluated in various regular and irregular waves using the URANS solver. Resistance and motion responses were compared not only for the regular waves but also for regular waves at various wave steepness and bichromatic waves that were superimposed with regular waves. Through this, the change of resistance performance and damping on motion response according to wave height was analysed. Also, it was generated that the irregular wave corresponds to the JONSWAP spectrum in various sea states, and the added resistance calculation was performed in irregular wave conditions. The added resistance was compared with the estimated value using the spectral method. Inhere, the spectral method can derive the added resistance in the target sea state using the regular wave results. This method uses a linear relationship between wave height and resistance, which is implemented by multiplying the quadratic transfer function and wave spectrum. The estimated value showed the difference from the direct calculation results, which is due to the nonlinearity of the resistance in the irregular wave. On the other hand, the motions responses showed a similar tendency to that of the regular wave, except the motion around the natural frequency. The motion responses at the natural frequency were relatively large, and it can be influenced by the wave height as observed in various wave steepness.

Keywords: CFD, URANS, KVLCC2, Added resistance, Irregular wave, Regular wave, Bichromatic wave, Wave steepness.

STUDY OF THE PROPELLER EFFECT ON THE SINKAGE OF SHIPS

Luis Perez-Rojas[1], Adrian Portillo-Juan[1]

[1] Universidad Politecnica de Madrid, Madrid, Spain

Abstract. Prior studies have shown the strong relation between the dynamic pressure field around the hull of a certain ship and the sinkage that it develops when it sails. Consequently, this phenomenon is possibly affected by the propeller due to its contribution to vertical pressure fluctuations on the stern. The main purpose of this research work is to confirm or reject the impact of the propeller on sinkage and evaluate it. A Victory cargo ship model was used to analyse the impact that the propeller may have on the sinkage of ships. Towing and self-propulsion tests were carried out to analyse how the propeller can influence the sinkage that a certain ship acquires at navigation. From the analysis done, it could be confirmed that the propeller produced a significant increase on sinkage, when the towing and the self-propulsion tests were compared. As well, the problem treated in the present research work was tackled numerically with CFD software Star-CCM+. From that analysis, the considerations made about the relation between sinkage and the dynamic pressure field fluctuations were proved, but the uncertainties of these tools at evaluating sinkage quantitatively were still a problem. Despite the mesh convergence study that was carried out based on the cell size, it was shown that mesh refinements with base cell sizes smaller than 1/5 of the model waterplane length do not improve the simulations uncertainties whilst it does increase vastly the time resources consumed.

Keywords: Sinkage, Propeller, Towing-Tank tests, Simulations, CFD.

STUDY OF WIND RESISTANCE REDUCING METHODS FOR COMMERCIAL VESSELS

Youngjae Kim[1], Doohyun Kim[1]

[1] Korea Shipbuilding and Offshore Engineering, Seongnam, Korea

Abstract. The importance of improving the aerodynamic efficiency of commercial vessels is rising as the demand for reducing greenhouse gas emissions increases. The main objective of this study is to develop a wind resistance reducing device for commercial vessels named "Hyundai Intelligent Air Resistance Saver (Hi-ARS)." Numerical simulations using Reynolds-averaged Navier-Stokes (RANS) model were employed to evaluate the wind resistance reducing effects of the device quantitatively. By performing numerical analysis, it was observed that the device intensifies the rotating flows formed in front of the rectangular structures and reduces high-pressure regions for the headwind condition. Additional thrust, generated by the pressure difference between the inside and outside of the device, was also identified. The average effect of the device was assessed by considering a sea route, which involves various wind directions and magnitudes. It is expected that the device would assist various vessels in satisfying the strengthened environmental regulations.

Keywords: Wind Resistance, LNGC, VLCC.

MODERN SHIP DESIGN

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Abstract. This paper investigates the requirements to the design of modern ships in view of the pressing needs to further improve ship safety and to limit emissions to air and water. In order to succeed, the ship's geometry must be optimized to limit the fuel needed at the estimated optimal speed for the purpose. For safety of crew and passengers as well as cargo, the ship must be stable during transit and have fully watertight compartments obtained with use of completely sealing bulkheads. Furthermore, double hull is required in case of damage to the outer hull. For the clean water requirements, ballast water handling must be installed to minimize the possibility to transfer foreign species and all waste generated must be collected and brought to shore for recycling. The emission from burning fuel has to be minimized, firstly by using light oil fuel or gas (LNG), and thereafter by switching to fuel types that do not give emission to air. In the process of selecting the cleanest possible fuel for the purpose, the safety must not be forgotten with respect to transporting the fuel onboard the ship, storing the fuel and burning the fuel. Furthermore, it should be noted that large size does not always represent the optimum design, as limitations related to ship channels and harbors must be taken into account. Although modern ships will be kept under close control from land-based stations; cyber security issues may limit the scope of autonomous ships. As the ice-cover may continue to be reduced in the Arctic during the summer months, ice strengthening, safe propulsion and improved lifeboat capabilities fit for Arctic voyages must be highlighted for Polar Class ships. Even with the best design possible, ships will be lost also in the future and the safe evacuation into safe escape means will still be an area of priority. Finally, the safety will not be better than the judgement of the captain and the crew. Training needs will increase, rather than going out of fashion.

Keywords: Vessel, Crew and passenger safety, Reduced emission, Autonomous vessels, Cyber disturbance, Selection of optimum size, Arctic transit, Search and Rescue, Training, Staff competence.

THE DESIGN KNOWLEDGE MANAGEMENT SQUARE - A FRAMEWORK FOR EARLY STAGE COMPLEX SHIP DESIGN

Joan le Poole[1], Nicole Charisi[1], Koen Droste[2], Agnieta Habben Jansen[3], Austin A. Kana[1]

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[2] DAMEN Naval, The Netherlands. Work performed during PhD research at Delft University of Technology, Netherlands
[3] Defence Materiel Organisation, The Netherlands. Work performed during PhD research at Delft University of Technology, Netherlands

Abstract. This paper presents and demonstrates a new design thinking framework for early stage complex ship design, called the Design Knowledge Management Square (DKMS) framework. The DKMS framework provides a structure that explicitly incorporates the collaborative nature of complex ship design, contrary to other models or frameworks that primarily focus on the technical integration of tools and methods to describe early stage complex ship design. The DKMS framework is applied to three case studies: 1) multi-disciplinary early stage design of complex ships, 2) the integration of concept design generation and analysis methods, and 3) the application of design rationale to support collaborative design decision-making. The case studies show that the DKMS framework provides added value by explicitly describing both the collaborative and technical nature of complex ship design. Thereby the framework helps to analyse, support, and understand complex ship design.

Keywords: Design framework, Complex ship design, Early.

INTEGRATED METHOD FOR THE ARRANGEMENT DESIGN OF A SHIP FOR IMPLEMENTING DIGITAL TWIN IN DESIGN

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Abstract. The arrangement design of the ship mainly depends on the past ship data or the experience of experts because there are various restrictions of the owner and the classification regulations. Therefore, it is difficult to select the optimal design by examining various alternatives. Accordingly, a method that can review and optimize various arrangement designs before construction is required. Digital twin technology is one of the methods by which alternatives can be considered before production by creating digital replicas of real physical entities. This study proposes a method for designing an optimal arrangement that satisfies the requirements of the ship-owner and several design rules and implements the result as a virtual twin. In the arrangement design process, locations of partitions dividing compartments and locations of equipment are set as design variables. Furthermore, as objective functions, the installation cost, the feasibility of expert knowledge, and space availability are considered. Also, the arrangement designed during the optimization process can be reviewed by the designer in advance as if the arrangement is actually manufactured through a virtual twin. The effectiveness of the method proposed in this study is verified by applying it to selecting the optimal arrangement design for an actual ship. In particular, it has a differentiated advantage from the existing arrangement design optimization method in that the designer can visually review the design first.

Keywords: Compartment arrangement design, Digital twin, Equipment arrangement, Optimal design.

SHALLOW-DRAUGHT VESSELS FOR THE VESSEL TRAIN

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Abstract. The Vessel Train is a novel semi-autonomous waterborne transport concept that implies a convoy of digitally connected vessels. Only the first vessel in the Vessel Train (the so-called "lead vessel") is fully manned, while the remaining vessels (the so-called "following vessels") are remotely controlled from the lead vessel and thus may sail either with a reduced crew or with the crew off-duty. The Vessel Train was the subject of the research project NOVIMAR (NOVel Iwt and MARitime transport concepts), funded by the European Commission within the framework of the Horizon 2020 program. One of the tasks of the project concerned the design of novel vessels for the Vessel Train. The Vessel Train ships were designed in compliance with a specific requirement: to utilize the horizontal (Ro-Ro) container handling. Additionally, two inland vessels had to fulfil another condition: to have as low design draught as possible, so as to provide for uninterrupted navigation even during the low-water periods which tend to be extended and more extreme on all major European inland waterways. Both the Ro-Ro handling of containers and the shallow draught considerably affect the ship general arrangement, cargo stowage and handling, structural strength, intact and damage stability, etc. Thus, this paper discusses the challenges encountered in design of large inland container Ro-Ro vessels with extremely shallow draughts, intended for the use in the Vessel Train.

Keywords: Vessel Train, Inland vessels, Container Ro-Ro vessels, Shallow draught, Unconventional vessels.

ON THE VALIDITY OF USING SMALL-SCALE FATIGUE DATA TO DESIGN FULL-SCALE STEEL WELDED STRUCTURES: TESTING ASSUMPTIONS ON RESIDUAL STRESS RELIEF

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Abstract. An accurate fatigue life prediction is vital for the effectiveness and safety of a ship structure. The fatigue limit state is typically governing and conservatism is included to provide for a safe design. On the other side, minimizing conservatism is favourable, for reasons of cost, stability and payload (i.e. weight). The fatigue life prediction of full-scale steel welded ship structures is based on fatigue test results of, mostly, small-scale specimens. TNO has performed strain gauge measurements on a specimen, which represents a structural detail that is common in ship structures, that challenge the widely accepted conservative assumption of lower residual stresses in small scale specimens. This research explains the measured strain increase perpendicular to the weld, when cutting small cruciform specimens from a larger plate. To do so, a thermo-mechanical coupled FE analysis is performed, using the Constant Initial Temperature model and amodelling of the restraint relief upon cutting the specimens. This has successfully demonstrated the physical basis for the measurements. These findings provide for a strong argument to assess the conservatism of the fatigue design standards case by case. The work provides for a computationally efficient framework to predict the effect of stress relief on the effective R-ratio that is applied to small-scale cruciform fillet welded specimens.

Keywords: Residual stress, Stress relief, Full-scale structures, Small-scale specimens, Fatigue of welded joints, Mean stress effect, Effective R-ratio.

BUCKLING ANALYSIS OF FPSO PANEL UNDER PITTING CORROSION

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Abstract. Pitting corrosion can be found in cargo tank of FPSO platforms operating in the hostile environment found at sea. The internal structure of cargo tanks, often uncoated, are exposed to corrosive gases, sea water and oil. The effect of this corrosion over years reduces the plate thickness and, consequently its structural strength. Pitting corrosion is one of the most dangerous forms of corrosion, because even though the total material loss is very small, the rate of corrosiveness can be very high, and it can lead to early catastrophic failures. It is an accelerated dissolution of metal that occurs because of breakage in the passive protective film of the metal surface. The present work aims to make a realistic study of corrosion by pitting, covering from the areas where they appear, to its distribution and geometric characteristics. This was made possible through extensive research in the related literature and analysis of real data pitting corrosion on an FPSO operating in Brazilian waters. Finally, a numerical model of cargo tank bottom plate was created, and different patterns and pitting corrosion intensities were applied, to investigate their structural effects through the finite element method. The results obtained show that the presence of corrosion in the panels has a detrimental effect on their resistance to buckling. A numerical methodology was proposed and implemented based on real measurement results of corrosion. The proposed methodology proved to be adequate for the analysis of the overall buckling resistance of corroded panels. This methodology can be applied to other ship panels from pitting measurements performed in loco.

Keywords: Ship panels, Pitting corrosion, Ultimate strength.

INFLUENCE OF PLATE ASPECT RATIO ON THE AXIAL LOAD EFFECT ON THE PLATE STRENGTH AGAINST LATERAL PRESSURE

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Abstract. Plate strength against lateral pressure is affected by the acting axial load, and existing classification rules take account of this effect in their scantling formulae. On the other hand, smaller aspect ratio of a plate close to a square enhances the plate strength, and this effect is appropriately reflected in the classification rules as a correction factor for the panel aspect ratio. However, these two effects, i.e., axial load effect and aspect ratio effect, have been treated separately, and their combined effect has been left unexamined. Actually, the axial load has much greater effect for transversely stiffened plate than longitudinally stiffened plate, causing irrational discontinuity when the plate aspect ratio close to 1.0 is considered. In this study, we propose a reasonable interpolation method of the axial load effect between the transversely and longitudinally stiffened plate based on the observations on the finite element analysis (FEA) results of a plate with the aspect ratio close to 1.0 under combined axial load and lateral pressure. The proposed aspect ratio effect is applied to the plate with various aspect ratios, lateral pressure and axial loads in combination with the aspect ratio correction factor without the axial load, and the results are compared with FEA results conducted based on a residual deflection criterion. As a result, it is demonstrated that the aspect ratio effects on the plate strength subjected to pressure and axial load can be covered conservatively by the proposed formulae.

Keywords: Plate, Aspect ratio, Axial load, Lateral pressure, Elastic-plastic FEA, Residual deflection, Bending moment, Classification rules.

IDENTIFICATION AND FATIGUE LIFE PREDICTION FOR CRITICAL BLADE ROOT BOLTS OF A FLOATING OFFSHORE WIND TURBINE (FOWT)

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Abstract. Identification and fatigue life prediction for critical blade root bolts of a NREL 5 MW Spar type FOWT is performed. Fatigue lives of high strength bolts are predicted by S-N curves and Palmgren-Miner's (PM) rule. A comparison between the fatigue life of each high strength bolt at different positions along the blade root circumference is conducted to identify the critical bolts that are prone to fatigue failure. It is found that the locations of critical blade root bolts that are prone to fatigue fracture are mainly distributed on both sides of the swing direction of the blade. A comparative study is further carried out to investigate the influence of different blade root joint forms, including single row T-bolt joint and improved double row T-bolt joint, on fatigue strength of the high strength bolts and the locations of the critical bolts. The results show that the joint forms have significant impact on the fatigue strength of the bolts but they may not have an evident impact on locations of the critical bolts.

Keywords: Floating offshore wind turbine (FOWT), Blade root bolt, Fatigue life prediction, Joint forms.

MON

MARE IV | 11:00 - 12:40

SEA STATES ENCOUNTERED BY SHIPS IN THE MAERSK FLEET - AN ASSESSMENT BASED ON REANALYSIS DATA (ERA5)

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Abstract. This study presents an overview of the sea states encountered by ships in the Maersk fleet. Based on vessel positions (GPS) and corresponding time stamps, sea state parameters (significant wave height, zero-upcrossing period, wave direction) have been obtained from the ERA5 database. Comparisons are made with the wave scatter diagrams (Global Wave Statistics) and significant deviations are observed in the probability density functions of *Hs* and *Tz*, likely explained because of operational effects from weather routing and seamanship. The study also includes a more direct assessment of the operational effects by comparing, for the severest wave encounters, the observed sea state with sea states in neighboring ocean areas. It appears, in line with expectations, that ships avoid the highest waves but due to the dependency on also wave period in wave-induced responses, the effect of operational decisions is not as evident in, for instance, the wave-induced vertical acceleration level, when a theoretical assessment is made.

Keywords: Sea states, ERA5, Global Wave Statistics, Effect of route optimization and seamanship.

EXTREME SEA STATE PARAMETRIZATION AND ITS CONSEQUENCES ON SHIP RESPONSES

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Abstract. Every simulation of ship behavior on waves starts with the description of the waves it encounters. This is usually specified as a wave spectrum. The most comprehensive description is a "full-spectrum", which can be given as a discrete wave energy density on the whole frequency/heading space. This discrete 2D spectrum is the direct output of modern wave hindcast models, which do not assume any parametric shape. However, such a comprehensive description is heavy and is very difficult to work with for long-term analysis. Furthermore, the number of dimensions is too high to enable any straightforward extrapolation to unobserved return periods. Thus, the full spectrum is usually parametrized, so that it can be described in a few parameters. Typically, wave spectra are described by a JONSWAP shape, with H_s, T_p, and γ parameters, together with wave spreading coefficients. Such a parametrization loses some information and thus induces an approximation on the ship response. The current work aims at answering two questions: what is the best way the parametrize the spectrum? And how does this parametrization affect the estimates of the long-term ship responses? To tackle this, full spectra from hindcast models at a few locations are used and compared with parametric spectra. It is shown that using T_p or T_{0m1} period provides much better results than using the up-crossing period T_z. Then, a dataset of ship response (RAOs) is leveraged to quantify the effect of the parametrization: long-term calculations using full spectra are compared to calculations using parametric spectra. Finally, the parametrization based on the Goda's peakedness and the spreading parameters are used to construct a map of the γ and n value over the entire globe. For extreme sea states, it shows constant values around γ=1.5 and n=3, with the caveat that values may be underestimated if the frequency resolution is not sufficient in the database considered in this work.

Keywords: Wave spectrum, Seakeeping, Long-term, Spreading, JONSWAP.

MODELLING STORM AVOIDANCE BEHAVIOUR BASED ON AIS DATA OF CONTAINER SHIPS IN THE NORTH ATLANTIC OCEAN

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Abstract. For ship safety, ship responses are predicted by encountered waves based on the position of ships in stormy conditions. Automatic Identification System (AIS) provides accurate ship position information nowadays. This study fitted a weather routing model to each segment of ship track recorded in AIS and reduced each track segment to a parameter. Many previous studies on weather routing focus prediction of the optimal route. In contrast, this study focuses on "reanalysis" of weather routing. The target sea area was the North Atlantic Ocean, where wave heights are high on average. This study also focused on container ships, which have high timeliness and are easy to model the storm avoidance behavior. The AIS data of container ships in the North Atlantic Ocean were obtained. In the AIS data, some ships avoided storms, but the others did not. Assuming ships run the shortest path, this study modeled the ship tracks in the storms using the Dijkstra method. The sea area was modeled as a graph, and the shortest path on the graph was regarded as the predicted track. The sea conditions were reflected in the graph. Eventually, the variation of the storm avoidance behavior was quantified. This study evaluated the model accuracy in comparison with the observed AIS data. The application of the model to ship response prediction was also discussed.

Keywords: AIS, Storm Avoidance, Weather Routing, Graph Theory.

DEVELOPMENT OF PRACTICAL SEA STATE NOW-CASTING SYSTEM WITH OPTICAL IMAGES USING MACHINE LEARNING

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Abstract. In this study, we developed a practical now-casting system for sea states. Without using radar or weather satellite information, the network was constructed by learning the images captured by the optical camera. The sea state for each image was derived by analyzing the signal from the wave height meter of the target region and then labeled for each image. As a machine learning technique, a convolutional neural network (CNN) was applied. After acquiring images in various time zones and learning the data, the now-casting results were confirmed. We checked the capability and availability of the trained network, then tried to expand their performance capability.

Keywords: Now-casting System, Optical images, Machine learning, Convolutional neural network, Sea state.

EFFECTS OF STEADY WAVE FORCES FOR OBLIQUE MOTION ON ESTIMATION OF MANOEUVERS OF FULL-SCALE SHIPS

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Abstract. In this study, we investigated the effects of the variation of steady wave forces generated by oblique motion on the estimation of ship manoeuvres. The investigation was based on a numerical simulation that took only the steady wave forces into account to conventional mathematical model of modular type in calm water. The simulation was conducted for a VLCC undergoing course-keeping manoeuvres in regular short waves. The results were validated by a comparison with the results of a free-running model test (FRMT) conducted by Suzuki et al. (2019), which involved various conditions of rudder effectiveness. In the simulation, the steady waves forces were given in two ways based on experimental results. In the first case (Case 1), the steady wave forces were interpolated from the values measured when the ship was at rest and moving in a straight line (without lateral drift). In the second case (Case 2), the steady wave forces were the values measured for the condition in which the ship's speed and (lateral) drift angle corresponded to the results of the FRMT. The simulation results show that the estimated drift angle and check helm of the rudder effectiveness for the full-scale ship did not exhibit good agreement with the FRMT results unless Case 2 was implemented. Nevertheless, the estimated check helm for the ship model could be reasonably estimated even for Case 1. This indicates that the variation of the steady wave forces generated by oblique motion is not negligible when estimating the manoeuvers of full-scale ships.

Keywords: Ship manoeuvring, Manoeuvrability in waves, Steady wave forces and moment, Manoeuvring simulation.

SENSITIVITY STUDY OF WAVE HEIGHT VARIATION DURING TURNING CIRCLES IN REGULAR WAVES

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Abstract. The sensitivity to variation of wave height during turning circles of a displacement type of hull, is investigated with a modular maneuvering model based on the two-time scale assumption. The wave heights in the Ocean Basin at SINTEF Ocean are documented with 480 wave probes, with 2m spacing, covering a significant part of the basin. There is a spatial variation in the wave heights, represented by two oblique wave patterns. Turning circles of the Duisburg Test Case (DTC) with 35° rudder angle are investigated for five regular waves in the range λ/L_{pp} = 0.280 – 1.20, in initial head and initial following waves. Free-running model tests are compared to numerical simulations with the modular maneuvering model. Simulations are performed using constant wave heights, and using time-varying wave heights according to the wave documentation tests. The difference between the two simulation methods is largest for the drifting distance, in particular for the longest waves. However, for some responses, there is almost no difference between the two simulation methods. Overall, this implies that the variation of wave height in a basin contributes less to the uncertainty than we originally expected.

Keywords: Maneuvering in regular waves, Free-running experiments, Wave documentation, Turning circles, Deep water.

NUMERICAL STUDY TO IMPROVE THE ESTIMATION OF MANOEUVRING FLUID FORCE FOR A CONTAINER SHIP IN DEEP AND RESTRICTED WATER

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Abstract. Safe navigation of vessels is important not only in terms of safety but also environment and economy. At the ship design stage, it is necessary to estimate whether the manoeuvrability criteria are met, and sufficient manoeuvrability is ensured. Computational fluid dynamics (CFD) is widely used in the initial design, but there are not enough examples of detailed studies on the calculation model such as whether to consider sub-parts which are equipped in tank test models. In addition to that, with the growing interest in automatic operation, the need for grasping manoeuvrability in shallow water and restricted waterways is also increasing. In this study, the influence of bilge keels, trim and sinkage are numerically evaluated for the DTC container ship, not only on deep water but also on shallow water and restricted waterways. As the result, the influence of the bilge keels is a few percent of the total lateral force, and the influence of trim and sinkage is a few percent of the total yawing moment in deep water. In shallow and restricted waters, the influence of bilge keels keeps the same ratio, but that of trim and sinkage is significantly increased. In summary, it was found that for low-speed vessels, it is not necessary to consider these factors in the calculation model in deep water areas, but it is particularly desirable to consider the running attitude in shallow or restricted water areas. This result will be useful in choosing an appropriate computational model.

Keywords: CFD, Manoeuvrability, Bilge keel, Trim, Sinkage, Shallow water, Restricted channel.

EFFECT OF HYDRODYNAMIC FORCES DUE TO DRIFT MOTION ON SHIP PERFORMANCE IN ACTUAL SEAS AT LOW SPEED

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Abstract. As the IMO GHG Reduction Strategy has been developed in 2018 and the EEXI regulation and CII ratings for ships in service have recently been adopted, a trend towards assessing the performance of ships through environmental regulations is being accelerated. In order to comply with further regulations, operations with slower speeds are inevitable, and ship performance in actual seas at lower speeds is an important consideration. In actual seas, winds and waves cause external forces acted on a ship, that is due to waves, winds, drift and rudder. At conventional design speed, forces due to winds and waves are dominant, and the contribution of forces due to drift and rudder is limited. At low speed, however, the angle of rudder is increased to balance the forces, and the contribution of rudder and drift forces to ship performance is thought to be increased. In this paper, attention is paid to the drift force, and the speed effect of drift force is investigated experimentally by conducting towing tests at a fixed angle of head. Comparison between experimental results and existing estimation models is conducted. Then, the experimental results are used to estimate the ship performance in actual seas, and the effect of hydrodynamic forces due to drift on the performance at sea at low speeds is investigated quantitatively. As a result, it is shown that the contribution of drift forces is larger than that at design speeds and the higher accuracy for the precise performance evaluation is also required.

Keywords: Ship performance in actual seas, Effect of winds and waves, Resistance due to drift, Low speed.

SYSTEMATIC DESIGN OF FUTURE MARINE POWER & ENERGY SYSTEMS

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Abstract. The design and realization of future zero emission power and energy systems on board ships is a challenging process. The resulting systems are complex, multi-disciplinary and need to be introduced in one radical step. A well-structured methodology is needed that ensures all requirements are addressed and risk are being reduced already early in the design process. This paper shows how Model Based System Engineering (MBSE) can be used to mitigate risks, keep clear traceability of user needs, functional requirements and physical realizations, and help designers to approach a design as a multi-disciplinary exercise. A 25m inland patrol vessel is taken as an example and systematically the MBSE steps are addressed touching upon the user needs, system architecture setup, logical arrangement up and the physical conceptual design of the power and energy system in the ship. The example case shows how a well-structured requirements analysis leads to specific system design choices and helps to identify support system requirements in an early stage of the design, well before basic engineering starts. This structured design approach lays the foundation for further simulation and testing (verification and validation) of the resulting systems, which will be addressed in future publications.

Keywords: System Engineering, MBSE, Zero emission, Power and energy systems, Design, Multi-disciplinary.

A FEASIBILITY STUDY OF A NEW CONCEPT OF VLFS

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Abstract. Moving structures to the open sea offers considerable relief from the overexploitation of the land and natural resources of coastal regions. Very large floating structures (VLFSs) are an environmentally sensitive technology that forms artificial land at sea. We developed a new type of VLFS: the Delta. Designed to withstand Mediterranean open sea conditions, the Delta provides a broad operational area and all-weather operability. An important feature is the formation of a sheltered basin that provides year-round accessibility. This research examines the feasibility of the Delta, focusing on hydrodynamic and structural design aspects, toward the implementation of this new concept of open sea structure. The design and structural analysis present engineering challenges due to the Delta's unique shape, extreme dimensions, and vast possible wave load scenarios that are difficult to predict. Unlike traditional marine structures to which design classification rules are applicable, the design of the Delta must rely on first principle approach and direct analysis. We established an analytical procedure for the rapid assessment of primary strength requirements. This design tool enables the fast scanning of hundreds of combinations of sea states and the identification of critical combinations. This led us to improve the geometry and reduce loads and load effects. Following shape optimization, we reanalyzed the hydrodynamic aspects. In view of the design aspects evaluated with the self-developed and commercial software, we conclude that the Delta is feasible and promising and recommend carrying out laboratory tests in a large offshore wave basin.

Keywords: VLFS, Floating structures, Hydrodynamic analysis, Structural design.

ON PREDICTION OF DRILLSHIP TRANSIT SPEED UNDER VARIOUS PROPULSION MODES AND OPTIMIZATION OF POWER DISTRIBUTION FOR BOW AND STERN THRUSTERS

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Abstract. A drillship is advantageous not only for drilling but also for transit. It is important to predict the transit speed for estimating working time. Typically, drillships have a hull form with large block coefficient and several high resistance sources such as moonpool, head boxes and huge topside. As a propulsion system, several azimuth thrusters composed of a ducted propeller and an electric motor are used. Generally, the azimuth thrusters are designed at a bollard pull condition in order to maximize the thrust at zero forward speed in station-keeping. Since the resistance and propulsion characteristics are significantly different from those of merchant ships, there are great uncertainties in predicting the transit speed and required power for drillships. In this paper, the transit performance of a Samsung 96k drillship is predicted using model tests and statistical methods, and the results are compared with sea trial data. This paper clearly shows that the good prediction of transit speed is possible even with various uncertainties from appendages and thrusters. Using the proven procedure, various scenarios are examined related to transit. First, the transit speed in case that some thrusters are damaged and are in trailing or locking mode is investigated. Next, an optimal power distribution to achieve the highest transit speed for a given power consumption is proposed.

Keywords: Drillship, Speed prediction, Moonpool, Head box, Azimuth thruster, Trailing, Locking.

FEASIBILITY STUDY ON DIFFERENT LAYOUTS OF POWER CABLE FOR FLOATING OFFSHORE SUBSTATION

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Abstract. This research discusses the survivability of floating substations with dynamic power cable under extreme environmental conditions, and the floating substation is located in the shallow water of the Hsinchu offshore area, Taiwan. By using OrcaFlex, the tension and curvature of the power cable under the extreme condition was analysed and discussed. Four kinds of power cable configurations are being investigated, this study focused on mooring force and bending moment in the power cable system. The simulated results show that when the power cable is configured on the downstream side of the floating substation, the curvature of the touchdown zone will be increased because of the power cable compression. Meanwhile, the deeper buoyancy section layout can decrease the maximum curvature. If more deformation space is provided for the power cable, it can be more easily complied with the tension and curvature constraints.

Keywords: Floating substation, Power cable, Lazy wave, Tension force, Curvature.

INFLUENCE OF LARGE SHELL OPENINGS GEOMETRY IN SHIP SUPERSTRUCTURE ON STRESS CONCENTRATION REDUCTION

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Abstract. The ship structure of modern multi-deck ships (e.g., cruise, passenger and RoPax ships, livestock carriers, RoRo ships etc.) is characterized by large openings in a superstructure shell plating. Such openings have a great influence on primary stress distribution over the ship overall depth and longitudinal ship strength. Due to a combination of shear-bending load, high stresses are concentrated around corners of large openings, which could be decreased by choosing the proper geometry of the opening. Parametric study is carried out to investigate the influence of geometry around the corners of the openings on stress concentration reduction. Thirty six (36) partial 2D models of superstructure side shell plating has been generated using a finite element method (FEM) and the structural response of the models has been analysed. The results are presented in dimensionless form by introducing a stress reduction coefficient. The stress reduction coefficient has been defined as the ratio of the stress of a geometrically improved corner (with a certain radius) and a corner without radius (right angle). Response surface of stress reduction coefficient with respect to a size of the corner radius and size of openings has been generated. The accuracy of the proposed response surface results was finally tested on a global full ship 3D FE model of large livestock carrier with a realistic set of the design load cases.

Keywords: Large side superstructure openings, Multideck ships, Stress concentrations, FEM.

DETERMINATION OF ULTIMATE STRENGTH FOR A BULK CARRIER UNDER COMBINED LOADS

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Abstract. In this paper, nonlinear finite element analyses are performed to determine the ultimate strength of a bulk carrier under vertical, horizontal and biaxial bending. The implicit ANSYS solver is applied successfully for the different load cases. A parametric finite element model is developed and the influence of different approaches for nonlinear material model, mesh size and model length on the ultimate hull girder strength is demonstrated for hogging and sagging conditions. An appropriate parameter set with respect to numerical efforts and accuracy is used to analyse the horizontal bending and combined biaxial load cases. Displacement controlled nonlinear finite element analyses are performed to ensure constant rotation ratios of the cross section in biaxial bending. Convergence is reached by using the full Newton-Raphson scheme as an incremental iterative solution approach. The results are validated against the well-established Smith method. The cross section of the bulk carrier is composed of stiffened plate panels. The stiffeners are connected by fillet welding to the plating and butt welding is used to connect the plate panels. Due to the welding process initial deflections and residual stresses are produced. For the proposed finite element model initial deflections of plating and stiffeners have been considered. Furthermore, the influence of welding residual stresses on the ultimate hull girder strength is analysed for the different load cases.

Keywords: Ultimate strength, Nonlinear finite element analysis, Smith's method, Welding residual stresses, Bending, Hull girder.

ON THE MODELING OF THE NONLINEAR DYNAMIC RESPONSE OF COMPOSITE WIND TURBINE BLADES

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Abstract. Within the energy transition towards renewable energy sources, offshore wind turbines represent a key solution and received much attention from researchers and classification societies over the last decades. However, among the different challenges engineers have to cope with is modeling the dynamic behavior of composite wind turbine blades. Those are made of multiple layers of fiber-reinforced composites and core materials, having an anisotropic behavior, leading to strong couplings between all degrees of freedom. Therefore, this research focuses on analyzing the performances of different anisotropic beam element formulations proposed in the literature and developing a fullyconsistent nonlinear 3D finite element (FE) beam model for composite blades using the co-rotational framework. Within the co-rotational approach, the nonlinear dynamic response is decomposed into the rigid body and pure deformational parts. Moreover, the internal and inertia force vectors, as well as the tangent stiffness and dynamic matrices, are defined using different element formulations and shape functions. This paper embodies the mathematical model, together with some essential insights on the numerical implementation. Finally, the newly developed nonlinear FE beam models are validated on standard tests for anisotropic beams, both static and dynamic.

Keywords: 3D anisotropic beam, Geometrically nonlinear dynamic, Corotational method, Finite rotations, Wind turbine blades.

FATIGUE ASSESSMENT OF COMPOSITES PARTS FOR MARINE RENEWABLE ENERGY CONVERTERS

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Abstract. Fibre reinforced composites are more and more used in the context of marine energy production devices. The specific properties of composites and their resistance to corrosion are of main interest for these applications. In this context, the Fibregy project aims at promoting the fibre reinforced plastics for marine energy converters. This project addresses the design and manufacturing aspects of two Renewable Energy Offshore Platforms: a tidal power turbine and a floating offshore twin-wind turbine. One of the main issues of these devices is usually the large number of cycles experienced during their service life. The characterization in fatigue of composite material is therefore necessary for technology developers. A fatigue analysis methodology is developed aiming to simulate the fatigue strength of composite parts similarly to quasi-static strength analysis. Using composite macro-mechanics, the forces applied on a laminate are converted into ply-by-ply stresses. A formulation, based on laminate failure theories, is proposed to separate the macro-mechanical ply-by-ply stresses into equivalent fibre and matrix stresses. By means of S-N curves data for uni-directional fibres and extrapolation using Goodman diagram, the quasi-static micro-mechanical stresses are used to predict the global damage of a composite structure during his service life. This methodology is developed to give fast results for design engineers and to minimize the amount of required tests.

Keywords: Composite materials, Fatigue, SN curve, Constant fatigue life diagram.

FLEET STRUCTURAL INTEGRITY THROUGH MONITORING AND DATA FUSION

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Abstract. Knowledge of the operational and loading history creates a powerful tool to aid in service lifecycle decisions for ship structures. Lifecycle structural integrity and related maintenance decisions can be improved by structural monitoring to gain information on the important uncertainties in loading and response history. Traditional hull monitoring relies on a variety and number of sensors to obtain this data. However, more efficient methods and combinations are being developed for fleet applications. In a virtual hull structure monitoring approach, AIS and hindcast wave data are combined with the numerical model of the vessel to obtain an assessment of the structural response. Compared to a fully instrumented ship, a virtual monitoring approach will be less accurate. But the technique can easily be applied to a fleet of vessels at relatively low investment cost. For that reason, virtual monitoring approaches will play an important role in the development of fleet monitoring solutions. Limited instrumentation on one or multiple vessels can help to identify the accuracy and uncertainties associated with virtual monitoring. The trade-offs between accuracy and system cost for several types of state-of-the-art structural response monitoring solutions are discussed in the context of application for a fleet of naval vessels. The discussion includes a view on data fusion including instrumented and non-instrumented vessels. The identification and classification of uncertainties in the structural response during the operational life are addressed. The accuracy and uncertainty associated with the use of hindcast data is examined. Uncertainties arising from the (nonlinear) structural response of the vessels are quantified using data from instrumented vessels. Combined, this results in data acquisition recommendations that reflect the information requirements to support fleet management decisions.

Keywords: Monitoring, Structural response, Hindcast, Data analysis.

FUNDAMENTAL INVESTIGATION ON MEASURING PROCEDURE OF SHIP MOTION AND HULL GIRDER DEFORMATION BY USING GLOBAL NAVIGATION SATELLITE SYSTEM

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Abstract. The Global Navigation Satellite System (GNSS) is the generic term for satellite positioning systems, e.g., GPS (USA), QZSS (Japan), GLONASS (Russia), Galileo (EU), and BeiDou (China). GNSS is widely used not only for military purposes but also for civil utilizations such as aerial/land/sea navigations. In the positioning system with GNSS, the position of each receiver is determined by specifying distances to each satellite based on the time information contained in radio waves from satellites. Recently, more accurate position information can be obtained with a combination of multiple satellites, and centimeter-class positioning has become possible. In this paper, the measuring procedure of ship motion and hull girder deformation by using GNSS is fundamentally investigated. The target ship is a Capesize bulk carrier, and five GNSS sensors are installed on board. In addition, one GNSS sensor is installed on land near the target ship as a reference station for the relative positioning. Positioning analyses based on measuring results by GNSS are performed using an open source program "RTKLIB" in this study. The results show that GNSS measurement on the order of centimeters is possible, and a ship's inclination of several degrees can be obtained. Furthermore, it may be possible to assess the hull girder deformation due to ballast loading and/or motion in waves. The discussion on applicability of GNSS measurement for large vessels is presented in detail.

Keywords: Global Navigation Satellite System, Measurement of Ship Motion and Hull Girder Deformation.

EVALUATION OF SHIP MOTIONS AND HULL STRUCTURAL STRENGTH FOR CONTAINER SHIPS BASED ON AIS DATA AND WAVE HINDCAST

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Abstract. With the recent improvement of communication between ship and shore, big data analysis and sensing technology, it is now becoming possible to grasp the conditions of hull structures in actual sea. The encountered wave spectrum can be derived from the wave hindcast along the ship track based on the Automatic Identification System (AIS) data. Furthermore, direct load structure analysis has been developed to improve the ship design and this analysis also makes it possible to evaluate the hull structural strength of ships in service by directly using AIS data and wave hindcast. In this study, the wave-induced motions of a container ship were estimated based on 3-D Green function method and encountered wave spectrum derived from the wave hindcast. We also estimated the longitudinal stresses of a container ship on upper deck longitudinals and lower part of longitudinal bulkheads on both port and starboard sides at fore part, midship part and aft part of the ship in the actual sea states by combining direct load structure analysis and encountered wave spectrum. In order to verify the accuracy of the estimated results, a comparison between estimated results and full-scale measurement data was conducted. Furthermore, comparison of wave spectrum settings between encountered wave spectrum derived by the wave hindcast and Pierson-Moskowitz wave spectrum was discussed in this study. It was found that ship motions and longitudinal stresses of targeted positions derived from encountered sea states based on the AIS data and wave hindcast showed a good correlation with the measurement data.

Keywords: Digital twin, Full-scale measurement, AIS data, Hindcast wave data, Container ships.

THE ANALYSIS OF THE CORROSION-INDUCED FAILURES OF THE INNER BOTTOM PLATING OF FUEL OIL TANKS

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Abstract. Corrosion causes the reduction of the original thickness of materials over time, affects the reduction of carrying capacity and longitudinal strength and causes failures that can lead to further pollution. The listed issues emerge when the plates of fuel tanks excessively decay and lose impermeability. The leakage of oil can cause the pollution of cargo, ballast tanks or the seawater. This research analyses data on the degradation of steel plates in order to determine the intensity of the corrosion on the inner bottom plating that are located between the fuel tanks and cargo holds of an aged bulk carrier. The data on the thickness of the plates for 25 years of exploitation facilitated the examination of a linear corrosion model which was expressed in mm of the wear of steel plates. The analysis of the segments of a steel plate, which was corroded and, therefore, replaced from the surface of the inner bottom plating, enabled the Energy Dispersive X-ray analysis of the samples from both sides of the plate. The obtained results indicated that the degree of the corrosion of the inner bottom plating significantly varies depending on the environment of the plate and that corrosion is more intensive on the bottom side that is in contact with fuel tanks. However, the compatibility of the linear model with the changes in chemical composition in all types of the environment is rather questionable.

Keywords: Ships corrosion, Inner bottom plates, Corrosion depth, Linear model.

MODIFIED MMG MATHEMATICAL MODEL FOR MANOEUVRING SIMULATIONS OF SHIPS DRIVEN BY AZIMUTH THRUSTERS

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Abstract. In this paper the modified MMG model for manoeuvring simulations of vessel with azimuth thrusters is presented. The azimuth thruster forces included in the equations of mathematical model were confirmed by experiments carried out on thruster model in oblique flow open water conditions. The hydrodynamic coefficients and hull-thrusters interaction coefficients were experimentally evaluated during tests with use of planar motions mechanism. The forces on rotated azimuth thruster were established by the simplified momentum equation and flow deflection coefficient taken from open water experiments on thrusters in oblique flow. The results of simulations were compared with turning manoeuvres carried out experimentally on free running model in tank and non-restricted water area (Isag lake). This approach shows a lot of promise in azimuth thrusters driven ship manoeuvring assessment at the early stage of design process.

Keywords: Simulation, Azimuth thrusters, MMG, Manoeuvring.

PREDICTION AND EVALUATION OF AN ANGLE OF HEEL DUE TO TURNING MANEUVER OF SMALL TRAINING SHIPS: COMPARISON OF DYNAMIC ANALYSIS AND STATIC DESIGN CRITERIA

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Abstract. In the contemporary International Code on Intact Stability (IS Code), the requirement limiting the angle of heel of passenger ships during turning manoeuvres is designed to prevent excessive heeling during rapid course alterations. The criterion, with the threshold set to 10 degrees heel, is evaluated at the ship design stage for all expected loading conditions. However, the contemporary static-based approach does not adequately capture operational situations requiring a sudden turn, occasionally applied as a last chance collision avoidance manoeuvre or a strong current counteraction. These sudden turns may introduce unsafe stability conditions, as evidenced by the capsizing of the Sewol ferry in 2014, resulting in a death toll of three hundred. Small training vessels are not obliged to meet the criterion. However, they are not less safety-critical than passenger ships, as they carry many people onboard, though not classified as passengers. Inspired by the Second Generation Intact Stability Criteria (SGISC) philosophy, we investigated the dynamic angle of heel during turns for small training vessels. A series of ship motion simulations are carried out to identify whether the contemporary GZ-based criterion is adequate. The simulations account for both the manoeuvrability and stability characteristics of a sample ship. An up-to-date 6DoF ship dynamics model is utilized to enable discovering any major deficiencies of the possibly oversimplified static approach. The contemporary IS Code criterion is compared to the results of simulations.

Keywords: Stability criteria evaluation, Stability during turning, Heel due to ship turn, Ship stability in operation.

COURSE-KEEPING ABILITY AND MINIMUM PROPULSION POWER ASSESSMENT IN ADVERSE WEATHER CONDITIONS USING A MANOEUVRING-SEAKEEPING UNIFIED MODEL

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Abstract. The installed power of ships can affect the manoeuvrability, especially the course-keeping ability and even navigation safety in severe sea state. IMO newly adopted the latest revised Guidelines for Determining Minimum Propulsion Power to Maintain the Manoeuvrability of Ships in Adverse Conditions in 2021. However, the guidelines have not yet specified clear requirement to ensure manoeuvrability in waves, which is one of the original intentions of proposing the guidelines. A manoeuvring-seakeeping unified model of ship motions in actual seas was developed to simulate the course-keeping manoeuvres of KVLCC2 in this work. Then, the course-keeping ability in different wave directions with different autopilot parameters, as well as a MCR limit of engine, were discussed. Following this, the level-3 comprehensive assessment of minimum propulsion power (MPP) was realized and compared with the level-1 and level-2 assessment results according to MPP Guidelines. The results indicate that the level-2 simplified assessment in the guidelines cannot fully ensure the safe manoeuvrability of ships. The level-3 assessment by time-domain method, considering the effects of complete wave drift forces and dynamic steering process, can demonstrate the course-keeping ability of ships in adverse conditions more clearly, which is in line with the essence of the MPP problem. Last but not least, the sensitivity investigation of the influence factors including minimum advance speed, maximum course deviation, range of wave direction and autopilot parameters on the MPP assessment provides some suggestions for the further development of the MPP Guidelines.

Keywords: Course-keeping ability in waves, Minimum propulsion power, Level-3 comprehensive assessment, Manoeuvrability in waves, Manoeuvring-seakeeping unified model.

MANEUVERING OF SUBMARINES AT PERISCOPE DEPTHS IN A SEAWAY

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Abstract. Successful execution of the tactically demanding surveillance submarine missions with high score operational effectiveness is crucially dependent of the maneuvering capabilities of a submarine. This is especially true in the situations when the mission(s) in question demands from the engaged submarine to execute series of the so called 'stealth' non-engagement observation maneuvers. During execution of the designated type of 'stealth' maneuvers the submarine can experience variety of the environmental loading conditions characterized by the seaway and current. Present study is dealing with the maneuvering analysis of a preselected type of submarine, namely Joubert BB2 submarine with sail design configuration operating at the periscope depth in actual seas described by Tabain's wind wave spectrum for Adriatic Sea while, the current load effects are neglected. The submarine is engaged in the preselected level type of maneuvers in the horizontal plane, namely Turning and Zig - Zag (ZZ) maneuvers. The mentioned type of maneuvers take place in deep water and at the forward speeds corresponding to the low and medium Froude numbers. The unified maneuvering and seakeeping analyses is carried out by following the two-time scale approach based on the modular maneuvering (MMG) concept having foundation on nonlinear slender-body theory. Prediction of the rudder loads is carried out by considering X configuration of the submarine rudder planes while, the submarine propulsion is achieved by considering a highly skewed type of propeller, i.e., MARIN 7371R propeller. The nonlinear viscous crossflow loads are accounted for by the crossflow principle. For determination of the submarine total resistance in calm water the generalized procedure outlined by ITTC is adopted. In particular, the focus has been given to the estimation of wave resistance component in calm and deep water according to the generalized ordinary Michell's thin ship theory without the viscosity effects and in particular case to the 3D Rankine panel method. The obtained results from the above investigated maneuvering trials related to the main maneuvering parameters of an investigated submarine are discussed from the perspective of operational effectiveness of the performed maneuvers.

Keywords: Combined seakeeping and maneuvering, Two-time scale model, Calm and Deep water.

BALANCING DESIGNER INFLUENCE WITH REWORK FOR DESIGN PATHS OF A SIMPLE POLYNOMIAL MODEL

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Abstract. Path selection is a temporal undertaking characterized by the order design activities are performed and decisions are made. It may be considered arbitrary in the grand scheme of marine design, but it can have far-reaching impacts on required rework in the maturation of an acceptable design solution. Marine design is largely human-driven in the handling of interdependent vessel characteristics between analyses, so any simulation capturing the progression and iteration of design activities must account for actual human tendencies. The following research extends a previous study exploring the likelihood of design convergence based on path selection. The new study assumes analyses cannot be executed in multiple directions nor combined, which introduces different types of rework. The updated model explores the same variables and paths as the previous study through two simulation sdiffering in experience and rework while simultaneously acknowledging the independent variables a designer has influence over with each design activity. Both simulations highlight the path benefits and flaws pertaining to convergence probability, designer influence, and requisite rework. With these new understandings, designers can begin to make more well-informed decisions on how to efficiently approach their own design problem.

Keywords: Design paths, Design activities, Requirements, Independent variables, Rework, Experience.

APPLICATION OF PROLATE SPHEROIDAL WAVE FUNCTIONS FOR ASSESSMENT AND PREDICTION OF SHIP RESPONSES

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Abstract. Prolate Spheroidal Wave Functions (PSWF) proposed by Slepian and Pollak possess several properties, a) Orthogonality, b) Band-limited, and c) Fourier invariance, amongst others. Thanks to these properties, it has been also known that every band-limited time signal and its spectra can be represented by a simple linear superposition of PSWF. In the present paper, three case studies of the application of PSWF to the prediction and assessment of ship responses making use of the above properties are presented. The first case study is concerned with extreme ship response prediction, where PSWF is utilized for ocean wave representation with a small number of stochastic variables. The computational efficiency of the extreme value predictions was demonstrated in combination with the First Order Reliability Method. The second case study is focused on deterministic time series prediction of ship motion. Herein, the autocorrelation functions of the responses are used for the prediction, where PSWF is utilized for smoothing the measured autocorrelation functions and associated power spectrum densities. By taking this means, the improvement of prediction accuracy was demonstrated. The final case is an application to time-domain sea state estimation, i.e. reconstruction of wave profiles, based on response measurements, by exploiting the Fourier invariance of PSWF to detect the phase angles of waves and responses. Use of PSWF offered accurate reconstructions of the incident wave profiles even based on relatively short-time response measurements.

Keywords: Prolate Spheroidal Wave Functions, First Order Reliability Method, Deterministic Prediction, Sea State Estimation.

AN IMPROVED APPROACH FOR ON-BOARD DISTRIBUTION SYSTEM ROBUSTNESS ESTIMATION IN EARLY-STAGE SHIP DESIGN

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Abstract. Reliability and survivability play a key role in the ship operation and ship design process of navy ships, but increasingly also of complex commercial vessels. These requirements prove relevant for different elements within the ship design scope, including the distribution system design of data, energy and fluid (water, fuel, oil, etc.). In early-stage ship design, distribution system robustness estimation is crucial in performing a substantiated trade-off between system availability and system investment costs. Van Mieghem et al. have developed a framework for computing topological network robustness; a generally applicable robustness approach using a graph representation as network system model. This framework has been applied on on-land power grids and more abstract networks such as the internet. However, due to the general nature of the framework, the applicability of the framework to on-board distribution systems is not self-evident. In this study, the required assumptions and adjustments to applythis mathematical approach to on-board distribution systems are described. Moreover, the usefulness of this method for system robustness estimation in early-stage ship design is considered and demonstrated. In conclusion, an improved robustness estimation of distribution systems makes for an overall more reliable ship; a property to be pursued for increasingly complex ships.

Keywords: On-board energy distribution systems, System robustness and vulnerability, Early-stage ship design and system design, Network Theory.

PROPELLER DESIGN PROCEDURE FOR A WIND-ASSISTED KVLCC2

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Abstract. Wind-assisted ship propulsion (WASP) has received much attention lately with research focusing on the different sail technologies, ship-hull design optimisation and weather route optimisation. However, the traditional propulsion system is still needed for wind assisted vessels and is associated with several challenges, related to the wide range of operating conditions and propeller loads due to the varying degree of wind-assistance that will occur. In this study we use an interactive design and optimisation methodology applied on propellers of wind-assisted vessels. The methodology involves handling the complete operating profile of the propeller, an optimisation method for interactive cavi-tation evaluation by the blade designer, and the use of a new objective, the total energy consumption (TEC) of the expected operation. We use a case study where the KVLCC2 tanker is retrofitted with six Flettner rotor sails, operating between two fixed destinations at constant speed. The purpose is to investigate to what extent a new propeller design can offer a significantly lower TEC when compared to the existing design. Based on the results of this study, approximately 0.9% further reduction in TEC was achieved with the WASP adapted propeller compared to the existing one.

Keywords: Marine propeller design, Wind-assisted ship propulsion, Interactive optimisation, Fixed-pitch propeller, Total energy consumption.

ACCOUNTING FOR THE NONLINEARITIES OF TANK SUPPORTS IN STRUCTURAL ASSESSMENT OF THE VESSELS EQUIPPED WITH INDEPENDENT TANKS

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Abstract. Many vessels nowadays are equipped with independent tanks either for the purpose of LNG/LPG transportation or for the use of LNG/LPG as a fuel. The particularity of the independent tanks is that they are not rigidly connected to the hull structure but are supported by an important number of dedicated supports. During the operations, and depending on the wave conditions, these supports can temporarily loose contact or the tank can slide over them. These effects have an important influence on the structural response, especially close to the contact region, and need to be accounted for consistently in the structural analysis. The problem of contact is fundamentally nonlinear and cannot be treated using a linear structural solver. Commercial software (Nastran, Abaqus...) provide a general solution to contact problems, but the computational time becomes prohibitive for practical applications of long simulations in waves. The method developed in the present work uses a set of pre-calculated linear responses and combines them in an iterative procedure in order to assess the nonlinearities of the contacts behavior. The method is validated by comparisons with the expensive Nastran simulations and it is shown that the CPU time is incomparably lower for the same accuracy. In addition the new method appears to be much more stable than the one implemented in Nastran. The efficiency of the proposed procedure is first validated on simplified cases and is finally applied to the practical case of real vessel.

Keywords: Independent tanks, Contact problem, Hydro-structure interactions.

COMPARATIVE GLOBAL STRENGTH ASSESSMENT STUDY FOR MEGA YACHTS

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Abstract: By several global strength calculations of mega yachts, it was noticed that it is difficult to generate reasonable equivalent design waves to match the typical envelopes of global bending moments as defined in classification rules. In this work a comparative study is conducted. The rules envelopes are compared with directly calculated global loads. For load generation a linear 3d Rankine source (potential theory) method with non-linear corrections is applied, while spectral methods are used for evaluation. This is done for a selected modern yacht shape and several examples simplified hull shapes. The structural capacity of the yacht is re-evaluated using the directly calculated loads. The work shows the impact of the quick changing hull shapes of the modern mega yachts on the global loads especially on the endured loads in the bow. Consequences to the design, new possibilities in the design when using of directly calculated loads are shown and discussed.

Keywords: Mega Yachts, Design, Structures, Global Loads.

APPLICATION OF MODAL STRAIN ENERGY ANALYSIS TO DAMAGE IDENTIFICATION IN MARINE STRUCTURES

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Abstract. The experimental identification of damage on plain and stiffened panels is performed using methods based on modal curvature and modal strain energy analysis. The techniques considered require setting up a reference (intact) configuration with which the damaged structure is compared. The type of damage experimentally analyzed consists of a local reduction in the thickness of the plate or a transverse cut of the stiffened plate. The calculation of the modal strain energy requires the identification of the structural modes, which are obtained with the roving hammer technique from the accelerometer data. The application of damage identification techniques to experimental data poses some difficulties in terms of numerical evaluation of modal curvatures and strain energy integrals. Thus, the refinement of the procedure considered for the identification of the damage is the necessary premise for more challenging structural health monitoring of naval structures.

Keywords: Damage identification, Modal curvature, Strain energy, Structural health monitoring.

THE HULL STRUCTURAL RESPONSE PREDICTION METHOD USING DISTORTION BASE MODE FOR VARIOUS LOADING CONDITIONS OF CONTAINER SHIP

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Abstract. Some researchers in the marine industry have developed key methods that can be utilized for digital twin technology for ship structure. Bigot et al. (2014) proposed a method to predict unmeasured stresses or hull girder loads using stresses measured at different positions based on a conversion method with orthogonal distortion mode. This method successfully predicted values under loading conditions with both hull girder loads and stress results but has a limitation in that it is valid only for a loading condition for that motion analysis and whole ship structural analysis are carried out. If the loading condition is different from the analysis case, its accuracy cannot be guaranteed since the stress and hull girder loads distortion modes are also changed. This issue becomes remarkable for a container vessel of which loading conditions are continuously changed. This paper performs a series of motion analysis to compute hull girder loads for various loading conditions of the 13300 TEU class containership Magellan and uses artificial neural network (ANN) to find out relationships between hull girder loads and stresses at locations of interest. ANN is used to predict the stresses for strain gage locations from the hull girder loads. Based on the predicted structural behaviors of the new loading condition, conversion method by the distortion base mode can be applied. The proposed method is verified for a numerical analysis data.

Keywords: Artificial neural network (ANN), Distortion base mode, Structural integrity, Digital twin technology, Structure monitoring.

EVACUATION ANALYSIS OF PASSENGER SHIPS CONSIDERING INTERMEDIATE FLOODING

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Abstract. Ship accidents worldwide continue to rise, resulting in an increasing number of casualties. For the safety of passengers on ships, the International Maritime Organization (IMO) regulates standards for evacuation analysis through SOLAS (International Convention for the Safety of Life at Sea.) Until now, the evacuation time was calculated using a simplified evacuation analysis that assumes the movement of a passenger as a flow of fluid as regulated by IMO. However, according to the revised IMO regulations in 2016, it is recommended to perform an advanced evacuation analysis method that reflects the characteristics of each passenger similar to the actual situation and calculates the passenger evacuation time through this. Therefore, a passenger behaviour model was proposed for an advanced evacuation analysis in this study. It was developed to make it easy to add, remove, and modify various characteristics of passengers by constructing a multi-channel behaviour model. The characteristics of passengers generally include individual characteristics for escaping the shortest distance to a destination and group characteristics in consideration of surrounding people. Furthermore, if the ship is damaged, it may be flooded and change attitude. Therefore, it was added as one channel in the passenger behaviour model. In this study, the effectiveness of the proposed model was evaluated by applying it to various scenarios according to the IMO regulations and examples similar to the actual accident.

Keywords: Evacuation Analysis, Passenger Ships, Intermediate Flooding, Multi-channel Behaviour Model.

GROUNDING ACCIDENT ANALYSIS USING CLASSIFIED FACTORS

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Abstract. Systematical classification of accident factors is very important for analysis and appropriate countermeasures to reduce accidents. In a former study, a checklist to analyze capsizing and sinking accidents was proposed by extracting and classifying factors from investigation reports published by the Japan Transport Safety Board (JTSB). Grounding accidents were thought to be consisted of similar factors since the three types of accidents were thought to branch from a common factor such as engine failure. The classified factors were tweaked to broaden the applicability to grounding. The aim of the study is to apply the checklist to grounding accidents and to organize countermeasures to decrease such accidents. The scope was investigation reports of grounding accidents published by the JTSB between April 2016 and March 2021. Event sequence of each accident was clarified by choosing the factors that were involved and by sorting them in chronological order. The accidents were divided into two main categories: grounding in waves or currents and grounding in calm water. The analysis clarified the factors that were highly involved. Hence applying countermeasures to such factors could prevent or mitigate accidents. The countermeasures introduced in the investigation reports and references were organized to specify the time series. It was shown that not only capsizing and sinking analysis but also grounding analysis could be facilitated by applying the unified checklist.

Keywords: Grounding, Accident Analysis, Accident Factor, Classification, Countermeasure.

AN INTEGRATED FMECA STUDY OF CRUISE SHIP PROPULSION MODULE SHAFTING SYSTEM USING INTERVAL TYPE-2 FUZZY EXPERT SYSTEM

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Abstract. With over twenty years of sea service since the first pod propulsion system was installed on board, it has revolutionized the performance of ship propulsion and maneuvering operations, ensuring ship safety, cost-effectiveness, energy efficiency, and optimized vessel performance. The primary objective of doing this accident-based failure mode, effects, and criticality analysis research for failures of the Cruise ship propulsion module shafting system is to investigate, identify and perform a quantitative risk assessment for further prevention of worst-case scenarios. This study is based on the real-ship accident case of the Cunard's 90,049 Gross tonnage cruise vessel Queen Victoria, which replaced a bearing on one of the ship's propulsion units. For accident-based FMECA studies, the expert team of engineers from the Ship's Marine engineering department and onshore Marine specialists provided their input. The experts' elicitations were based on the indices given by them on the risk assessment parameters such as severity (S), occurrence (O), and non-detection (D), further used to calculate Fuzzy risk and risk prioritization number (FRPN) values. An artificial intelligence technique such as Interval type-2 fuzzy expert system is developed by employing a rule-based fuzzy logic system for risk quantification and prioritizing based on data collected from the experts' elicitations. It is modeled and evaluated using Trapezoidal membership functions to compute the corresponding risk values and assess potential failure impacts. The risk analysis method employed in this study can be utilized in a real-world situation, and the findings can be used to considerably reduce and eliminate probable failures, improving the ship's safety and system reliability.

Keywords: Propulsion module shafting system FMECA, Maritime safety, Cruise ship accidents, Ship Pod Propulsion, Type-2 Fuzzy expert system, Marine Machinery operation, Integrated Electric Propulsion.

APPLICATION OF A RISK ANALYSIS BASED ON HISTORICAL DATA TO PREVENT CARGO IGNITION ON RO-RO, RO-PAX AND CAR-CARRIER SHIPS

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Abstract. Statistics reveal that 90% of fires in ro-pax ships are initiated in the carried cargo. Today, all cargo (except dangerous goods) is loaded without consideration to the hazards they involve in ro-ro ships, leaving room for improving the stowage process from the ignition prevention perspective. This paper describes the methodology followed to perform a risk assessment of the cargo based on historical data, mainly gathered from maritime sources of information but also from other relevant environments. The initial step consisted of a compilation of incidents caused by a fire, located in ro-ro spaces and that have been started in cargo, since it is the scope of LASH FIRE, an H2020 funded project (Grant Agreement #814975). Once completed the population of the database, next step involves an evaluation considering two main variables: the ro-ro space and the cargo type. This evaluation will calculate not only the risk that, given its placement, a specific cargo has, but also the risk considering the cargo located in the surroundings. The methodology used includes a variant of a criticality analysis, commonly used in maintenance, adapted to the frequency of occurrence and severity of the different types of origins and causes of the fire.

Keywords: Fire safety, Risk assessment, Ignition prevention, Fire hazard management.

08:30 - Onwards	REGISTRATION		
09:00 - 09:45	PLENARY LECTURE 3 - MARE I J.J. Jensen: **Extreme Value Predictions and Critical Wave Episodes for Marine Structures**		
09:45 - 10:30	PLENARY LECTURE 4 - MARE I Q. Derbanne: **Brief History of Rule Loads and Longitudinal Strength of Ships**		
10:30 - 11:00	**Coffee break**		
11:00 - 12:40	13. TECHNICAL SESSIONS **Mare II** **Seakeeping I** X.B. Chen, M.Q. Nguyen, I. Ten, C. Ouled Housseine, Y.M. Choi, L. Diebold, S. Malenica, G. De-Hauteclocque, Q. Derbanne: **New Seakeeping Computations based on Potential Flows Linearised over the Ship-Shaped Stream** A. Olmez, F. Cakici., P. Sahoo: **Validation of Strip Theory Based Frequency-Domain Ship Motion Code** D.J. Jung, S.H. Kim: **Study of Submarine Seakeeping Performance at Free Surface Condition in Regular Waves** A.K. Banik, M.R. Teja, S. Roy: **Hydrodynamic Performance of Single and Double-Row Floating Breakwaters**	14. TECHNICAL SESSIONS **Mare III** **Design IV** B. Sulkowski, A. Magistro, J. Van Houten, M.D. Collette: **Long-Term Voyage Decision Making for Crewless Platforms** S. Jung, S. Ha, J. Cha, J. Lee, S. Kang, P.A. Rahmanto: **Configuration of Small Unmanned Surface Vessel Prototype with Autonomous Navigation** N.P. Ventikos, A. Koimtzoglou, V. Podimatas, A. Rammos, E. Trifonopoulos: **Initial Design Elements for the Development of a Testbed for Safety Analysis of MASS** T. Kuroda: **Evaluation and Countermeasures for Excessive Acceleration at the Bridge Caused by the Ship Stability**	15. TECHNICAL SESSIONS **Mare IV** **Structures, Structural analysis IV** A. Tatsumi, Y. Kageyama, M. Fujikubo: **Development of Bayesian Statistical Model of Welding Initial Deflection and Ultimate Strength Assessment of Plates under In-Plane Compression** T. Miyashita, K. Mikami, M. Kobayashi, Y. Komoriyama, C. Ma, K. Toh, H. Murayama: **Deformation Estimation of Container Ship in Waves by Inverse Finite Element Method** J. Choung, D.H. Yoon: **Structural Damage Assessment of an Icebreaker due to Collision with a Small-Sized Iceberg Considering Hydrodynamic Forces** J.P. Pineau, E. Lerondel, P. De Champs, T. Looten, F. Conti, H. Le Sourne: **Ship Side Grounding Parametric Analysis based on a Super-Element Approach**
12:40 - 14:10	**Lunch**		

	16. TECHNICAL SESSIONS Mare II **Seakeeping II**	17. TECHNICAL SESSIONS Mare III **Design V**	18. TECHNICAL SESSIONS Mare IV **Systems, Process & Operations**
14:10 - 15:50	E.H. Min, H.J. Jeong, W.J. Seong, J.B. Kim, W.C. Koo: **Comparison of Wave Loads and Free Surface Displacements According to Free Surface Update Numerical Schemes** T.T.D. Nguyen, H.T. Vu, H.K. Yoon: **Study of the Effect of Ship's Principal Dimension on Seakeeping Performance of Fishing Trawler in Bering Sea** T. Petranović, I. Gledić, A. Mikulić, J. Parunov: **Frequency Independent Model Error of Closed-Form Expressions for Calculating Wave-Induced Ship Motions in Vertical Plane** M. Zu, , K. Garme, A. Rosén, N. Costa: **Specifying Seakeeping Criteria for Efficient Task Performance**	J. Heiskari, J. Romanoff, A. Laakso, J.W. Ringsberg: **Thickness Optimization of Insulating Glass unit in Cruise Ships** T.L. Mai, M. Jeon, A.K. Vo, H.K. Yoon: **Establishment of Empirical Formulae for the Hydrodynamic Derivatives of Submarine considering Design Parameters** W. Cai, X. Zhang, M. Hu, Z. Chen, X. Tan, T. Zhang: **Intelligent Layout of the Accessible Cabin of Cruise Ships** D.J. Kim, H. Ahn, D.J. Yeo: **Estimation of Calm Water Powering and Manoeuvring Performance of ONR Tumblehome based on Towing Tank Tests**	L. Huang, W. Hetharia, A. Grech La Rosa, S. Riyadi, D. Setyawan, I.K.A.P. Utama, G. Thomas: **Computational Study on the Potential Transmission of COVID-19 Virus on an Indonesian Fishing Vessel** Y. Kim, K. Lee, L. (Y.O.) Kim, Y. Han, H.B. Yeo: **A Study on the Application of Augmented Reality-Based Remote Maintenance System using MWP Database** V. Ložar, N. Hadžić, T. Opetuk, R. Keser: **Efficient Algorithms for Evaluation of the Steel Hull Process** L. Braidotti, J. Prpić-Oršić, M. Valčić: **Free-Outflow Modelling in the Linearised Progressive Flooding Simulation Methodology**
15:50 - 16:20	**Coffee break**		
	19. TECHNICAL SESSIONS Mare II **Hull form optimization**	20. TECHNICAL SESSIONS Mare III **Performance analysis**	21. TECHNICAL SESSIONS Mare IV **Construction & Design**
16:20 - 18:00	B. Kossmann, O.B. el Moctar: **Design and Optimization of a Pusher Boat Barge Unit under Shallow Water Conditions** Y. Xing-Kaeding, A. Papanikolaou, A. Kanellopoulou, G. Dafermos, G. Zaraphonitis: **Hydrodynamic Studies on a Zero Emission Battery-Driven Fast-Ferry** Y. Wei, W. Zhao, D.C. Wan: **Parallel Efficient Global Optimization Algorithm for Ship Hull Form Optimization** Z. Liu, W. Zhao, D.C. Wan: **Fitting Body Deformation Method for Global and Local Deformation of Ship**	Y. Cho, K.H. Jeon, S.B. Lee, I. Lee: **Prediction of the Ship Performance using Dynamic Model (Multi-Input / Single -Output, MISO) based on Ship Operation Data** T. Katayama, M. Kinugasa, M. Namba: **Development of Acceleration Simulation from Rest of Planing Craft with Outboard Engine by using Time History Input Data of Engine Torque** J.H. Lee, B. Kim, Y.H. Kim: **On Estimating Speed Performance of Ships in Irregular Head Seas: Comparison between Two different Schemes** H.A. Tvete, B. Guo, C. Agrell, C. Ferreira, S. Eldevik, M. Schmidt, G. Storhaug: **Uncertainty Analysis on Vessel Technical Index for Technical Ship Performance**	D.H. Chun, M.I. Roh, H.W. Lee: **A Method for Automatic Control of Cranes for Block Lifting in Shipyard** S.Y. Kang, S. Ha, J.H. Cha, P.T. Laras, J.H. Lee, H.J. Kim, D.H. Jang, K.P. Park: **Shape Recognition for Automation of Grinding Operation in the Shipyard** E. Holzerbauer, T. Modaleck, D. Pejković, I. Ćutić: **Innovative Waste Management System for Ships** H.J. Kang, K.K. Lee, D. Lee, Y.S. Kim: **Real Ship Implementation of Buoyancy Support System for Damaged Ships**
18:10 - 18:20	GROUP PHOTO		
18:30 - 20:00	STANDING COMMITTEE MEETING		

Jørgen Juncher Jensen
Department Of Mechanical Engineering, Fluid Mechanics, Coastal And Maritime Engineering, Technical University Of Denmark (DTU), Lyngby, Denmark

LECTURE

EXTREME VALUE PREDICTIONS AND CRITICAL WAVE EPISODES FOR MARINE STRUCTURES

A discussion of useful stochastic procedures for stochastic wave load problems is given, covering the range from slightly linear to strongly non-linear (bifurcation) problems. The methods are: Hermite transformation, Critical wave episodes and the First Order Reliability Method (FORM). The procedures will be illustrated by results for e.g. wave bending moment in ships, intact stability assessment of ships and overturning of a jack-up rig.

BIOGRAPHY

Jørgen Juncher Jensen is Professor Emeritus in Maritime Engineering at the Department of Mechanical Engineering, working with wave induced stochastic load and response processes for marine structures. He was born in Copenhagen, Denmark in 1947, where he obtained MSc and PhD degree in Mechanical Engineering in 1972 and 1975, respectively. Professor Jensen worked at DTU from 1974 to 2017 and during his career he published number of papers and received number of awards, as for instance: Direktør P. Gorm-Pedersens Prize in 1977, Bronze Medal from Royal Society of Naval Architects in 1980, Alexander Foss Gold Medal in 1993, Statoil Prize in 1995, Dr. techn. Mechanical Engineering in 1995, SNAME Davidson Medal in 2014, Thirty-seventh Georg P. Weinblum Memorial Lecturer in 2014, Peachman Lecturer in 2018, etc. His focus is on hydro-elastic responses and much of the research is done within the theory of conditional stochastic processes.

Quentin Derbanne
Bureau Veritas Marine & Offshore, Research Department, Saint-Herblain, France

LECTURE

BRIEF HISTORY OF RULE LOADS AND LONGITUDINAL STRENGTH OF SHIPS

Class Society rules have always played a major role in ship design. However, it is often difficult to understand how and why these rules were made. In the old days, the rules were only based on empirical formulations giving the required scantling of plates and stiffeners, depending on the ship size. Today we have moved from an empirical approach to a more physical and statistical approach, based on first principles: the rules are now based on load formulations representative of 25 years of navigation in North Atlantic, and several structural limit state criteria (yielding, buckling, fatigue...). But some formulations, such as the minimum section modulus, the minimum inertia, the material factor or the wave vertical bending moment, have been developed more than 50 years ago, at a time where the direct approach was not feasible. I will bring you to a journey, from 1930 to 2022, describing how these rules formulations were made, trying to understand their technical background, looking at the most recent developments, and trying to see how we could update some of them.

BIOGRAPHY

Quentin Derbanne is graduated from Ecole Polytechnique (2000) and has a Naval Architecture degree (2002). He joined the French Defense Ministry in 2002, working as a seakeeping expert in the French Navy Hydrodynamic Laboratory. In 2009 he joined Bureau Veritas in the Hydro-Structure section of the Research Department. Since 2014 he is Director of the Research Department, and Scientific Director since 2019. His research activities cover both theoretical and practical aspects of ship and offshore hydrodynamics (potential flow, first and second order, CFD...), hydro-structure interactions (quasi static and hydroelastic coupling, local and global), structural integrity (fatigue, yielding, buckling...), design methodologies (sea state statistics, definition of design conditions, response based design, design waves, reliability analysis...) and rule development. His main goal is to try to close the gap between the rule approach, based on prescriptive and empirical formulae, and the direct computation approach, based on first principles.

NEW SEAKEEPING COMPUTATIONS BASED ON POTENTIAL FLOWS LINEARISED OVER THE SHIP-SHAPED STREAM

Xiaobo Chen[1], Minh Quan Nguyen[1], Igor Ten[1], Charaf Ouled Housseine[1], Young-Myung Choi[2], Louis Diebold[1], Sime Malenica[1], Guillaume De-Hauteclocque[1], Quentin Derbanne[1]

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Abstract. We present our new seakeeping model HydroStar-V and numerical results including added mass and damping coefficients, wave excitation loads and induced motions. Within the theoretical framework, the ship-shaped stream (often called double-body flow) is chosen as the base flow over which is superposed the perturbation flow composed of a wavy steady flow and an unsteady flow. The boundary conditions on the free surface satisfied by the steady and unsteady potentials are then formulated. A set of boundary integral equations (BIE) is established by applying the Green theorem. The resultant BIE includes the classical integral on the ship hull, a localized free-surface integral in the vicinity of ship and extra integral equations imposed over the waterplane inside the ship hull to guarantee that the whole system is well-conditioned to yield stable and convergent solutions. The Green function associated with a pulsating and translating source is reformulated by considering the viscous effect so that the singular and highly-oscillatory behaviours disappear naturally. The integration of Green's function over flat panels is evaluated accurately by making use of analytical formulations. Furthermore, a new and consistent decomposition of radiation forces is developed by taking into account the speed-effect stiffness due to the steady flow. Together with recent enhancements including the treatment of both lower-order (flat panels) and higher-order meshes (quadratic curved patches), this solution method for ship seakeeping with forward speed has been shown to be reliable and practical in the application for ship design.

Keywords: Forward speed, Seakeeping, Green function, Extended BIE.

VALIDATION OF STRIP THEORY BASED FREQUENCY-DOMAIN SHIP MOTION CODE

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Abstract. An attempt has been made to validate the frequency-domain seakeeping code presented in this paper. Two-dimensional hydrodynamic added mass and damping coefficients are calculated by using Ursell and Tasai's multipole expansion theory and conformal mapping. Lewis conformal mapping technique is used to obtain the hydrodynamic coefficients. Excitation terms for pitch and heave motions are computed by using head seas approximation. A user-friendly code interface is designed for presenting frequency-domain computations. Response Amplitude Operators for the motions of AMECRC hulls are plotted at different advance speeds and in head waves. The results are compared with those obtained by experiments and a good agreement is observed. The entire process has been conducted using MATLAB code.

Keywords: Motion Simulation, Frequency Domain, MATLAB.

STUDY OF SUBMARINE SEAKEEPING PERFORMANCE AT FREE SURFACE CONDITION IN REGULAR WAVES

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[2] Department of Naval Architecture & Ocean Engineering, Inha University, Incheon, Korea

Abstract. Submarines spend most of their time below the water surface, so the design is optimized for submerged condition. However, a performance in free surface condition is also important because submarines face various scenarios and the free surface condition is unavoidable for port departure and arrival. Generally, a potential flow theory is used for seakeeping analysis of a surface ship, and it is known for excellent numerical accuracy. In case of a submarine, the accuracy of potential flow theory is high at underwater, but it is low at free surface condition because of the non-linearity near the free surface area. In this study, seakeeping performance of Canadian Victoria Class submarine in regular waves was investigated to improve the numerical accuracy at free surface condition by using Computational Fluid Dynamics (CFD) and the results were compared to those of the model tests. In addition, Hydrostar, the potential theory software developed by Bureau Veritas is also used for seakeeping performance to compare with CFD results. From the calculation results, it is found that the seakeeping analysis by using CFD give good results compared with those of potential theory. In conclusion, the seakeeping analysis based on the CFD can be good solution for estimating the seakeeping performance of submarines at free surface condition.

Keywords: Submarine, CFD, Potential flow theory, Seakeeping performance, Regular waves.

HYDRODYNAMIC PERFORMANCE OF SINGLE AND DOUBLE-ROW FLOATING BREAKWATERS

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Abstract. Breakwaters (or Wave attenuators) are the structures that protect the coastal line from erosion, protect the marine structures, and provide ideal harbourage conditions against strong water waves. Despite high protecting performances, bottom-founded fixed breakwaters are obsolete now due to their disadvantages like un-economical constructions, blocked water circulation, etc. Floating breakwaters (FBW) which attenuate incident wave energy either by reflection, dissipation, transmission, or any combination are common in use due to their low profile, least effect from tidal variations, and ability to rearrange and re-usage. Up to now, a number of floating breakwaters with novel configurations have been proposed based on better performances and/or high-cost effectiveness. The objective of this paper is to study the hydrodynamic performances of pontoon-shaped, pontoon with top wing-shaped and plus-shaped floating breakwaters in terms of performance parameters that are: a) Wave transmission coefficient (C_t), b) Response amplitude operators (RAO), and c) Mooring tensions. For determining the hydrodynamic performances, FEM-based ANSYS AQWA software is employed, and its hydrodynamic diffraction and hydrodynamic response plug-in results are utilized. For validation, the double-row rectangular-shaped floating breakwater is selected from the work of Rajabi and Ghassemi (2021), and associated hydrodynamic performances were calculated, and compared with the considered data. Results showed there is good agreement between considered and calculated results. Then, the Hydrodynamic performances of pontoon-shaped, pontoon with top wing-shaped and plus-shaped floating breakwaters in a single row and double rows under varied irregular waves are presented and compared. The results showed that the plus-shaped floating breakwater has preferable performance in reducing wave transmission, RAO response, and mooring tension.

Keywords: Floating Breakwater, Wave transmission coefficient, RAO, Mooring tensions, Ansys, Plus-shaped FBW.

LONG-TERM VOYAGE DECISION MAKING FOR CREWLESS PLATFORMS

Brendan Sulkowski[1], Adam Magistro[1], Joseph Van Houten[1], Matthew Collette[1]

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Abstract. The desire to operate crewless platforms for months autonomously requires platforms thatcan sense their current state, maintain themselves, and perform long-term mission planning tasks to optimize their effectiveness as they degrade. How these long-term tasks are currently organized, executed, and regulated on human-crewed vessels is unexplored compared to more immediate navigation and hazard avoidance. This paper presents a series of inter-related explorations of the issues of longerterm mission planning in a fully autonomous framework. Based on the current state-of-the-art, a new three-component ranking scale for crewless platforms is proposed. Semi-structured interviews with retired military crews and commercial mariners were used to identify what planning tasks crews were currently carrying out. At the end of the interview process, themes from all interviews were reviewed, and an affinity diagram was created from the themes. The interviews revealed a surprising diversity in approaches, especially for tasks beyond machinery health assessment. Complementing this bottom-upanalysis, a top-down analysis via a modified STAMP/STPA framework identifies critical information paths and control structures surrounding these tasks. By integrating the results of these two complementary analyses, gaps in our current ability to achieve long-term autonomous operations are identified. Three proposed demonstration cases are developed to help develop approaches to fill these gaps.

Keywords: Autonomy, Planning, STPA, Interview, Long duration.

CONFIGURATION OF SMALL UNMANNED SURFACE VESSEL PROTOTYPE WITH AUTONOMOUS NAVIGATION

Sunjong Jung[1], Sol Ha[2], Juhwan Cha[2], Jihwan Lee[2], Seyoung Kang[2], Putra Adrian Rahmanto[2]

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Abstract. This study proposes a prototype of small unmanned surface vessel so that it that can easily make a hull at low price and practice autonomous navigation, monitoring and surveillance system. The hull was designed in 3D model and then medium-density fiberboards (MDFs) and Balsa wood sheets were manufactured using a laser cutter. The hardware mounted on the vessel consists of single-board computer (SBC), various sensors including LiDAR, network devices, and batteries connected each other. The software used was robot operating system (ROS) installed in Linux-based operating system as middleware, and it provides autonomous navigation functions and sends information to be monitored to a remote server. This study tested the proposed prototype for surrounding recognition, autonomous navigation and obstacle avoidance in a small water tank.

Keywords: Small craft vessel, Autonomous navigation, Robot operation system.

INITIAL DESIGN ELEMENTS FOR THE DEVELOPMENT OF A TESTBED FOR SAFETY ANALYSIS OF MASS

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[1] Maritime Risk Group, Laboratory for Maritime Transport, School of Naval Architecture & Marine Engineering, National Technical University of Athens, Greece

Abstract. The safety analysis of Marine Autonomous Surface Ships (MASS) is an issue that has been attracting the attention of researchers, especially over the last years. Due to MASS introduction and imminent application various studies are trying to analyse their safety issues to conclude that MASS can be considered safer than conventional ships. This paper presents the concept of our "NAUSICAA" initiative and aims at developing a testbed which will be utilised to study MASS safety issues, e.g., autonomous collision avoidance algorithms, autonomous navigation, controllability issues, etc. Furthermore, the paper focuses on the analysis of initial design elements and the construction of a small model which will be a part of the testbed under development. The design elements presented on this paper consist of the methodology followed for the selection of the real scale vessel, i.e., identifying the criteria to properly select the appropriate vessel (i.e., ship type, ship particulars, etc.) as well as the process for the construction of the model. In particular, the model was built based on a double ended open type Ro-Ro ferry, it was made of composite material, containing 3 layers of hand lay-up polyester resin reinforced by glass fibres, and was built by adopting the one-off sandwich core technique. The paper concludes by presenting the future research that is to be conducted and the next steps that are scheduled for the successful development of the testbed.

Keywords: MASS, Autonomous systems, Sea testbed, Mobile lab, Composite boatbuilding.

EVALUATION AND COUNTERMEASURES FOR EXCESSIVE ACCELERATION AT THE BRIDGE CAUSED BY THE SHIP STABILITY

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Abstract. Excessive acceleration failure mode is among of the five stability failure modes in the interim guidelines for second generation intact stability criteria approved by the International Maritime Organization. It has been pointed out that many of the existing ships cannot meet the criterion of the excessive acceleration failure mode, with the interim guidelines indicating that they may require further refinements. Thus, this study first evaluated the validity of the assessment method for the excessive acceleration failure mode. The assessed results of the excessive acceleration failure mode for 37 existing ships indicated that only 30% of the vessels passed under both full and ballast conditions. Subsequently, a model test using a sample ship similar to the accident ship caused by excessive acceleration was conducted under the conditions when the accident occurred. The results indicated that the maximum expected value of the lateral acceleration within 2 h was less than the level 2 threshold of 9.81 m/s^2. In addition, the environmental data used in the criteria were replaced, the sample ship was assessed, and the influence of the environmental data on the assessed results was determined. In addition, countermeasures for excessive acceleration were proposed. An operational support system was developed to provide the ship operators with unacceptable sailing conditions in a graphical form. Furthermore, harnesses, handrails, and rope banisters were illustrated and proposed as safety devices for ships with wide and narrow bridges, tackling excessive acceleration at bridges.

Keywords: Excessive acceleration, Second generation intact stability criteria.

DEVELOPMENT OF BAYESIAN STATISTICAL MODEL OF WELDING INITIAL DEFLECTION AND ULTIMATE STRENGTH ASSESSMENT OF PLATES UNDER IN-PLANE COMPRESSION

Akira Tatsumi[1], Yuji Kageyama[1], Masahiko Fujikubo[1]

[1] Osaka University, Graduate School of Engineering, Osaka, Japan

Abstract. Welding initial imperfection is one of the important uncertainty factors in ultimate strength assessment of ship structures. Especially, welding initial deflection has a significant influence on the buckling/ultimate strength of stiffened panels. The initial deflection has been measured in real ship structures in order to understand its characteristics and reduce the uncertainty in the strength assessment. These investigations show that so-called hungry-horse initial deflection is generated in a plate between longitudinal stiffeners attached by fillet welding. The hungry-horse initial deflection is usually represented by superposition of sinusoidal waves. The purpose of this study is to quantitatively evaluate the uncertainty of plate ultimate strength under in-plane compression due to the welding initial deflection. For this purpose, a statistical model of the initial deflection of plate is developed. Bayesian statistical modelling is adopted since it can give estimations and predictions considering the uncertainty accompanied by insufficient number of measured data. A simple linear regression model of the initial deflection is proposed, where response variables are the amplitudes of the hungry-horse initial deflection measured in past studies. Probabilistic distributions of the ultimate strength of rectangular plates are calculated by Monte Carlo method. Samples of the initial deflection are generated from the developed statistical model and applied to the simply supported plates. The ultimate strength of the plates with the statistical initial deflection is analysed by FEM. The obtained distribution of the ultimate strength is discussed while considering collapse behaviours of the plates.

Keywords: Ultimate strength, Welding initial imperfection, Uncertainty, Bayesian Statistics, FEM.

DEFORMATION ESTIMATION OF CONTAINER SHIP INWAVES BY INVERSE FINITE ELEMENT METHOD

Tomoya Miyashita[1], Kohei Mikami[1], Makito Kobayashi[1], Yusuke Komoriyama[2], Chong Ma[2], Kimihiro Toh[3], Hideaki Murayama[1]

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Abstract. The inverse finite element method (iFEM) is a model-based algorithm for estimating structural displacements and stresses in real-time based on strain information on structures. iFEM has recently attracted attention in the field of structural health monitoring as a fast and robust estimation method for shape sensing. In this study, we reconstruct displacements in real time for an overall model of a complex structure using iFEM, and investigated the applicability of iFEM. The structure studied is a 6,600 TEU container ship under head or oblique waves, and the full ship model is made by the National Maritime Research Institute (NMRI) of Japan . Firstly, the wave loads are computed based on the hydrodynamic calculation by using the Direct Load and Structural Analysis (DLSA) developed by NMRI. Secondly, the calculated loads are applied to the finite element (FE) model of the container ship in the forward analysis using a general-purpose FE code, and the strains used in iFEM are obtained. Finally, the inverse analysis by iFEM is conducted to estimate the displacements. In comparison with results between iFEM and FEM, it is confirmed that the various deformation modes can be accurately reconstructed by iFEM. In addition, the applicability of iFEM to real-time monitoring is investigated by reducing the computing time. The calculation speed is improved by eliminating the time required for each calculation through efficient pre-calculations and by making matrix calculations in parallel with CPU and GPU.

Keywords: Shape sensing, Structural health monitoring, Inverse finite elementmethod, Container ship.

STRUCTURAL DAMAGE ASSESSMENT OF AN ICEBREAKER DUE TO COLLISION WITH A SMALL-SIZED ICEBERG CONSIDERING HYDRODYNAMIC FORCES

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Abstract. To ensure successive sea-going ice-prone areas, it is of importance not only to predict ice impact induced-ship motions but also to minimize structural damages of icebreakers under impact loads due to iceberg collisions. This paper aims to more quantitively evaluate collision-induced ship motions and structural damages of the Korean research icebreaker ARAON based on fully coupled fluid-structure interaction technique. Hydrodynamic constants of hydrostatic stiffnesses, added masses, radiation damping coefficients, and wave excitation forces obtained from the frequency response analysis were used for input of the HydroQus that is a user-subroutine code to realize fluid-structure interactions using a commercial finite element code Abaqus. The HydroQus generated the real-time hydrostatic and hydrodynamic loads acting on the icebreaker, while the Abaqus solves equation of motion. Seven collision cases were set according to material stiffnesses (rigid or elastic-plastic) and hydro-forces (with/without hydrostatic restoring, radiation, and wave excitation). A spherical shape iceberg with the half mass of the icebreaker was assumed. There were significant differences of the motion components due to the collision between the icebreaker and iceberg, while minor differences in the structural damages in terms of residual stresses and plastic strains were observed. It can be concluded that a more realistic structural damage assessment will be possible after consideration of various shapes of collision objects.

Keywords: Restoring stiffness, Radiation, Wave excitation, Ship collision, Iceberg, Icebreaker, Structural damage.

SHIP SIDE GROUNDING PARAMETRIC ANALYSIS BASED ON A SUPER-ELEMENT APPROACH

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Abstract. In this paper, we present a ship grounding simulation tool which couples a fast super-element solver based on analytical formulations with a ship external dynamics program that accounts for the action of hydrodynamic forces. The study is focused on the damage of a cruise ship subjected to side grounding events. The solver is first verified by confrontation to finite element simulations considering different hard grounding scenarios. Second, the rapidity of the tool is advantageously used to simulate hundreds of scenarios, varying the rock shape, impact location, friction coefficient between rock and hull as well as material and structural properties. The influence of each parameter on damage extent is thus discussed. It transpires from the analysis that although the side shell plating is less thick than bottom and double bottom, resulting breach length is surprisingly lower in side grounding than in bottom grounding, the impact energy being the same. This is due to the sway and yaw motions of the ship which is pushed away by the rock during the impact. Moreover, transverse frames and bulkheads are shown to dissipate much less energy compared to side shell and decks. Finally, it is demonstrated that a structural reinforcement will always be more efficient in bottom grounding than in side grounding.

Keywords: Ship grounding, Simplified method, Super-element, Plastic analysis, Finite element, Ship crashworthiness.

COMPARISON OF WAVE LOADS AND FREE SURFACE DISPLACEMENTS ACCORDING TO FREE SURFACE UPDATE NUMERICAL SCHEMES

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Abstract. In this study, wave force calculation for a surface piercing floating body and free surface displacements generated by a submerged moving cylindrical body were analysed according to the free surface boundary update scheme in the process of time integration for numerical simulation. A two-dimensional Numerical Wave Tank (NWT) and Numerical Towing Tank (NTT) using the boundary element method based on potential flow were used. To represent nonlinear water particle behaviour, the MEL (Mixed Eulerian-Lagrangian) method was used, which updates the nodes of the free surface boundary at every time step. The MEL technique can be classified into a semi-Lagrangian approach and a full-Lagrangian approach (material node approach) according to the movement of free surface nodes. The Runge-Kutta 4th-order time integration scheme was used to calculate time histories of free surface elevations during the time marching. The time integration is also divided into the frozen coefficient scheme and the full update scheme according to the boundary (geometry) update in the internal sub-time steps. First, the frequency component of wave load of a surface piercing body was analysed from the 1st-order to the 3rd-order vertical forces. The results of the full update scheme showed better convergence for higher-order vertical forces. Second, an experiment was performed in a two-dimensional mini towing tank, and the measured free surface displacements were compared with the numerical results. The depression wave elevation near the submerged body was similar, but a difference in free surface elevations after the body passed the measurement point was found.

Keywords: Numerical Wave Tank, Numerical Towing Tank, Mixed Eulerian-Lagrangian Method, Full Update Scheme, Frozen Coefficient Scheme, Surface Piecing Body, Submerged Body.

STUDY OF THE EFFECT OF SHIP'S PRINCIPAL DIMENSION ON SEAKEEPING PERFORMANCE OF FISHING TRAWLER IN BERING SEA

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Abstract. Seakeeping performance is affected not only by the loading condition of a ship but also by its principal dimensions. Therefore, already at the stage of the design process, the ship should be checked and tested to reach the best seakeeping performance. This study aims to investigate the effect of the principal dimension of a vessel on the ship's motion in the Bering Sea. A fishing trawler is chosen as a research object to calculate the ship motion. Firstly, the sea condition in the Bering Sea is investigated based on the measured data from buoys in the Southeast of the Bering Sea given by the National Oceanic and Atmospheric Administration. Secondly, the ratios of the ship length to ship breadth and ship breadth to ship draft are changed by 10% to investigate the effect of the dimension on the ship's motion responses. The ship motion of the fishing trawler is estimated using a numerical method. The RMS value of roll and pitch is compared to the criteria of the fishing vessel suggested by other researchers. Finally, the sensitivity of ship motions due to the effect of ship dimension is analyzed. The results of the present study can be used to predict and provide knowledge about the seakeeping performance of fishing vessels to ensure its safety in the design phase, especially when the fishing vessel operates in the Bering Sea.

Keywords: Fishing Trawler, Seakeeping performance, Ship motion, Principal dimension, Design phase.

FREQUENCY INDEPENDENT MODEL ERROR OF CLOSED-FORM EXPRESSIONS FOR CALCULATING WAVE-INDUCED SHIP MOTIONS IN VERTICAL PLANE

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Abstract. Closed-form expressions (CFE) enable rapid computation of amplitudes of transfer functions of ship motion and global loads, based only on main ship particulars. As preliminary comparisons indicated reasonable agreement of CFE with experimental results, CFE have been used in many conceptual studies where fast computation of ship motions and loads is crucial. Since there is still an open question of the model error introduced by using CFE instead of more complex seakeeping tools, the aim of the present study is to quantify frequency independent model error (FIME) of CFE for ship motion in vertical plane. FIME is determined by comparing transfer functions calculated by CFE with model-scale experiments. Measured transfer functions of heave and pitch for eleven ships of different types and sizes are taken from the literature, where several speeds and heading angles are available for some of them. Multivariate linear regression analysis is performed to show dependence of FIME on the main parameters of the analysis. Outcomes of this study could enhance practical applicability of CFE.

Keywords: Closed-form expressions, Frequency independent model error, Seakeeping.

SPECIFYING SEAKEEPING CRITERIA FOR EFFICIENT TASK PERFORMANCE

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Abstract. Determining the operability of a vessel is a critical task for the naval architect since it provides valuable information for vessel owners and operators on the vessel's performance. This task requires a seakeeping analysis and a set of seakeeping criteria to evaluate predicted vessel motions. These seakeeping criteria link the performance and safety of the crew and vessel to the operability. Existing seakeeping criteria (e.g., NORDFORSK, NATO STAGNAG 4154) are specified for certain vessel types and not applicable to different tasks and operational activities aboard work vessels such as pilot boats, ocean research vessels, dredgers, pipe laying crane vessels. Being relatively small in size, these work vessels are susceptible to the perils of waves, yielding motion responses that can degrade crew performance. This paper proposes a framework for specifying seakeeping criteria for efficient task performance, focusing primarily on the effects of motions on the crew and system performance. Findings from preliminary interviews with crew at the Swedish Maritime Administration and the Swedish Sea Rescue Society align with the literature on the effects of motions on crew performance, including motion-induced interruptions, motion-induced fatigue, motion sickness, and effects on motor skills and perception. These findings from the interviews are used in a case study to demonstrate the approach of the proposed framework. The proposed framework refines further and adds to the established structure of the traditional seakeeping assessment since it captures, in addition, the effect of motions on crew performance.

Keywords: Work vessels, Seakeeping criteria, Operability, Human factors, Motion-induced interruptions (MII), Motion-induced fatigue (MIF), Motion sickness incidence (MIF).

THICKNESS OPTIMIZATION OF INSULATING GLASS UNIT IN CRUISE SHIPS

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Abstract. Modern cruise ships employ more and more windows and glass structures, especially on the top decks. However, lightweight solutions are desirable as the cruise ships are weight and stability sensitive vessels. The design of the windows according to the classification rules is common for all type of passenger vessels and is based on linear plate theory for monolithic glass panes. However, the windows separating the indoor and the outdoor spaces are insulating glass unit-type (IGU) windows that consist of at least two glass panes separated by a hermetically sealed cavity. These IGUs exhibit two effects that the rules do not currently consider: 1) geometric nonlinearity of the glass panes and 2) load sharing between them. The authors recently included these effects in a nonlinear Finite Element analysis and showed their beneficial influence on the generated stress state of a rectangular IGU under static uniform pressure. There, only maximum principal stress design constraint was considered. However, there are other design constraints (e.g., deflection limit) that arise for fulfilling the IGUs intended function. Therefore, the nonlinear FE model and the design constraints are implemented in a Particle Swarm Optimization (PSO) routine to calculate the optimized thicknesses of the glass panes for different sized IGUs. Thus, this study aims to present how the different designs constraints affect the IGUs response and what are their implications on the reflected classification rules. The results indicate that the thickness determination is sensitive to the chosen constraints. Choosing the constraints is not a trivial task and requires further experimental work.

Keywords: Classification, Cruise ship, Insulating glass unit, Load sharing, Nonlinear Finite Element Analysis, Particle swarm optimization.

ESTABLISHMENT OF EMPIRICAL FORMULAE FOR THE HYDRODYNAMIC DERIVATIVES OF SUBMARINE CONSIDERING DESIGN PARAMETERS

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Abstract. Maneuverability plays a vital key in the safety of navigation and operation efficiency. Therefore, when evaluating the dynamic characteristics of a submarine, such as stability and maneuvrability, it is necessary to accurately predict the hydrodynamic derivatives. This paper proposes new empirical formulae for the hydrodynamic derivatives of a submarine based on multiple regression analysis. The estimation formulae are obtained by simulating the hydrodynamic forces and moments using Computational Fluid Dynamics (CFD). The BB2 generic submarine, which has a similar profile to the future submarine introduced by Joubert (2004, 2006), is selected to establish the empirical formulae to design a similar submarine. The design parameters of the BB2 submarine, such as the length-to-diameter ratio, sailplane position, and sailplane height, are changed to adapt to different kinds of submarines for various purposes. Then, the variation of hydrodynamic derivatives with changing design parameters is given. Additionally, the influence of design parameters on hydrodynamic derivatives is evaluated by correlation analysis, since it can be used to determine the regression model with the dependent variables being the design parameters for each hydrodynamic derivative formula. The effectiveness of the empirical formulae is confirmed by applying the empirical formulae to the submarines of BB2 and 2,000 ton. The high accuracy indicates that the empirical formulae can be used to predict the hydrodynamic derivatives of the submarines with a profile similar to the BB2 and 2,000 ton submarines, and extended to general submarines at the design stage.

Keywords: Empirical formula, Hydrodynamic derivative, BB2 Submarine, Computational Fluid Dynamics, Design parameters.

INTELLIGENT LAYOUT OF THE ACCESSIBLE CABIN OF CRUISE SHIPS

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Abstract. The accessible design is usually one of the critical elements of the rating and competitiveness of cruise ships, the cabin layout design needs to consider the daily living activity of passengers, especially for the group with mobility limitations. In order to improve the accessible environment of cabins in the cruise ship, this paper attempts to propose an intelligent layout design method combining accessible elements. In this paper, accessibility elements of the cruise ship are classified according to the special needs of the passengers. Then the accessible cabin configuration modules (ACCM) are established based on the accessibility elements and function of furniture, which are used as the basic unit. Furthermore, a cabin layout optimization mathematical model is constructed on the Energy Method. The ACCMs are assigned the corresponding energy value according to the position in the cabin based on the design principles of accessible cabins and the layout suitability. Finally, the genetic algorithm is used to search the layout scheme with the maximum energy value to achieve the intelligent layout optimization process. The experimental results show that the optimal layout scheme obtained by this method meets the requirements of accessible design and the design principle of cruise ships cabin. In addition, the proposed method is practical in the actual design, and could also improve the efficiency of cabin design.

Keywords: Cruise ship, Accessible design, Cabin layout, Ergonomics, Genetic algorithm.

ESTIMATION OF CALM WATER POWERING AND MANOEUVRING PERFORMANCE OF ONR TUMBLEHOME BASED ON TOWING TANK TESTS

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Abstract. A modern surface combatant, ONR Tumblehome (ONRT) has a wave piercing hull with tumblehome sides and transom stern. Its dynamic stabilities in waves were often focused on in several previous researches with 4 or 6 degrees of freedom motion analyses, but its calm water full-scale powering performance seems to be not sufficiently investigated. And mathematical model based manoeuvring simulations were carried out in other previous studies. Various experiments and CFD calculations were performed in order to derive hydrodynamic coefficients related to hull, propeller, and rudder, but further detailed investigations of the hull-propeller-rudder interaction coefficients are required by means of experimental approaches. In this study, 1/20.866 scaled ONRT captive model tests are performed in a towing tank of Korea Research Institute of Ships and Ocean Engineering (KRISO) in order to estimate its powering and manoeuvring performance in calm water. The model ship length is 7.38 meters. Resistance & propulsion tests and horizontal planar motion mechanism (HPMM) tests are carried out at the full-scale speeds up to 30 knots and 19 knots, respectively. Full-scale powering performance is predicted through propeller open water, resistance, and self-propulsion test results. HPMM tests are conducted to derive 3 degrees of freedom hydrodynamic coefficients, in particular, the hull-propeller-rudder interactions are focused on in order to clearly identify the propulsion and steering forces of such a twin screw vessel. Manoeuvring simulations in the horizontal plane are carried out with the mathematical models based on present captive model tests, simulation results are in good agreements with other available free-run experimental data.

Keywords: ONR tumblehome, Twin-screw vessel, Towing tank test, Full-scale powering performance, Manoeuvrability.

COMPUTATIONAL STUDY ON THE POTENTIAL TRANSMISSION OF COVID-19 VIRUS ON AN INDONESIAN FISHING VESSEL

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Abstract. During fishing operations, fishers often need to work in close proximity to each other on deck in a very limited space. This open-air working area can be subjected to various airflow conditions which might foster the airborne transmission of COVID-19 virus. To understand the risk of contagion in such a working environment and develop effective mitigation strategies to ensure the fishermen's safety, the present work establishes a computational model to analyse the virus' airborne transmission. Specifically, the work applies Computational Fluid Dynamic (CFD) to simulate various airflows occurring on an Indonesian fishing vessel, which is combined with Lagrangian particles that are used to model and track COVID-19 viruses. The concentration and coverage of COVID-19 viruses are analysed, considering the infected person working in different deck locations and under the influence of different vessel/wind speeds and directions. Subsequently, a set of guidelines including safe distance for the fishermen is suggested for each scenario.

Keywords: COVID-19, Fishing Vessel, Virus, Airborne Transmission, Computational Fluid Dynamics, Particle modelling.

A STUDY ON THE APPLICATION OF AUGMENTED REALITY-BASED REMOTE MAINTENANCE SYSTEM USING MWP DATABASE

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Abstract. Along with the 4th Industrial Revolution, interest in autonomous ships has increased, and interest in ship maintenance as well as basic performance such as ship movement, steering, and safety has increased. In response to this interest, research on a remote support system that supports non-experts to professionally perform maintenance on onboard equipment is being actively conducted. However, existing studies have limitations in providing rapid decision-making to non-experts who do not have basic knowledge about maintenance work because remote support is provided based on voice. Therefore, in this study, a system was developed to enable efficient work support for non-experts by changing the existing voice-based remote maintenance method to an augmented reality-based remote maintenance method that visualizes useful information of maintenance in front of the user. In addition, in this study, a database in which maintenance information (drawing, work history, manual, 3d cad model, etc.) required for maintenance called MWP (Maintenance Work Package) is built, and useful information is quickly acquired when performing maintenance work.

Keywords: Remote Maintenance, Augmented Reality, Maintenance Work Package.

EFFICIENT ALGORITHMS FOR EVALUATION OF THE STEEL HULL PROCESS

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Abstract. Algorithms make our daily life and work much easier than before. Computers solve these step-by-step instructions faster than a human can and open new opportunities for designing and monitoring production facilities. The steel hull process supplies the whole ship production process with the necessary steel parts for the hull. It is, therefore, very important to enable the shipyard management and the ship design office with efficient and reliable mathematical tools capable of evaluating the key performance indicators of the production process. Therefore, we briefly present two mathematical models to describe the splitting production lines: the analytical approach and the finite state method. Some of the most important key performance indicators, like the production rate, the work-in-process, the probability of blockage, and the probability of starvation will be presented. These mathematical models will be compared in a theoretical case including five machines and four buffers. Also, a numerical approach is employed to simulate the steel hull process in a shipyard. Such efforts are expected to enhance the negotiating position of a shipyard through a more reliable definition of production dynamics as well as through rational planning of production activities.

Keywords: Ship production process, Algorithms, Key performance indicators, Splitting production line, Finite state method.

FREE-OUTFLOW MODELLING IN THE LINEARISED PROGRESSIVE FLOODING SIMULATION METHODOLOGY

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Abstract. In linearised progressive flooding simulations, special attention shall be given to the damage and internal openings modelling. The steady Bernoulli equation, which is usually employed in quasistatic progressive flooding simulations, applies to the deeply-submerged case only. However, during progressive flooding of a damaged ship, free-outflow often occurs. In a linearised simulation tool, the integration of the different hydraulic behaviour related to free-outflow is not straightforward, since affects the linearisation process of the governing equations. Nevertheless, to assure the reliability and accuracy of the simulation technique, it is mandatory to consider the free-outflow case too. In this work, a methodology is presented to extend the linearised progressive flooding simulation technique to cope with free-outflow. The object is achieved through the introduction of a correction coefficient on the free-outflow area of the opening that is computed at each time step during differential equations integration. The proposed method is validated with a model scale flooding test highlighting also the errors that arise by discarding the free-outflow modelling.

Keywords: Progressive flooding, Fast simulation, Linearisation, Free-outflow.

DESIGN AND OPTIMIZATION OF A PUSHER BOAT BARGE UNIT UNDER SHALLOW WATER CONDITIONS

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Abstract. Extreme weather phenomena of recent summers caused periods of extreme shallow water on European rivers, which limited or even prohibited freight traffic. This paper deals with the design and optimization of a pusher boat barge unit able to operate under extreme shallow water conditions. The pusher boat can operate to a minimum draft of 0.6m. The unit's length is 110m. A barge with this same draft has a deadweight of over 130t, whereas a barge with a design draft of 2.5m has a deadweight of 1300t. Based on available data from 2019, this would enable the unit's continuous operation on the entire Elbe River for 194 days a year. Indeed, if certain bottlenecks were eliminated, operating for 365 days a year is realistic. The pusher boat's two height-adjustable rudder propellers are to be used for deep water propulsion. For shallow water operation, the pusher boat's two water jets and a pump jet at the bow of the barge are to be used for propulsion. The pump jet also helps manoeuvring and stopping the unit as its thrust can be directed to provide lateral forces. The barge is equipped with a bow rudder for improved manoeuvrability at higher speeds. An inflatable jacket between pusher boat and barge minimizes the resistance. For safe operation in shallow waters, the active hydraulic trim mechanism installed on the pusher boat enables level keel operation to avoid grounding. The concept was numerically optimized using systematic simulations based on an unsteady Reynolds-averaged Navier-Stokes solver and compared with existing concepts currently operating on the Elbe River.

Keywords: Push boat, Barge, Extreme shallow water, Resistance, Propulsion system, Design, Optimization.

HYDRODYNAMIC STUDIES ON A ZERO EMISSION BATTERY-DRIVEN FAST-FERRY

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Abstract. This paper presents extensive experimental and numerical CFD studies focusing on the optimisation of the hull form and propulsion of a novel, battery-driven, fast shortsea catamaran. Numerical results of the achieved speed-power performance and of the very high propulsive efficiency of close to 80% were verified by model experiments at the Hamburgische Schiffbau Versuchsanstalt (HSVA), proving the feasibility of the concept. Additional numerical investigations have been conducted recently on the seakeeping and manoeuvrability of the vessel. The seakeeping characteristics of the vessel have been comparatively studied by the potential flow code NEWDRIFT of NTUA and the RANS code FreSCO+ of HSVA, showing a reasonably good agreement. The turning manoeuvring of the catamaran has been simulated in time domain by the RANS method, with the catamaran fitted with up to four propulsors (two propellers plus two bow thrusters) operating simultaneously. The manoeuvrability of the vessel proved satisfactory, while the simulated physical phenomenon showed a very complex free surface deformation and flow around the vessel. The subject vessel is designed in the framework of the Horizon 2020 European Research project "TrAM - Transport: Advanced and Modular" (2018-2022). Presently, a prototype of the vessel named "Medstraum" is on the delivery stage and it will start operations on a multi-stop commuter route in the Stavanger area, Norway, before the end of 2022.

Keywords: Battery-driven ship, All electric, Fast-ferry, Zero emissions, Catamaran design, Parametric model, Hydrodynamic optimisation, High propulsive efficiency, CFD validation, RAOs in seaway, Seakeeping, Manoeuvring.

PARALLEL EFFICIENT GLOBAL OPTIMIZATION ALGORITHM FOR SHIP HULL FORM OPTIMIZATION

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Abstract. With the development of computer technology, Computational fluid dynamics (CFD) provides a numerical tool for evaluating the comprehensive hydrodynamic performance of ships. However, in the process of ship optimization design, one of the difficulties is that the time of numerical simulation is so long that it will not only consume a lot of computing resources but also reduce the optimization efficiency due to a large number of sample ships. The efficient global optimization (EGO) algorithm is currently one of the most widely used algorithms for solving this time-consuming optimization problem. It can achieve an appropriate tradeoff between the prediction value and its uncertainty when exploring the uncertain region to find the global optimum. Based on the EGO algorithm, this paper introduces the developed parallel efficient global optimization (PEGO) algorithm and uses the test functions to verify its feasibility in the field of ship design optimization. Then, the developed parallel efficient global optimization algorithm is used to optimize the calm water resistance of Wigley. The results indicate that the parallel efficient global optimization algorithm is an excellent method for ship optimization design and can further be applied to other ship hull form optimization design problems based on CFD.

Keywords: CFD, EGO, Parallel efficient global optimization, Ship optimization design.

FITTING BODY DEFORMATION METHOD FOR GLOBAL AND LOCAL DEFORMATION OF SHIP

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Abstract. The deformation of marine structures is the basis for marine structure hydrodynamic performance optimization. In this paper, a generalization deformation of barycentric coordinates called fitting body deformation is introduced based on maximum entropy theory. This method ensures the non-negative barycentric coordinates inside any polygon. Newton's method is used to calculate the weights by solving a convex optimization. At the same time, it achieves the global and local deformation by utilizing an algorithm for a point inside the polyhedron. Some marine structures (hull, wind turbine blades) are used to demonstrate the deformation effect. The deformation results show the highly effective and flexible of fitting body deformation method.

Keywords: Barycentric coordinate, Maximum entropy theory, Non-negative, Fitting body deformation.

PREDICTION OF THE SHIP PERFORMANCE USING DYNAMIC MODEL (MULTI-INPUT / SINGLE -OUTPUT, MISO) BASED ON SHIP OPERATION DATA

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Abstract. Prediction of ship performance is very difficult due to the complex effects of many external forces in actual operating conditions. ISO15016 and ISO19030 standards are commonly used to evaluate operating performance. ISO15016 requires many variables, time and cost by a complex calculation formula, and ISO19030 only evaluates the ship speed drop due to the wind excluding the effect of waves. This study is about the method for prediction of ship performance to improve the existing method using actual operational data. When external forces such as relative wind speed and wave height increase(fluctuation) during actual operation, the speed of ground (SOG) fluctuates as the wind resistance and wave resistance increase accordingly. And there is a frequency characteristic (time-lag) due to a time constant according to the size and type of the target vessel. The dynamic model of this study is to obtain power fluctuations in which the influence of environmental variables (external forces) is removed by modelling the Linear Multi-Input / Single-Output (MISO) system for unknown frequency characteristics and determining the optimal Linear Transfer Function. The input data of the MISO model was selected by evaluating the correlation of each variable in the operation data, and the effect of each input variable on the speed loss was evaluated. And other factors affecting SOG were assumed to be noise (N), which are expected to be aging and fouling. Noise is expected to have a constant value within the same voyage, and N-components for a specific period were plotted and compared with ISO19030's Performance Value (PV)s.

Keywords: Ship Performance, Operational data, Dynamic model, Multi-Input /Single-Output (MISO) system.

DEVELOPMENT OF ACCELERATION SIMULATION FROM REST OF PLANING CRAFT WITH OUTBOARD ENGINE BY USING TIME HISTORY INPUT DATA OF ENGINE TORQUE

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Abstract. The power of outboard engines has been increased in recent years to improve the acceleration performance of planing crafts. On the other hand, various sizes and forms of hull have been developed to use full of the increased power. For developer of outboard engine, in order to optimize fuel consumption and running performance for various combinations of hulls and outboard engines by tuning of engine control without real craft tests, it is required to develop a bench test system of the outboard engine including boat's running simulation. The purpose of this study is to propose an acceleration motion simulation of planing craft for bench test system of the outboard engine. The simulation considers a propeller rotation equation of the outboard engine into the previous simulation method of straight forward acceleration of planing craft. The propeller thrust and torque coefficients of the propeller rotation equation are obtained by a fully captive model test with propulsion behind the hull, and a time history data of torque of propeller of outboard engine is obtained by a transient bench test using real craft acceleration test data. The simulated results are compared with the real craft test results.

Keywords: Acceleration, High-Speed Planing Craft, Outboard Engine, Propeller Performance, Transient Bench Test.

ON ESTIMATING SPEED PERFORMANCE OF SHIPS IN IRREGULAR HEAD SEAS: COMPARISON BETWEEN TWO DIFFERENT SCHEMES

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Abstract. In the present study, the speed performance of a commercial ship navigating in an actual seaway is addressed. To this end, two different schemes, Reversed Procedure of ISO15016: 2002 sea trial analysis and RTIM (Resistance and Thrust Identity Method) of ITTC, are considered. Both methods are based on thrust identity. RTIM estimates the increment of delivered power and propeller rotation in an irregular seaway when the speed of a ship remains constant, while the reversed procedure of ISO15016: 2002 estimates the decrement of the speed of a ship when the propeller rotation remains constant. In the implementation of the two different methods, environmental loads on the ship are calculated from the summation of the calm-water resistance and added resistance due to wind and waves. Calm-water resistance and wind loads are estimated using Holtrop-Mennen and Fujiwara's empirical formula, respectively. For added resistance in waves, the strip method based on Salvesen-Tuck-Faltinsen theory and Maruo's momentum conservation formula are applied, and accuracy of the added resistance in short wavelength region is improved by introducing enhanced asymptotic formula. Then, the added resistance in irregular waves can be obtained from the superposition of its transfer function on the wave energy spectrum. Finally, the involuntary speed loss (EEDI f_w factor) of a ship in the representative sea condition is predicted using the two methods and their results are compared. Through the present study, it is concluded that both methods are of practical use in determining the speed loss in actual seas and the results obtained from the two different approaches show good agreement.

Keywords: Speed loss, Sea trial, EEDI, f_w factor, ISO15016: 2002, RTIM.

UNCERTAINTY ANALYSIS ON VESSEL TECHNICAL INDEX FOR TECHNICAL SHIP PERFORMANCE

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Abstract. In line with decarbonization targets, indices such as EEDI, EEOI, AER and CII have been introduced to enable various maritime stakeholders like regulators, operators, and charterers to monitor and reduce fossil fuel consumption and associated emissions. Going forward, it is expected that improved environmental performance will be a precondition for ship owners to gain access to capital and cargo. However, several indices and their ratings are heavily influenced by weather conditions and operational considerations, factors which are often beyond a ship owner's control. As a response, a Vessel Technical Index (VTI) has been proposed by DNV, which isolates the technical condition of a ship, accounting and adjusting for relevant operational factors. However, measuring and evaluating the VTI is a complex process dependent on amongst others stochastic loads from the environment and dynamic draft conditions. Simplifications carry different uncertainties. For the users of the VTI to have the required confidence to make optimal decisions based on its results, it is important to understand how uncertainties in the measured situation and methodology translate into uncertainty in the VTI. This naturally leads to questions related to how accurate the VTI is; how this accuracy affects the quality of the decisions; and what purposes the VTI can be used for. This paper explains how to measure, evaluate and verify the VTI, including assessing the relevant sources of uncertainties and how these propagates through the evaluation and affect the confidence in the decisions made based on the VTI.

Keywords: Technical ship performance, Measurements, Data analytics, Uncertainty quantification.

A METHOD FOR AUTOMATIC CONTROL OF CRANES FOR BLOCK LIFTING IN SHIPYARD

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Abstract. Ships and offshore structures are constructed in a way that several units of blocks are assembled. In the block lifting process, a block is controlled indirectly through the interaction of the crane, hooks, equalizers, and wire ropes (simply, wires). Therefore, it is difficult to control the unexpected motions of the block accurately with several connected objects. Furthermore, it is important to construct a robust control model to cope with the modeling uncertainty of the block and the change of lug arrangement. In this study, we proposed the automatic control of the block lifting process with deep reinforcement learning (DRL), which can provide a robust control under uncertainties. The state of a block and wires, such as position, orientation and angular velocity of the block, and the lifting speed of each wire, were used as the input of DRL. Then, the lifting speed of each wire was obtained as the output action of DRL. The reward was applied to reduce the roll and pitch angle of the block and to stabilize the speed of block lifting. The proposed method was applied to various simulation examples of block lifting and compared with traditional control algorithms. As a result, it was confirmed that the proposed method could effectively control the block with unexpected motions due to the modeling uncertainty and the change of the lug arrangement.

Keywords: Block lifting, Automatic control, Deep reinforcement learning, Crane dynamics.

SHAPE RECOGNITION FOR AUTOMATION OF GRINDING OPERATION IN THE SHIPYARD

Se-Young Kang[1], Sol Ha[1], Ju-Hwan Cha[1], Puspita Trinita Laras[1], Ji-Hwan Lee[1], Hyeong-Jun Kim[1], Dong-Hyeok Jang[1], Kwang-Phil Park[2]

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Abstract. This paper proposes a method that detects the outlines of steel outfitting used in shipbuilding using a camera image. Many factors interfere with shape recognition at the workplace. To remove unnecessary factors in the camera image, we separate the background and objects by utilizing the difference in contrast. The remaining noise is removed through repetitive morphology operations. To remove holes, scratches, and rust inside the object, the interior is filled with a minimum degree of contrast. As a result, a pure outline of the object could be obtained and applied to the operation of automation grinding.

Keywords: Camera image, Shape recognition, Automation grinding.

INNOVATIVE WASTE MANAGEMENT SYSTEM FOR SHIPS

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[2] Maritime Center of Excellence d.o.o., Opatija, Croatia

Abstract. A plasma-assisted gasification system for conversion of solid waste to synthesis gas (gaseous fuel mainly comprised of hydrogen and carbon monoxide) was developed by ERMAFA Environmental Technologies of Austria and is currently in the prototype stage. This paper analyses the feasibility of the application of this technology for the conversion of oily residue and solid shipboard waste such as plastics, paper, cardboard, textile, dried food leftovers and hazardous waste to usable electric and heat energy, with the goal to achieve three main targets: considerable reduction of waste volume, reduction of overall greenhouse gases emission and cost savings. Solid and liquid waste collected on board is subject to pre-treatment before being fed to the reactor. A three-stage gasification process within the reactor converts the feedstock into raw synthesis gas, leaving a small percentage of solid residue in the form of inert ash. The raw synthesis gas is cleaned in the gas treatment system and, finally, fed to a gas engine for the generation of electrical energy. This paper describes in detail the operation principle of the plasma-assisted waste management system and contains several case studies to assess the system size, interface requirements, mass and energy balance and high-level economic assessment for several characteristic ships and usage scenarios. The system is deemed feasible and applicable to ships with a large number of persons on board (e.g. mid and large cruisers) or larger military vessels where the primary driver is waste volume reduction.

Keywords: Plasma gasification, Syngas, Waste-to-energy, Ship waste management.

REAL SHIP IMPLEMENTATION OF BUOYANCY SUPPORT SYSTEM FOR DAMAGED SHIPS

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Abstract. Buoyancy support system (BSS) is a technology that can delay or prevent the sinking of a damaged ship in the event of an emergency. In 2018, the developed technology acquired AIP (Approval In Principal) from Korean Register of Shipping, and ISO standards established in 2019. If the watertight zone of a ship is sufficiently divided, the damage stability can be improved, but the hull becomes heavy and the cost for the ship building increases. The BSS is a technology that can be installed inner hull space with minimal capital cost and reduced need for ship modification, maintenance during the life cycle. In this proceeding, practical efforts is introduced and achievements for improving ship safety through the practical application of the BSS to electric powered small car ferry ships are introduced.

Keywords: Buoyancy support system, Flooding, Accidents (incidents), Evacuation, Stability.

08:30 - Onwards	REGISTRATION		
09:00 - 10:40	22. TECHNICAL SESSIONS Mare II **Model tests I** H.J. Tang, R.Y. Yang, H.C. Yao: **Flume Experiment of Mooring Line Failure on a Net Cage under Irregular Waves and Currents** K.H. Jung, S.B. Park, H. Park, A.H. Mohamed, Hyun Soo Kim: **Hydrodynamic Characteristics of Rectangular Structure in Various Water Depth** Y. Kitagawa, Y. Tsukada, K. Ohashi: **On Measurement of Hydrodynamic Pressures on Hull and Rudder Surface in Free-running Model Test** J. Lee, S. Hwang, Y.Y. Lee, S.M. Yoo: **Towing-tank Measurement of Added Resistance of a Tanker in Regular Head Waves under Off-design Conditions**	23. TECHNICAL SESSIONS Mare III **Artificial intelligence, Machine learning I** J. Lee, D.W. Park: **Multi-Parametric Hull Form Design Based on Optimization Technique and AI** C. Gui, Z. Zhou, Y. Huang, N. Kiji, M. Sadano, K. Aoyama: **Data-Driven Multi-Agent Simulation of Subassembly Production at Shipyard** M.C. Kong, M.I. Roh, J. Ha, E.S. Jin, D. Yu: **Design of the Integrated System for the Safe Operation Based on Augmented Reality** M.K. Lee, I. Lee: **An Optimization Study for the Design of Flow Control Fin using Artificial Intelligence**	24. TECHNICAL SESSIONS Mare IV **Energy efficiency I** B. van Veldhuizen, L. van Biert, K. Visser, H. Hopman: **Comparative Analysis of Alternative Fuels for Marine SOFC Systems** F. Xing, K. Pazouki, A.J. Murphy, R. Norman: **A Comparison of NOx Mitigating Technologies for Ships using Fleet-Wide Continuous Emissions Monitoring** E. Yfantis , C. Ioannou, A. Paradeisiotis, G. Mallouppas, A. Ktoris: **Comparative Investigation of Different Methodologies for the Assessment of Shipping Transportation Environmental impact – The CMMI ISEF Emission Assessment Model** A. Dell'Acqua, R. Eggers, J. Benedictus: **Alternative Ship Propulsion System fuelled by Ammonia: Environmental, Feasibility and Economic Assessment for a NewcastleMax Bulk Carrier**
10:40 - 11:10	**Coffee break**		
11:10 - 12:50	25. TECHNICAL SESSIONS Mare II **Model tests II** C. Pouw, B. Starke: **Numerical Calculation and Evaluation of Extrapolation Coefficients as used in Speed-Power Predictions based on Model Tests** R. Kołodziej: **Impact of Ship's Metacentric Height on the Prediction of IMO Standard Maneuvers with the use of Free Running Models** S. Kim, B. Bouscasse; G. Ducrozet, S. Delacroix, G. de Hauteclocque, P. Ferrant: **Experimental Investigation on Wave-Induced Bending Moments of a 6,750-TEU Containership in Oblique Waves** K. Mikami, H. Houtani, M. Kobayashi, K. Toh, H. Murayama, H. Suzuki: **Measurement of Deflection Distribution of Elastic Container Ship Model Using Stereo Imaging and Fiber-Optic Sensors**	26. TECHNICAL SESSIONS Mare III **Artificial intelligence, Machine learning II** H.Y. Son, G.Y. Kim, S.J. Oh, J. Choi, D.K. Lee, Y.M. Choi, E.S. Kim, S.C. Shin: **BiLSTM-based Time to Capsize Prediction using Damaged Ship Motion Data** D. Jeon, G.Y. Kim, C. Lim, S.C. Shin: **Minimization of Shift for Container Stowage Planning based on Reinforcement Learning** L. (Y.O.) Kim, K.H. Lee, Y. Kim, H.B. Yeo: **Necessity of Advanced Integrated Digital Engineering & Management (AIDEM) Tools** G.Y. Kim, G.S. Jin, S.J. Oh, C. Lim, S. Lee, M. Seong, S.C. Shin: **Deep Neural Networks with Ensemble Model for HVAC Capacity Estimation of Ship**	27. TECHNICAL SESSIONS Mare IV **Energy efficiency II** J. Barreiro Montes, P. Ballester Falcon, S. Zaragoza Fernández, V. Díaz Casas: **Energy Efficiency of Ships** Y. Zhou , K. Pazouki, A.J. Murphy, Z. Uriondo, I. Granado, I. Quincoces, J. A. Fernandes-Salvador: **Modelling Tuna Purse Seiners Fuel Efficiency in Real-World Operations using Machine Learning Approaches** N. Vladimir, M. Koričan, H. Kozmar, V. Slapničar, A. Fan: **A Simplified Formulation of the Energy Efficiency Index for Purse Seiners** N. Vladimir, M. Koričan, N. Alujević, V. Slapničar, T. Haramina, A. Fan: **Real Time Fuel Consumption Measurements of a Fleet of Fishing Vessels in the Adriatic Sea**

12:50 - 14:20	Lunch		
14:20 - 16:00	28. TECHNICAL SESSIONS **Mare II** **Propulsion I**	29. TECHNICAL SESSIONS **Mare III** **Artificial intelligence, Machine learning III**	30. TECHNICAL SESSIONS **Mare IV** **Energy efficiency III**
	K.W. Shin, W. Jin, R.M. Bering: **CFD Prediction of Cavitation on a Full-scale Marine Propeller in Hull Wake**	J.H. Kim, M.I. Roh, I.C. Yeo, K.S. Kim, M.J. Oh, S. Oh: **Estimation Model of Hydrodynamic Performance Using Hull Form Variation and Deep Learning**	K. Kim, M. Leer-Andersen, S. Werner: **Towards an Effective Ship Design and Operation taking into Account Surface Roughness**
	S. Hamzeh, M.R. Hadavi, H. Rostami, S. Nickabadi, E. Rostami: **Numerical Investigation of Effect of Replacement Stator with Secondary Rotor in a Water-Jet Propulsion System**	S.H. Byun, K. Sim: **On Dimension Reduction of Vibration data for Condition Monitoring of Marine Engines**	R. Eggers , A. Dell' Acqua, J. van den Akker, J. Wisse: **Exploration of Wind Propulsion: Performance and Economical Assessment for a NewcastleMax Bulk Carrier**
	M. Reichel, H. Pruszko, K. Czerski, M. Necel: **Innovative Twin-CRP-POD Propulsion System for Ultra Large Container Ships - Challenges and Opportunities**	W. Yunlong, M. Jie, Z. Yu, Z. Xin: **Research on Ship Parts Layout Problem Based on Hybrid Improved Genetic Simulated Annealing Algorithm**	J.H. Lee, H. Kim, J.H. Jang, H.S. Ahn, D.W. Seo: **Study on the Speed Trial of a Large Container Ship during a Commercial Voyage**
	Y.J. Hyun, S. Sung, K.J. Paik, J. Park, S.H. Lee, J. Park: **Proposal for a Method to Reduce Propeller Vibration through Harmonic Injection of Motor**	L. van Rooij, R. de Winter, A.V. Kononova, B. van Stein: **Explainable AI for Ship Design Analysis with AIS and Static Ship Data**	C. Emmersberger, B. Carstensen, A. Lübcke, S. Krüger: **A Method for Dimensioning Hybrid Power Supply Systems of Ships within the Early Design Stage**
19:30 - Onwards	CONFERENCE DINNER		

FLUME EXPERIMENT OF MOORING LINE FAILURE ON A NET CAGE UNDER IRREGULAR WAVES AND CURRENTS

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Abstract. This study conducted a flume experiment of the hydrodynamic behaviours of the mooring line failure on a net cage under irregular waves and currents. An eight-point mooring net-cage model with two load cells in its upstream mooring lines and with a gyroscope on its floating collar was installed in a wave tank to measure the upstream mooring force and the rotational motions of the net cage. A device equipped with a pneumatic cylinder and a blade was designed to cut the mooring line. The experimental results were analysed in both the time domain and frequency domain. The results showed that as one of the upstream mooring lines was cut, the mooring load in the other line increased greatly. In addition to the strong mooring tension response, a significant yaw rotation of the floating collar of the net cage was also observed. As increasing the current velocity, the higher tension spectral responses in both the wave-frequency and low-frequency regions were discovered.

Keywords: Aquaculture, Net cage, Mooring line failure, Irregular waves, Water current, Flume experiment.

HYDRODYNAMIC CHARACTERISTICS OF RECTANGULAR STRUCTURE IN VARIOUS WATER DEPTH

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Abstract. Hydrodynamic characteristics of a rectangular structure were experimentally studied in various wave and water depth conditions in a two-dimensional wave tank. The rectangular structure was installed in fixed and soft spring moored conditions in beam sea. The experiment was performed in regular wave conditions varying a wave period, a wave height, and the water depths. At the fixed condition, the horizontal and vertical forces were measured to quantify the wave loading on the rectangular structure. To study the water depth effect on the hydrodynamic motion, the rectangular structure was moored with soft spring to allow 3-DOF (sway, heave, roll) motions in the beam sea condition. It was performed of tests for four wave heights at one wave period to investigate the nonlinear effect on the roll and heave motion in various water depths. Free decay tests were employed to quantify the damping effect on roll and heave motions at various water depths. It showed trends of roll and heave natural periods increasing and those damping ratios getting larger at shallow water depth. And, it was provided that numerical and experimental results of response amplitude operators (RAOs) of roll, heave, and sway motions was compared at various water depth.

Keywords: Water depth effect, Natural period, Damping ratio, Response amplitude operator (RAO).

ON MEASUREMENT OF HYDRODYNAMIC PRESSURES ON HULL AND RUDDER SURFACE IN FREE-RUNNING MODEL TEST

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Abstract. Research and development for the autonomous ship have been internationally progressed, and safety assessments for the automatically manoeuvred ship will be more important. Here, though ship's manoeuvring motions have been conventionally predicted by solving the equations of the planar motion whose external force terms are consisted on the basis of quasi-steady process, considering complex hydrodynamic forces in harbour manoeuvring as represented as a berthing operation, the direct simulation of freely manoeuvred motions using the CFD method is promising in such the operation. Similar to the mathematical manoeuvring models, the detailed validations of the CFD method are desirable, especially, on manoeuvring motions including a berthing operation. In this study, the experimental measurement of hydrodynamic pressures at multiple points on hull and rudder surfaces, which can be contribute to the validation of the CFD method, under the free-running model test are performed. An experimental facility for the free-running model test is the Actual Sea Model Basin in the National Maritime Institute Japan , and the FBG pressure sensors (132 points in total) are introduced to measure the hydrodynamic pressures. With deeply explaining the experimental setting of the FBG sensors for the free-running model test, measured results and those analyses of ship motion and surface pressures in the turning test are revealed.

Keywords: Free-running model test, Hydrodynamic pressure, FBG pressure sensor, Turning test.

TOWING-TANK MEASUREMENT OF ADDED RESISTANCE OF A TANKER IN REGULAR HEAD WAVES UNDER OFF-DESIGN CONDITIONS

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Abstract. Ship hydrodynamic performance in off-design conditions is crucial for both the model test-sea trial correlation and ship propulsion performance evaluation during real sea state operations. However, only a few previous studies have examined this. Therefore, the number of databases related to these conditions is less than that of design conditions. The estimation or empirical approach may have limitations because of the lack of data in relevant domains. This study considers different loading conditions and second order Stokes incident waves to fill this gap in public experimental data. During the experiment, an appropriate incident wave generation, analysis method and measurement devices were selected based on uncertainty quantification. Several conclusions were drawn from the test results. Even in linear incident wave condition, the bow and stern wetted surface in ballast condition differ from the design waterline. Dynamic motion characteristics are different due to fore and aft restoring force and moment differences, and vertical hull form variation. If the wave slope becomes higher, the nonlinear effect is magnified. Instantaneous bulbous bow emersion, breaking waves, relative wave maximum point, phase difference, dry hull bottom, and several nonlinear phenomena should be considered in off-design conditions. The basic assumptions made for linear theory calculations or simple estimation methods may lead to inaccuracies when breaking waves and severe wetted surface changes are present, and these methods should be applied with circumspection.

Keywords: Wave resistance, Off-design, Towing-tank test, Tanker, Added resistance.

MULTI-PARAMETRIC HULL FORM DESIGN BASED ON OPTIMIZATION TECHNIQUE AND AI

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Abstract. This paper suggests a standard method to optimize hull form from the perspective of hydrodynamic performances based on the design space exploration, optimization technique and AI(Artificial Intelligence) using multi-parameter and objective function. Target ship is a 50k DWT class oil tanker, and optimization of the hull form has been performed to improve speed performance using computational method. The design parameters of the bow and stern hull are related to translation of control point of surface, and the objective is to minimize the total resistance with constraint conditions. To suggest the standard method, the process consisted of hull form variation, performance analysis and design exploration has been automated. A study of the bow hull form optimization without change of the stern hull form has been implemented, and it has been performed to optimize the bow and stern hull form together. Each best hull form that the speed performance is improved was searched as a result of the design exploration. The standard optimization method developed from this parametric study based on the AI can be utilized to design optimal hull form of medium-range ships.

Keywords: Artificial intelligence, Design exploration, Optimization, Automation, Hull form, Performance.

DATA-DRIVEN MULTI-AGENT SIMULATION OF SUBASSEMBLY PRODUCTION AT SHIPYARD

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Abstract. To survive in an increasingly competitive shipbuilding market, shipyards must optimize the utilization of resources, facilitate scheduling, and eliminate waste during production. To address these problems, various simulation-related technologies have been widely adopted in the ship building industry. However, to date, there are few reports on enhancing the fidelity of the simulation model using historical process information. In this study, we propose using a YOLO-based object detection method to extract the valuable process information from surveillance videos and estimate the work status based on the detection results. The work status information is then used to evaluate workers' performance, which serves as the input of the simulation to enhance fidelity. The problem of validating and improving the existing production plan is formalized as a flexible job shop scheduling problem and is addressed using a contract net protocol-based multi-agent simulation model. Finally, a case study was conducted in which the production plan of a subassembly workshop at a shipyard was validated and improved so that the original production goal could be achieved. This study demonstrates the potential of employing the historical production record to enhance the fidelity of the model and proposes an approach for the foreman at the shipyard to improve the existing production plan in the flexible shipbuilding environment via the multi-agent simulation.

Keywords: Multi-agent simulation, Subassembly, Flexible job shop scheduling, Performance rating.

DESIGN OF THE INTEGRATED SYSTEM FOR THE SAFE OPERATION BASED ON AUGMENTED REALITY

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Abstract. Recently, the demand for technology to help workers safely navigate has been emerging. Therefore, many studies have been conducted to identify other ships using various sensors and propose a collision-free route by collision risk assessment. Such supporting technology for safe navigation requires analysis of various sensor information. By using multiple sensors such as automatic identification system (AIS), radio detection and ranging (RADAR), and light detection and ranging (LIDAR) with appropriate sensor fusion, other ships around an own ship could be identified. However, such information is complex for the navigator to interpret and isn't easy to utilize because it is not intuitive. Also, such information is visualized in graph-like form through the display; there is a significant difference from the actual field of view seen from the wheelhouse. Therefore, an effective visualization technology that displays various operational information such as the collision risk with other ships and the collision-free route of the own ship is required. This study proposed augmented reality (AR) technology to display various results of image detection, collision risk, collision-free routes, and sensor information on actual navigation images for safe navigation. As a result, a system that integrates the image detection module, collision-avoidance module, and sensor fusion module was designed, generating ship detection results with the YOLO v5 model. For this, the integrated framework that can connect various modules and exchange various information between them was designed and implemented. This model was applied to the real-time video and sensor data taken during the actual voyage. Its effectiveness was confirmed by visualizing video overlays of various information to help the navigator.

Keywords: Augmented Reality, Integrated System, Integrated Framework, Data Visualization.

AN OPTIMIZATION STUDY FOR THE DESIGN OF FLOW CONTROL FIN USING ARTIFICIAL INTELLIGENCE

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Abstract. The fin optimization of ship is generally conducted as a case study through Computational Fluid Dynamics (CFD), which requires a lot of time. In this study, artificial intelligence was applied to learn the wake field distribution in the propeller plane of the ship and to select the optimal fin location. The wake distribution data have been collected systematically by CFD. Based on the collected data, the wake distribution according to fin position was learned by Neural Network (NN) and the optimal fin position was selected through optimization technique. The neural network and optimization technology, which are widely applied in the engineering field, are well known as on of the prospective methods for prediction, classification and diagnosis of real complicated problems. For neural network learning, fin position information and axial velocity component values are configured as processing nodes of input and output layers, respectively. Based on the learned output data, optimization technique was applied with constraints for homogenous wake distribution. The results from this study may provide the designer with an optimal fin location without using simulation in the initial fin design.

Keywords: Flow Control Fin Design, Wake Distribution, CFD, Artificial Intelligence, Neural Network, Optimization Technology, Learning Algorithm.

COMPARATIVE ANALYSIS OF ALTERNATIVE FUELS FOR MARINE SOFC SYSTEMS

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Abstract. To continue its operations, the marine industry needs to comply with emission regulations. Solid Oxide Fuel Cells (SOFCs) are considered a promising solution, since it can generate energy athigh efficiency and low NO_x, SO_x and particulate matter emissions. Another advantage of SOFCsis fuel flexibility, meaning several fuels can be applied in SOFC systems. This brings up the questionwhich fuel is most effective for a marine SOFC system. In this research, marine gas oil (benchmark),liquefied hydrogen, biodiesel, Fischer-Tropsch diesel, natural gas, methanol, dimethyl ether, and hydrogenare compared as bunker fuel. A comparison framework is proposed specialised for marineapplications. The following decision criteria are selected: production capacity, volumetric/gravimetricenergy density, technological readiness, safety, fuel cost, cost of the fuel storage system, and emissions.The performance indicators are quantified for every fuel based on literature and supplier information.In the end, five alternative fuels are selected for marine SOFC systems on the selected criteria, whichwill be used in further research.

Keywords: Marine fuels, Power generation, SOFC, Emissions.

A COMPARISON OF NOX MITIGATING TECHNOLOGIES FOR SHIPS USING FLEET-WIDE CONTINUOUS EMISSIONS MONITORING

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Abstract. Maritime transport is the backbone of domestic and international trade and economy. Around 80% of global trade by volume and over 70 % by value are carried by sea. The global proportion of NOx emissions from shipping is estimated at around 15 %. One of the key aspects to reduce emissions is to use mitigating technologies, however these technologies can only be effectively deployed, and system design decisions made, if their actual performance in real operational settings is known. This paper investigates the effectiveness of several NOx emissions mitigating technologies, applying them on 10 older inland waterway vessels. These measures include primary and secondary measures applied at and after the engine, respectively and the use of alternative fuels. The real-world NOx emissions and other engine operational parameters were recorded using continuous monitoring systems over extensive time periods (>1 year). The data were analysed to generate specific load-dependent NOx emission factors for each technology which were then generalised using averages with weighting functions that are relevant to those used in EU regulations. The emission factors are used to determine the effectiveness of each of the mitigating technologies under different operating conditions and their relative performance is compared. This paper considers the detail and challenges of monitoring ship emissions at fleet-scale over long periods of time and considers the relative performance of the NOx mitigating technologies that the analysis revealed.

Keywords: Onboard monitoring, Load dependent NOx emission factors, Effectiveness of NOx mitigating technologies, Inland waterway vessels.

COMPARATIVE INVESTIGATION OF DIFFERENT METHODOLOGIES FOR THE ASSESSMENT OF SHIPPING TRANSPORTATION ENVIRONMENTAL IMPACT – THE CMMI ISEF EMISSION ASSESSMENT MODEL

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Abstract. Climate change accentuates the need to raise social awareness to conserve energy and reduce fuel consumption, especially in the shipping sector, since 80-90% of the international trade occurs through shipping and represents approximately 3% of the global Green House Gas (GHG) emissions. Decarbonization is vital to eventually eliminate carbon dioxide emissions, using the appropriate radical and incremental innovative technologies, policies, and incentives at local and international level. Nevertheless, proper tools are not yet feasible neither to estimate and/or calculate CO_2 emissions nor to continuously monitor and evaluate them. Consequently, it is important to develop an accurate and reliable method to monitor combustion emissions from shipping that will hopefully encourage organizations that provide transportation services to review their strategies and motivate governments and regulatory bodies to improve their policies (taxation, incentives). To begin with, research is carried out to examine the existing methods that are used to estimate the emissions of ships. Furthermore, comparative investigation of the different methodologies is assessed to adopt the most accurate approach for the estimation of shipping transportation environmental impact. The second-stage target is the real-time monitoring of commercial ships to map atmospheric pollution in the Eastern Mediterranean region by calculating the GHG emissions and utilizing meteorological models to estimate the dispersion. The third-stage target is the development of an evaluation platform for decarbonization measures that have been or will be adopted. Finally, the CMMI ISEF emission assessment model is introduced which can aid practical ship design.

Keywords: Shipping transportation, GHG emissions, Emission monitoring, Vessel environmental footprint, AIS.

ALTERNATIVE SHIP PROPULSION SYSTEM FUELLED BY AMMONIA: ENVIRONMENTAL, FEASIBILITY AND ECONOMIC ASSESSMENT FOR A NEWCASTLEMAX BULK CARRIER

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Abstract. The growing environmental awareness of the shipping industry has posed the objective of achieving significant reductions in greenhouse gas emissions (GHG) and introducing alternative fuel sources. The energy carrier choice, the design and the implementation of the future low/zero emission power systems on board ships is a challenging process in which the reduction of emissions is not the only determining factor. The presented paper explores this field. In co-operation with Compagnie Maritime Belge (CMB), a NewcastleMax bulk carrier was used as reference for the application of carbon free/neutral fuels. Different combinations of power system designs and fuels were reviewed based on their estimated CO_2 emissions, impact on the design, capital and operational expenditure and technology readiness level in order to come up with the most suitable solution. The exploration unveiled how ammonia can be a valid and feasible alternative on the way to a reduced dependence on fossil fuels. Despite the assumptions and limitations encountered due to the novelty of this technology, preliminary results and system's layouts show a relevant step towards the application of ammonia as marine fuel.

Keywords: Ammonia, Bulk Carrier, NewcastleMax, Green shipping, Hybrid propulsion, Greenhouse gas (GHG).

NUMERICAL CALCULATION AND EVALUATION OF EXTRAPOLATION COEFFICIENTS AS USED IN SPEED-POWER PREDICTIONS BASED ON MODEL TESTS

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Abstract. A comparative analysis has been made of the extrapolation of model tests results using form factors and wake scale effects obtained from both a statistical method and viscous-flow computations. When similar values would be obtained from the numerical approach compared to the statistical method, no change in correlation allowance is needed to predict the same full-scale power. For slender ships, however, this is not the case and the lower form factor and higher wake scale effect from the numerical approach results in a lower correlation allowance in the order of 0.00010. For fuller ships the numerical approach predicts similar form factors but a higher wake scale effect. The ballast draught compared to the design draught is normally extrapolated with an additional correlation allowance but when the numerical extrapolation coefficients are used this additional allowance is reduced, more for slender ships then for fuller ships. A correlation of ballast and design draughts with trial data show an opposite trend where the slender ships need an additional reduction of the correlation allowance in ballast.

Keywords: Model-to-ship extrapolation, Form factor, Wake fraction, Design draft, Ballast draft, CFD.

IMPACT OF SHIP'S METACENTRIC HEIGHT ON THE PREDICTION OF IMO STANDARD MANEUVERS WITH THE USE OF FREE RUNNING MODELS

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Abstract. The IMO standards assume that the maneuverability of the ship can be assessed on the basis of the characteristics of the conventional trial maneuvers. In this case, either free running model tests or captive model tests in conjunction with mathematical model of ship motion are considered as a reliable prediction method on an early stage of ship design. Although roll motions of the ship during maneuvering play an important role in navigation safety it is a common practice that the roll-coupling effect on maneuvering is considered as negligible and not taken into consideration during initial predictions of ship maneuvering performance. This paper presents study over impact of roll motions generated by the hull on the results of IMO standard maneuvers on the example of zig-zag and turning model tests conducted for a three different types of vessels. Each tested free running model was balanced dynamically for a three different metacentric heights so that it could achieve significant roll angles during maneuvering. The study brings practical knowledge for designers interested in both numerical simulations of ship motions as well as class acceptance tests and have broad applications in the entire process of ship design.

Keywords: Ship model tests, Roll-coupling effect, IMO standards, Ship maneuvering prediction, Ship metacentric height.

EXPERIMENTAL INVESTIGATION ON WAVE-INDUCED BENDING MOMENTS OF A 6,750-TEU CONTAINERSHIP IN OBLIQUE WAVES

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Abstract. This study aims at the experimental investigation of wave-induced motions and loads of a containership model without forward speed in 120deg oblique regular waves to provide reference data for future benchmark studies. A mooring system with 4 horizontally arranged spring lines was used to maintain the heading angle of a 1:65 scaled 9-segments model designed to be as rigid as possible. Focuses were on studying the nonlinear effects due to the wave steepness on the vertical bending moment (VBM) and horizontal bending moment (HBM) near amidships, and 6DOF motions at the center of gravity (COG) of the model. Accordingly, several wave series in wave steepness consisting of various wave period cases were generated in the model test. The wave period range of each series was intended to cover the peak of the wave bending moment transfer function, thus the wave's nonlinear effect on the response near the resonance period was discussed. From the experimental results, it was found that the weight of the wave's nonlinear effect on the motions and loads increases as the wave becomes steeper. In addition, the contribution of the additional bending moment by the mooring system was qualitatively evaluated through a comparative study with linear numerical calculation results of Hydrostar, that was performed with/without the mooring system.

Keywords: Wave bending moments, Oblique wave condition, Wave steepness, Horizontal mooring system.

MEASUREMENT OF DEFLECTION DISTRIBUTION OF ELASTIC CONTAINER SHIP MODEL USING STEREO IMAGING AND FIBER-OPTIC SENSORS

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Abstract. Elastic deformation of ship structures occurs when subjected to hydrostatic and wave loading. Tank tests using an elastic ship model are often carried out to understand such structural responses. In conventional experiments, sensors such as strain gauges and load cells have been used to evaluate the vertical bending moment of the section to which the sensor is attached, and a few examples are focusing on the deformation distribution. In this study, the tank test is implemented with an elastic model of a container ship with an aluminum beam as its backbone, aiming to measure the deflection distribution of the global deformation of the hull. By applying the beam theory, the deflection distributions of the backbone are estimated using strains measured by distributed fiber-optic strain sensors installed on the backbone. Simultaneously, the deformation of the hull was measured using stereo imaging sensors and compared with the results of the fiber-optic sensors. Firstly, the deflection distributions measured using fiber-optic and stereo imaging sensors were verified in a three-point bending test with only the backbone. A hammering test of the backbone was conducted, and dynamic vibration was also measured successfully. Then, a three-point bending test with the ship model was conducted on a surface plate, and it was confirmed that the deflection distribution of the ship model can be estimated using both sensing techniques. In addition, static deformation caused by changes in the weight distribution in still water and dynamic deformation caused by wave loading were measured in a test tank. The results showed that the deflection distributions due to static and dynamic loads could be reasonably estimated, respectively. Hence, it was shown that the deflection distribution of the elastic ship with the backbone can be estimated using stereo imaging and fiber-optic sensors without the backbone or hull material information.

Keywords: Fiber-Optic Sensors, Stereo Imaging Sensors, Elastic Ship Model, Elastic Response.

BILSTM-BASED TIME TO CAPSIZE PREDICTION USING DAMAGED SHIP MOTION DATA

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Abstract. When a marine accident such as a collision or stranding occurs, taking appropriate initial response at an early stage influences on reducing the expand of the accident. Several researches have been conducted to determine the possibility to capsize within the first hour, the status of capsizing if the possibility is high. In this study, we developed a model that classifies the time to capsize into survivability stages based on the motion data of the damaged ship. Survivability stages are classified into 4 stages: capsizing within 15 minutes, 30 minutes, 1 hour, and over 1 hour before capsizing. To obtain the trend estimation in these roll and pitch time series data, the butterworth low-pass filter was adopted in this study. The low-pass filtered roll and pitch data are used as features for the classification model. The classification model for all stages at once can leaded to the overfitting in the training. In order to solve this problem, a deep learning model that classifies into Stage 0 and the rest was initially generated. Since the f1-score of the model classifying Stage 0 and the rest stages using roll and pitch as features is 0.94, it is turned out that the proposed model has a sufficient accuracy. After classifying into Stage 0 and others with this model, a model that classifies into Stage 1, 2, and 3 for non-Stage 0 cases is newly introduced. For the model classifying survivability stages 1, 2, and 3, the model using roll, pitch, and lpf_p as features performed the best, as the f1-score was 0.93, therefore, the proposed model can provide a sufficient accuracy to represent the survivability of capsizing ship.

Keywords: Bidirectional LSTM, Decision Support System, Damage Control System, Time to Capsize Prediction.

MINIMIZATION OF SHIFT FOR CONTAINER STOWAGE PLANNING BASED ON REINFORCEMENT LEARNING

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Abstract. The stowage planning for container ships is the task of allocating containers in a plan to reduce waiting time and costs at a port. Containers have information for sailing such as weight, dimensions, and port of loading and discharge. The stowage planner should consider the information of the containers with hydrostatic data of the container ship, and the navigation route to make optimal stowage plan. However, most planners rely on their experience to decide the location of each container. Therefore, container loading problems take a lot of time, and the results are different for each planner because there are no general rules. In addition, since the number of containers to be loaded increases as the size of the ship continues to grow from the past, there is a limit to the existing method. Methodologies for generating optimal stowage plans for container ship is being proposed to solve this problem. In this study, we introduce reinforcement learning as a method of generating an optimal stowage plan. This method put focus on minimizing the number of shifts. Shift is an unnecessary task that occurs due to POD (Port of discharge), increasing the waiting time at the port. The results were verified by checking the time measurement and objective function were satisfied.

Keywords: Container ship, Reinforcement learning, Shift, Stowage planning.

NECESSITY OF ADVANCED INTEGRATED DIGITAL ENGINEERING & MANAGEMENT (AIDEM) TOOLS

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Abstract. In a viewpoint of successful linkage to build a Smart Seamless Value Chain for the Port, Shipping, Shipbuilding and Vendor's Industries, it should be defined the relations among the industries, also found what is the key factor to give sustainable development of these industries. Nowadays, it also should be very important how to implement the Justification of ESG management with decarbonization through digitalization. In the speech, it would be shown the status of the linkage for the industries, and why it does need their seamless relations for the value chain. It would designate the corner stone to make strategic passage of intelligent linkage through the industrial experiences with lesson learnt.

Keywords: Digitalization, Seamless Value Chain, Sustainable Development, ESG management, integrated Augmented Reality, Seamless Value Chain, Sustainable Development.

DEEP NEURAL NETWORKS WITH ENSEMBLE MODEL FOR HVAC CAPACITY ESTIMATION OF SHIP

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Abstract. HVAC (Heating Ventilation Air-Conditioning) is one of the essential equipment for ships and offshore structures, and is an important safety device. When engineers design HVAC system, it is necessary to estimate reasonable HVAC capacity and equipment to meet a delivery date of a ship's main equipment. However, it is difficult to accurately estimate HVAC capacity that satisfies various condition, such as IMO rules, a ship owner's requirements, and design changes. In this study, we developed a model to estimate the HVAC capacity (Air volume) in the initial design using data from existing ships. We extracted features from HVAC data of ships designed over the past 15 years, and useful combinations of features were selected through statistical analysis. Then, HVAC capacity is estimated by learning a neural network for each feature combination. In addition, an ensemble model is applied to reduce variance by probabilistic characteristics that occur in the learning process of neural networks and improve accuracy. Finally, a final model is selected by comparing the estimated results of test data of a trained single model and an ensemble model. As a result, we analyzed and selected useful features for estimating HVAC capacity from raw design data. Also, we supplemented the performance of a single model and confirmed the possibility of stable estimation through the application of an ensemble model.

Keywords: HVAC (Heating Ventilation Air-Conditioning), Deep-learning, Ensemble model, Capacity estimation, Initial design.

ENERGY EFFICIENCY OF SHIPS

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Abstract. More than 90% of the international trade is transported by ships, and this growth has contributed significantly to increasing the number of emissions from ships, not only from CO_2, but also nitrogen and sulphur oxides, along with particulate matter resulting in around 3% of the world's total greenhouse emissions coming from this sector. The concept of Energy Efficiency Design Index was developed by the IMO as a standard that addresses the lowering of emissions on the sector year by year, focusing primarily on the CO_2. There are several ways to reduce emissions from those ships, ranging from improving engine performance to using alternative fuels with low carbon density. However, it must be noted that merely the employment of one or several of these measures might not be enough to make a significant impact on the EEDI classification or the emissions of the ship, at least not without a considerable cost increase. The emergence of innovative technologies can help mitigate these problems, offering alternatives for more efficient and cost-effective vessels. In this research, various innovative technologies will be examined and described, using a case study of a bulk-carrier ship, and analysing whether the effect they have on the EEDI is significant or not, and which is the most cost-effective option available.

Keywords: Energy efficiency, Ship design, New energy sources, Naval engineering.

MODELLING TUNA PURSE SEINERS FUEL EFFICIENCY IN REAL-WORLD OPERATIONS USING MACHINE LEARNING APPROACHES

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Abstract. Accurate and reliable predictions of ship operating fuel expenditures can significantly increase the ship's operation environmental sustainability and profitability. Given there are general aims of shipping economically and reducing greenhouse gas (GHG) emissions worldwide, fuel consumption needs to be reduced to mitigate operational costs and GHG emissions. Improvement of operational strategies through accurately attributing ship fuel consumption rates to relevant ship operating modes is a way of achieving these aims. This, however, is difficult because the state of the vessel and its machinery systems are not constant (e.g., fouling extent and engine condition). Moreover, the state of the environment (currents, waves and winds) is also not constant. One commercial example where this challenge is particularly acute is in the case of distant fleet fishing operations, where fuel consumption often represents 50% or more of the total operational costs. In this industry there is a demand to develop a decision support system for optimal routing and planning. In this paper, these fishing operations are used to demonstrate a comparison of multiple regression algorithms for a fishing ship's fuel oil consumption prediction model based on two in-situ vessel monitoring systems and environmental conditions forecast from public sources. Based on these data, the Correlation-based Feature Selection (CFS) method is carried out to select the best subset of predictive variables. Multiple regression algorithms are developed and applied, including Linear Regression, Random Forest, XGBoost and Neural Network with the result of Random Forest outperforming the rest of the algorithms for the two fishing vessels. The final selected models show accuracies of over 90% in all the speeds greater than 4 knots when the vessel is not in fishing-related operations but searching for fishing grounds, which accounts for over 90% of the total fuel consumption. From the sensitivity tests carried out on the developed models, it was found that ship speed through water is the variable with critical importance for predicting fuel consumption in both engine operating modes, which contributes to over 94.20% deviation to the baseline in kilograms per nautical mile, followed by month after last drydock (up to 4.34%) and environmental variables (up to 3.30%). This paper considers the practicalities of dealing with the complex data aggregation process from the two distinctly different sources, and demonstrates the relative performance merits of the different algorithms according to key indicators, such as the custom accuracy and the mean absolute error (MAE).

Keywords: FOC prediction, Ship energy efficiency, Multiple regression, Machine learning, Route Optimization.

A SIMPLIFIED FORMULATION OF THE ENERGY EFFICIENCY INDEX FOR PURSE SEINERS

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Abstract. Emission reduction is a very actual and highly investigated topic in maritime sciences. Many research studies are focused on decarbonisation and implementing technical and operational measures to reduce carbon dioxide (CO_2) emissions. The environmental impact of fishing vessels has been neglected for a long time, but by enacting new legislation and general trends, each industrial sector oversees implementing measures to reduce global warming. Fishing vessels are generally powered by low-efficient diesel engines that result in high CO_2 indexes. The obsolescence of the fishing fleet makes it difficult to integrate new technologies and alternative fuels into the existing system, without the necessary analysis and calculations that would provide insight into the effectiveness of such procedures. Decarbonisation of the fishing sector also brings an important social aspect since most vessels operate in the coastal waters and affect the living conditions of the population. This paper is a part of a project aiming to connect fishermen and scientists to improve the environmental friendliness of the Croatian fishing fleet operating in the Adriatic Sea. The possibilities of CO_2 emissions reduction are investigated for 10 fishing vessels with different technical characteristics from the Croatian fishing fleet. 5-year data on fuel consumption and catch of ship is used to calculate CO_2 indexes of diesel-powered vessels. The specificity, when it comes to calculating the carbon footprint of fishing vessels, is the dependence of energy consumption on the type of fish caught. Considering the type of fish, the calculated CO_2 indexes of two purse seiners are compared and an insight into their relative environmental impact is obtained.

Keywords: Fishing vessels, CO_2 index, Alternative fuels, Adriatic Sea, Carbon Footprint.

REAL TIME FUEL CONSUMPTION MEASUREMENTS OF A FLEET OF FISHING VESSELS IN THE ADRIATIC SEA

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Abstract. In recent years, a high focus is set on achieving higher environmental friendliness of vessels through emission reduction and fuel consumption control. Fuel consumption is directly connected to the energy efficiency of a ship and is a crucial factor in analysing its environmental impact and choosing effective optimisation methods. The environmental impact and economic benefit are often calculated using different life-cycle methods, but the equations are mainly based on the estimated values of fuel consumption. Therefore, the results conceal an error, and the extent depends on the resolution of obtained data (daily, weekly, or yearly measurements). The error is especially emphasized when analysing fishing vessels, where the fuel usage is different in various operating modes, such as purse seining, trawling, idling etc. To overcome the mentioned difficulties, fuel monitoring devices are being installed onboard vessels to determine the exact fuel consumption and evaluate the energy efficiency of vessels. This type of research is conducted in the Croatian fishing fleet, on a research group consisting of several purse seiners and trawlers. The paper presents different monitoring devices installed on fishing vessels operating in the Adriatic Sea. The measurements gathered for a purse seiner are presented and discussed. The results are presented for a specific period, taking into account the travelling route. Thus, the paper shows that it is possible to analyse the fuel consumption according to operational modes characteristic of a purse seiner.

Keywords: Fishing vessels, Fuel consumption, Real-time monitoring, Adriatic Sea, Energy efficiency.

CFD PREDICTION OF CAVITATION ON A FULL-SCALE MARINE PROPELLER IN HULL WAKE

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Abstract. There is an increasing interest in CFD predictions of cavitating flows on a full-scale propeller because cavitation-related issues may arise in sea trials and actual ship operations. However, it is challenging to resolve micro-scale cavitation bubbles in CFD simulations on a full-scale propeller due to computational effort. As unsteady propeller cavitation is closely related to hull wake, it is important to take into account hull wake in cavitation simulations. Therefore, the possibility of a practical prediction method is examined by looking into scale effects on propeller cavitation and hull wake separately. Cavitation simulations are made on a 4-bladed propeller by DES with an interphase mass transport model for cavitation modelling and VOF method for multiphase flow modelling. Hull wake is numerically modelled as a propeller inflow instead of including a hull model. CFD simulations are repeated on model- and full-scale propeller models. The CFD result is compared with borescope cavitation observations taken on a full-scale bulk carrier, which is the test case considered in Lloyd's Register Workshop. CFD shows a reasonable agreement with observations in sheet cavitation near the blade tip, but the extent and thickness of tip vortex cavitation are underestimated. When comparing the model- and full-scale simulations, no significant difference is shown in sheet cavitation, but tip vortex cavitation is less extended in the full-scale simulation. When hull wake fields from model- and full-scale bare-hull simulations are applied to the model-scale propeller simulation, overall cavitation is slightly intensified for the model-scale hull wake.

Keywords: Marine propeller, Cavitation, CFD, Hull wake, Scale effect.

NUMERICAL INVESTIGATION OF EFFECT OF REPLACEMENT STATOR WITH SECONDARY ROTOR IN A WATER-JET PROPULSION SYSTEM

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Abstract. In conventional water-jet propulsion systems, the fixed blades of the stator regulate the flow exiting the rotor, thereby reducing the waste of energy. The idea suggested in the present paper is the replacement of the stator with a secondary rotor turning in the opposite direction of the primary rotor. The numerical simulation conducted shows that this change causes a 36.8% rise in the generated thrust and thus increases the thrust ratio to the weight of propulsion equipment. One reason for the lower tendency for using a water-jet propulsion system is the low ratio of the thrust to the weight of propulsion equipment. Improving this ratio can be effective in utilizing this efficient thrust system which is known for high maneuverability and safe operation at low depths.

Keywords: Water-jet Propulsion, Rotor, Stator, Numerical Simulation.

INNOVATIVE TWIN-CRP-POD PROPULSION SYSTEM FOR ULTRA LARGE CONTAINER SHIPS - CHALLENGES AND OPPORTUNITIES

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Abstract. The paper presents possibilities for improvements in ship propulsion efficiency and navigational safety for Ultra Large Container Ships (ULCS). The investigated idea combines three well-known solutions that have never been combined for one ship - twin-screw arrangement, pod propulsors, and contra-rotating propellers (shafts+pods). Each of these specific solutions has the advantage of increased efficiency over the traditional single screw configuration. However, it is interesting to verify how a combined system with all those solutions would operate in actual conditions. Therefore, a project called "twin-crp-pod ULCS" has been established to check the opportunities of this unique idea. In particular, the paper presents challenges related to propulsion systems and equipment arrangement that might be crucial in the design phase. During the analyses, the LNG as the main fuel has been taken into account. It allows for reducing NOx to a level corresponding to ECAs along the US coastline and in the Northern and Baltic Seas in Europe, without the necessity to implement additional equipment like SCR. Additionally, shaft generators of permanent magnet type characterised by very high efficiency were checked, and Energy Stored System (batteries modules), which reduced fuel consumption and improved energy efficiency design index (EEDI), were studied. The paper shows that from the propulsion system point of view, using a twin-crp-pod solution in the case of Ultra Large Container Ships might be an excellent answer to present and coming environmental regulations, although some drawbacks have to be overcome.

Keywords: 16000 TEU, MarTERA, Propulsive efficiency, ECA, EEDI, Ship handling, Model tests.

PROPOSAL FOR A METHOD TO REDUCE PROPELLER VIBRATION THROUGH HARMONIC INJECTION OF MOTOR

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Abstract. The propellers have been used to generate the propulsion of ships with a long history. Many studies have been conducted to improve propulsion efficiency and to reduce vibration by optimizing the shape of propellers. Due to the shape of the stern of the hull, the inflow velocity entering the propeller plane has non-uniform characteristics, which is called a nominal wake. The propeller rotates in the wake, which generates vibration and noise. In terms of the vibration, the fundamental frequency corresponding to the rotation frequency of the propeller is evoked. Moreover, it includes harmonic frequencies caused by the number of propeller blades, which leads to torque ripple and thrust fluctuation. Conventional vessels used by internal combustion engine rotate the propeller directly. It can control only the fundamental torque of the propeller and is difficult to control torque ripple generated by harmonic frequency due to the shape of the propeller. On the other hand, recently, the development of electric propulsion ships using electric motors rather than internal combustion engines is increasing rapidly. The key feature of electric vessels is that the electric motor rotates the propeller, and it has the advantage of having a high speed controllable of the propeller torque. A Permanent Magnet Synchronous Motors (PMSM) and Induction Motors (IM) are used as propulsion motors of typical electric propulsion ships and PMSM is commonly used due to its high power density, large torque to inertia ratio, and high efficiency. A PMSM uses current controller based on Field Oriented Control (FOC), which controls the stator winding current for speed and torque control of the propeller. A torque ripple is generated due to harmonic frequencies contained in back electric magnetic force (EMF) by permanent magnets. To reduce the torque ripple, a harmonic injection method has been conducted. In this paper, the harmonic injection method of the motor is proposed to reduce harmonic frequencies due to the nominal wake and the torque ripple of propeller. This method is applied by the numerical algorithm and CFD (Computational Fluid Dynamics) computation, dynamic simulation.

Keywords: Propeller vibration, Harmonic injection, FFT, Torque fluctuation, PMSM, Electric ship, CFD.

ESTIMATION MODEL OF HYDRODYNAMIC PERFORMANCE USING HULL FORM VARIATION AND DEEP LEARNING

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Abstract. In the design process of hull form, several candidates of hull forms are generated. CFD (Computational Fluid Dynamics) analysis is typically used to evaluate the hydrodynamic performance of the candidates. However, there is a problem that CFD analysis takes a long time to calculate. To solve this problem, in this study, we proposed a method to evaluate the performance within a short time by substituting direct CFD analysis for a deep learning model. Once the deep learning model is trained well, the performance of the hull form can be estimated quickly using the trained model. In this study, the hull forms used to train the model are generated by the parameterized hull form. The performances derived from the CFD analysis are used as a ground truth. As a result, the proposed model can evaluate candidates' performances sufficient to find an optimal hull form.

Keywords: Hull form design, Hydrodynamic performance, Deep learning, CFD (Computational Fluid Dynamics).

ON DIMENSION REDUCTION OF VIBRATION DATA FOR CONDITION MONITORING OF MARINE ENGINES

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Abstract. In this study, we experimentally investigate the use of dimension reduction techniques forvibration-based ship engine condition monitoring by machine learning algorithms. In particular, lineardimension reduction techniques of the principal component analysis (PCA) and the nonnegative matrixfactorization (NMF) are applied to vibration spectrum data to reduce their dimension, and the dataof reduced dimension are used to monitor the engine condition using supervised machine learningalgorithms. The effectiveness of the dimension reduction is evaluated by the fault diagnosis accuracy ofthe machine learning algorithms. When tested with an experimental data of full-scale diesel generator,all faulty cases designated in the experiment were well identified by the employed machine learningalgorithms using the data of reduced dimension. The fault classification accuracy improves as thenumber of dimension increases and after a certain number of dimensions are reached, all faults areidentified accurately and stabilized. This shows that the dimension of the vibration spectrum data canbe considerably reduced without sacrificing the performance of fault classification. Comparison of twodimension reduction techniques shows that the NMF is more advantageous over the PCA at the rangeof dimension where the most machine learning algorithms achieve stable fault classification accuracy.

Keywords: Engine condition monitoring, Vibration analysis, Dimension reduction, Machine learning, Principal component analysis, Nonnegative matrix factorization.

RESEARCH ON SHIP PARTS LAYOUT PROBLEM BASED ON HYBRID IMPROVED GENETIC SIMULATED ANNEALING ALGORITHM

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Abstract. This paper presents a hybrid improved genetic simulated annealing algorithm to solve the problem of two-dimensional irregular parts layout optimization. Firstly, aiming at maximizing the utilization rate of the motherboard, the mathematical model of hull irregular parts layout problem is established with the technological and geometric constraints in the process of parts discharge as constraints. Then vector graph method is used to represent irregular polygons. Finally the hybrid improved genetic simulated annealing algorithm (HIGSAA) based on genetic algorithm (GA) and simulated annealing algorithm (SA) is proposed to solve the optimal layout sequence and rotation angle of parts. HIGSAA is designed with GA as the outer cycle and SA as the inner cycle, and the traditional GA is modified by designing an initial population creation method combining fixed and random, and using a weighted random selection operator, after one iteration of selection, crossover, and variation for individuals from the initial population, all individuals are simulated and annealed using SA as the initial population for the next iteration. HIGSAA takes advantage of both GA and SA to improve global search capability while alleviating the problem of falling into local optimality. The high efficiency of the algorithm is verified by experiments.

Keywords: Irregular parts layout problems, Vector graph method, Heuristic algorithm, Genetic algorithm, Simulated annealing algorithm.

EXPLAINABLE AI FOR SHIP DESIGN ANALYSIS WITH AIS AND STATIC SHIP DATA

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Abstract. Decisions made in the early phases of ship design have a large influence on the capital andoperational expenses of a vessel. In order to support decision making in this phase, big data and machinelearning techniques can be of great use. This work shows how Explainable Artificial Intelligence (XAI) and Global Sensitivity Analysis (GSA) combined with Autonomous Identification System (AIS) and static ship data can be used to find important design characteristics of ships. A data collectionframework is setup that collects AIS data over a five month time period. Static ship design data is usedto predict performance related target features that are calculated from AIS data. By applying XAI andGSA methods to the regression models that predict these target features, insight can be gained on howdesign features influence the performance of ships. Experiments showed that for most ship types, theoverall length is the most important design feature for speed related target features. Besides the overalllength, the draught also has a significant impact on the rotation capabilities.

Keywords: Explainable Artificial Intelligence, AIS, Machine Learning, Global Sensitivity Analysis.

TOWARDS AN EFFECTIVE SHIP DESIGN AND OPERATION TAKING INTO ACCOUNT SURFACE ROUGHNESS

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Abstract. This paper addresses two aspects; fundamental change of design practice optimized for actual operational condition and hull management strategy for operational cost savings when hull surface roughness is considered. The hull surface roughness effect on ship performance is analysed numerically through its various stages of design and operation throughout its life cycle. Five example ships are investigated and they include two tankers, a ro-ro ship, a twin skeg LNG and a twin skeg RoPax. A systematic roughness simulation has been performed for the 5 test ships with 13 partial hull cleaning cases designed to reproduce hull surface treatment events: dry-docking and in-water hull cleanings. The results from the numerical simulation and the roughness/cleaning effect is quantified in terms of percentage increase of EHP/DHP and cleaning efficiency index (CEI), which is defined as the ratio between DHP reduction per unit cleaning area for partial cleaning cases and for full hull surface cleaning. A cost benefit analysis has been performed to illustrate the cost saving potential expected in ship operation by hull maintenance through dry-docking and hull surface cleaning. The present research will provide insight into effective ship design practice considering surface roughness and a cost effective strategy for maintaining the hull surface reducing fuel consumption, industry costs and shipping's carbon footprint.

Keywords: CFD, Surface Roughness, Ship Design, Ship Operation, Dry-Docking, Partial Hull Cleaning, CEI.

EXPLORATION OF WIND PROPULSION: PERFORMANCE AND ECONOMICAL ASSESSMENT FOR A NEWCASTLEMAX BULK CARRIER

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Abstract. Wind propulsion is gaining traction in shipping as a method for fuel and air emissions savings and monitoring of several installations have shown that savings of about 5% to 15% are generally achievable in a retrofit scenario. These achievements are already relevant for the decarbonisation in shipping. However, it is clear that larger savings are possible, particularly when design and operational changes are considered. And there is also the potential to transfer the technology to bigger ships. Further, in general, information on the economic feasibility (without subsidies) is hardly available publically. Finally, routing has shown to be beneficial to increase the performance of wind propulsion. However, it has mostly been shown with the optimising algorithms already knowing exactly how the wind will evolve. In reality this will not be the case. The presented research explores this field. In co-operation with ship owner CMB, NewcastleMax bulk carriers were taken as a study case. These vessels are interesting for savings from wind propulsion due to the relatively low speed and relatively favourable wind on the long routes they sail. Also, with many bulk carriers and tankers sharing similar characteristics, the conclusions are widely relevant.

Keywords: Wind Propulsion, Bulk Carrier, NewcastleMax, Suction Wing, Cost, Payback Period, Routing.

STUDY ON THE SPEED TRIAL OF A LARGE CONTAINER SHIP DURING A COMMERCIAL VOYAGE

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Abstract. This paper covers the overall contents of a speed trial of a large container ship from preparation to execution, as well as the speed-power performance analysis and results of data in real sea condition. The container ship was provided as a test bed from a shipping company. Various onboard measuring equipment and data acquisition systems were mounted on the ship for long-term performance monitoring. To perform a speed trial of the ship during a commercial voyage, the voyage operated under the loading condition very close to the design draft was adopted. The results of speed-power performance obtained in real sea condition are inevitably subjected to various uncertainty factors. In this paper, the influence of systematic error due to the shaft power measurement system of the ship was examined using the Monte Carlo simulation through the uncertainty analysis.

Keywords: Speed trial, Large container ship, Commercial voyage, Speed-power performance, Uncertainty.

A METHOD FOR DIMENSIONING HYBRID POWER SUPPLY SYSTEMS OF SHIPS WITHIN THE EARLY DESIGN STAGE

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Abstract Growing requirements from regulations regarding energy efficiency lead to innovative machinery layouts. A recent trend tends towards hybrid ship drive systems. While these systems may offer a large potential, a thorough analysis is needed as this potential is strongly dependent on the intended purpose, thus on the operational profile. Especially since the additional investment costs have to be recouped through savings in the operation or lower installed power capacity, those systems need to be accurately examined. The early fixing of costs in shipbuilding projects, leads to the necessity of an early and precise evaluation of the drive systems efficiency. The ideal dimensioning of the components of hybrid drive systems determines the actual added value of such a system regarding reduction of emissions and savings of operational costs. In this paper a method for dimensioning hybrid ship power systems with electrical propulsion is introduced. A key importance of the method is using only basic input parameters available in the early design stage, while producing sufficient results for optimal dimensioning. The method uses time series or cumulative density function of the power as input data. Different system configurations can be assessed and compared. The optimal load distribution on the different power suppliers is implemented with a rule-based approach and orientates towards maximum efficiency within the systems technical and specified constraints. For the comparison of different systems, the method provides cost and system relevant results. This includes the fuel consumption, operating hours, state of charge and load cycles for lifetime calculations of the battery.

Keywords: Hybrid, Ship, Calculation Method, Battery, Early Design Stage.

08:30 - Onwards	REGISTRATION		
09:00 - 10:40	31. TECHNICAL SESSIONS Mare II **Propulsion II**	32. TECHNICAL SESSIONS Mare III **Offshore Wind**	33. TECHNICAL SESSIONS Mare IV **Underwater radiated Noise**
	J.H. Kim, B.K. Ahn, T.G. Lee, K.S. Lee: **Numerical Prediction of Face Cavitation on the Marine Propeller** K.G. Varghese, A. Bhattacharyya, O.P. Sha: **Marine Tandem Propellers: Some Design Aspects** R. Kant, A. Bhattacharyya, M.A. Siddiqui, O.P. Sha: **Oscillating Foil Propulsors with Leading-Edge Modifications** H. Vollset Lien, M. Nataletti, K. Henning Halse: **Model tests at different scales for NTNU research vessel Gunnerus** L. Vishnevskii, A. Togunjac: **The Using of Multi-Mode Variable Pitch Propeller on Various Purpose Vessels**	G. Wang, P. Xujie, Z. Zhou, Z. Fang, R. Dou, G. Dong, L. Su, W. Chen: **Some Challenges and Opportunities to Floating Wind: Perspectives of Naval Architects** D.A. Dao, A. Struve, J. Grabe: **Numerical Investigation on the Effect of Anchor Modelling on Anchor Chain-Soil Interaction for Floating Offshore Wind Turbines** S. Kashyap, N. Saha, Z. Jiang: **Blade Load Assessment of an Offshore Wind Turbine under an Earthquake** Y.A. Shankar, S. Kashyap, N. Saha: **Effect of Misaligned Rotor-shaft on Monopile-Supported Offshore Wind Turbine**	M. Perić: **Prediction of Flow and Cavitation in the Tip Vortex of a Ship Propeller** J.Y. Lee, D.S. Cho, M.C. Kim, H.S. Yoon, J.G. Kang, M.I. Kim, S.G. Park, S.Y. Shin: **A Study on the Underwater Radiated Noise Evaluation Method Induced by the Fluctuating Hydrodynamic Pressure of a Submarine Hull and Non-cavitating Propeller** T. Keizer, R. Gaudel, L. Macleane, C. Bae, B. Paterson, D. Tolman: **Experimental Assessment of Uncertainties in Underwater Sound Measurements of Ships** Z. Zhao, N.Z. Chen: **Propagation Characteristics Investigation of Acoustic Emission Signals for Structural Health Monitoring of Wind Turbine Blades**
10:40 - 11:10	Coffee break		

	34. TECHNICAL SESSIONS Mare II **Operation**	35. TECHNICAL SESSIONS Mare III **Renewable energy**	36. TECHNICAL SESSIONS Mare IV **Sloshing & Hydro-structure interactions**
11:10 - 12:50	B. Buchner, B. Abeil, L. Kaydihan, J. Koning, R. van 't Veer: **Research into Container Loss above the Dutch Wadden Islands after the MSC ZOE Incident** H.W. Lee, M.I. Roh, S.H. Ham, B.W. Nam: **Coupled Analysis of the LNG Offloading Operation Based on Multibody Dynamics** M. Hoogeland, H. van der Werf, N. Werter, A. Grammatikopoulos: **Connector Response of a Multibody VLFS Subject to Wave Loading** H. Yu, Y. Li, L.X. Li, X. Yu: **Motion Simulation and Risk Assessment of Dropped Objects in Offshore Operations**	I. Ćatipović, N. Alujević, D. Smoljan, A. Mikulić: **A Review on Marine Applications of Solar Photovoltaic Systems** D.N. Konispoliatis, S.A. Mavrakos, I.K. Chatjigeorgiou: **Hydrodynamic Loading and Mooring Fatigue Estimation of an Offshore Oscillating Water Column Wave Energy Converter** J.H. Lee, K.J. Paik, J. Hwangbo, T.H. Ha, S.H. Shin: **An Experiment and Numerical Study on the Characteristics of Motion and Load for Floating Solar Power Farm in Regular Waves** L. Tang, X. Guo, W. Liu: **Study on Motion Characteristics of Floating HAWT considering Coupling of Aerodynamics and Hydrodynamics**	S. Paboeuf, W. Rehman: **Validation of a Fluid Structure Interaction Tool for Flexible Propellers in Composite Materials** Y. Ahn, J. Lee, T. Park, Y.H. Kim: **Grouping Method for Long-term Prediction of Sloshing Loads on LNG Cargo** H.B. Ju, B.S. Jang: **Prediction of Sloshing Pressure in Membrane Type LNG CCS** H. Wang, J. Chen, W. Duan, S. Ma: **Time-domain TEBEM for Hydroelastic Responses of a Container Ship with Forward Speed**
12:50 - 14:20	**Lunch**		
16:00 - 18:00	**GUIDED CITY TOUR**		

NUMERICAL PREDICTION OF FACE CAVITATION ON THE MARINE PROPELLER

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Abstract. In recent years, according to the increase in size and speed of the ship, the shape of the hull has been changed and the load acting on the propeller surface has been also gradually increasing. Accordingly, cavitation of a different aspect from the existing ones has occurred, and in some cases, cavitation appears not only on the back side of the propeller but also on the face side. Although the effect of face cavitation on the ship has not been quantitatively investigated, it has been expected to reduce the propulsion efficiency of ships by causing additional pressure fluctuations and erosion of propeller blades. However, in the case of face cavitation, the occurrence range is relatively small, so it is difficult to predict with the existing numerical prediction methods. Despite of its importance, it has been estimated and improved depending on model tests and designers' experiences. In this paper, the shape and volume of the face cavity are predicted using an unsteady propeller analysis based on the lifting surface theory. A relatively simple and stable method are used to predict the shape of the face cavitation by comparing the pressure distribution on the face side with the cavitation number. In addition, results are compared with experimental observations to verify the numerical method.

Keywords: Marine Propeller, Face Cavitation, Lifting-Surface Theory, Boundary Value Problem.

MARINE TANDEM PROPELLERS: SOME DESIGN ASPECTS

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Abstract. A tandem propeller configuration consists of multiple co-rotating propellers mounted on the same shaft. The simple design consists of a forward propeller and an aft propeller of generally similar diameter having an axial spacing. One characteristic feature is a high blade pitch of the aft propeller, as it operates at an accelerated and swirling inflow generated in the slipstream of the forward propeller. The present work investigates some critical design aspects which influence the open water performance of each propeller in tandem, and hence the thrust and torque characteristics of the integral unit. While the limited research on tandem propellers includes development of series using a standard pitch difference, it is observed that the thrust performance of the aft propeller is far from optimal. For the aft propeller the advance coefficient calculated using the rotational speed and advance speed is offset by the induced velocities from the forward propeller. This limits the maximum thrust from the tandem propeller, typically for high propeller loading close to the bollard condition. It is observed from CFD investigations that the pressure difference between the pressure and suction sides of the aft propeller blades is considerably lower compared to a single conventional propeller of similar pitch, especially at lower advance coefficients. In the present study, a tandem propeller is designed using vortex lattice lifting-line method considering an optimum circulation distribution over the propeller blades. Under similar thrust loading assumption for the forward and aft propellers, the circulation distribution of the aft propeller is optimised by considering the effect of induced velocities due to the forward propeller, and an optimum radial pitch distribution for both the forward and aft propellers are calculated. From the application point of view, tandem propellers may be used for vessels having certain restrictions in draught and propeller diameter. An inland vessel operating in shallow waters at high propeller loading could be considered as an example

Keywords: Tandem Propellers, Aft Propeller, Radial Pitch Distribution, Vortex Lattice Lifting-Line Method.

OSCILLATING FOIL PROPULSORS WITH LEADING-EDGE MODIFICATIONS

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Abstract. Oscillating propulsors are inspired from the fin-aided swimming mechanisms of aquatic animals. Rigid flapping foils have been widely investigated in this regard, where thrust generation is generally associated with reverse von Kármán vortex street in the wake. We study the hydrodynamic performance of 3-D pitching foils with NACA sections, and investigate the influence of leading-edge modifications on the thrust. The modifications are in the form of humps or protuberances, which are generally linked with post-stall lift enhancement along with a lower maximum static lift. Experiments with oscillating foils are conducted with a baseline design and a modified leading-edge design to understand its influence on thrust and efficiency at the Strouhal number of 0.28. Pitching angle amplitudes of 10 deg and 20 deg are used. It is observed that the influence of the modifications on the thrust depends on the pitching angle. CFD analyses are performed to identify the influence of geometry on the vortex patterns in the wake. The protuberances shed vortices, and hence modify the flow patterns depending on the instantaneous angle of attack. Finally, in order to establish a generic comparison, the influence of foil thickness-chord ratio on the thrust performance is presented using NACA0006, NACA0012 and NACA0021 section hydrofoils. The foil thickness impacts the leading-edge suction peak, and hence the effect of design modifications during pitching motions. It is observed that the thrust coefficient and propulsive efficiency depend on the geometry and pitching amplitude, and the relative performance comparisons depend on the pitching angle.

Keywords: Hydrofoil, Pitching, Leading-edge protuberance, CFD, Experiments, Thrust.

MODEL TESTS AT DIFFERENT SCALES FOR NTNU RESEARCH VESSEL GUNNERUS

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Abstract. Model testing of ship hulls still is the most accurate way of verifying the design calculations prior to construction. With reducing model size, a number of uncertainties appear which will be examined and discussed in this paper. One of the validation points has been to verify the accuracy of model tests results performed in a limited size towing tank compared to tests performed in much larger, commercial test basins. The small basin at Norwegian University of Science and Technology Campus Ålesund is normally used for educational purposes in ship design topics, as well as for verification of hydrodynamic solutions, such as comparing different bow shapes. A 1:48 scale model of the research vessel RV "Gunnerus" was manufactured and towed resistance tests with an unappended hull was conducted in the 11 metres long towing tank. Due to the short towing length and the small size of the model, the achievable accuracy would be expected to be limited. In an effort to quantify this expected inaccuracy, the test results were compared with model tests of a geometrically identical model of scale 1:9.135, performed at SINTEF Ocean test basin in Trondheim in January 2021. The experience gained and the challenges identified from model tests in a small towing tank are discussed. The results may serve as a benchmark for further resistance tests and numerical results as well as correlation with full scale measurements on board the "Gunnerus". In general, the paper demonstrates that the results from calm water resistance test in a small towing tank with a small unappended model hull can within certain limits be relatively reliable.

Keywords: Model test, Calm water resistance, Small scale, Scale effects, Unappended, Comparison.

THE USING OF MULTI-MODE VARIABLE PITCH PROPELLER ON VARIOUS PURPOSE VESSELS

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Abstract. Information about a multi-mode variable pitch propeller (MVPP) and its hydrodynamic characteristics is given. Based on the calculated data, it has been shown that using of MVPP on vessels with various modes of movements, for example, on patrol vessels with a mode of patrolling water areas and of forced mode, the using of such propellers can be very promising from the point of view of improving the sailing performance of the vessel. Moreover, MVPP can perform the functions of two-position variable pitch propellers (CPP), which are considered as propellers for widespread using. The above results can be useful in designing ships for various purposes. The experimental data of the hydrodynamic characteristics of the MVPP and the calculated data are used in the design of a virtual three-shaft security vessel. The obtained data can be used to select the propulsion screw of the designed vessel. It is shown that MVPP, in comparison with fixed pitch propellers, can be a more effective propulsion device in sense of improving the ship's running characteristics.

Keywords: Multi-mode variable pitch propeller, Operational and forced mode, Two-position control pitch propeller.

SOME CHALLENGES AND OPPORTUNITIES TO FLOATING WIND:PERSPECTIVES OF NAVAL ARCHITECTS

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Abstract. With the rapid maturing in technology, harnessing wind energy has become commercially feasible. The majority of existing and planned wind farms worldwide are onshore or near shore in shallow waters. Many upcoming wind farms will be further offshore and in deeper waters, use larger turbines, and demand for lowered LCOE. In meeting with the requirements of society and industries, naval architects have to deal with many challenges in order to find cost-effective and technologically feasible solutions. This paper intends to address some of the technical challenges and also touches upon the potentials and opportunities in technology development. The discussions will be based on surveys of actual projects, research programs, patents, AIPs, rules and standards on a worldwide basis, and also on the experiences of building China's first floating wind platform. Efforts will be made to identify the issues in design, analyses, construction, transportation, installation, in addition to offshore wind farm planning and collaboration with turbine makers, mooring vendors and other stakeholders. Currently, the design of floating wind platform is largely based on adoption of offshore oil and gas industries and their customizations to meet the requirements of IEC. However, fundamentally, the risks associated with offshore wind are very different from those of offshore O & G or of onshore wind. This may also require a change in how we manage risks unique to offshore wind development. A major goal of this paper is to share the perspectives of naval architects in hope of promoting a more successful collaboration among stakeholders to advance this rising new industry of floating wind.

Keywords: Floating Offshore Wind Turbine (FOWT), Offshore Wind Turbine (OWT), Rotor and nacelle assembly (RNA), International Electrotechnical Commission (IEC), Rules, Regulations, Motion performance, Design...

NUMERICAL INVESTIGATION ON THE EFFECT OF ANCHOR MODELLING ON ANCHOR CHAIN-SOIL INTERACTION FOR FLOATING OFFSHORE WIND TURBINES

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Abstract. Floating offshore wind turbines (FOWTs) are moored, e.g., by anchor chains connecting the anchorage in the seabed and the floating unit. At various marine foundation infrastructures, erosion has occurred along the anchoring system, reducing soil resistance. This reduction is assumed to be caused by the anchor chain movement. Numerical simulations in 2D investigating anchor chain-seabed interaction only provide limited results. Also, typical catenary forms resulting from the installation process of drag embedment anchors are usually not considered. In this work, a 3D model of an anchor chain is created. This work investigates the changed stress state in the soil and its deformation due to anchor chain ploughing. Furthermore, different methods of modelling the anchor are compared: Modelling the anchor as fixed bearing, as anchor mass in the first chain segment closest to the anchor shackle or in a separate body allowing anchor displacement. The numerical simulations are based on the finite element method (FEM) with the coupled Euler-Lagrange approach (CEL) due to expected large deformations. The anchor chain is modelled 'wished in place' as an inverse catenary, and the soil is modelled assuming a linear elastic behaviour with Mohr-Coulomb failure criterion. There are significant differences in deformation and in stress distribution in taking anchor mass displacement into account. Both displacement- and force-controlled, the anchor mass was displaced and thus significantly influenced the results. The numerical results show the possibility of better understanding the anchorchain- soil interaction to ultimately ensure a safer and more economical installation of FOWTs.

Keywords: Anchor chain, Floating offshore wind turbine FOWT, Offshore geotechnics, Offshore foundations, CEL.

BLADE LOAD ASSESSMENT OF AN OFFSHORE WIND TURBINE UNDER AN EARTHQUAKE

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Abstract. Monopile-supported offshore wind turbines are being installed under harsh environmental conditions, which may require earthquake load assessment of the various components of the wind turbines. This paper studies the dynamic response of the NREL 5-MW reference wind turbine under the combined wind, wave, and earthquake loads. Three wind speeds have been considered (8 m/s, 11.6m /s, and 16 m/s) with a significant wave height of 5 m and a time period of 12.4 s conforming to the JONSWAP spectrum. Turbulent wind fields (Class A, IEC, Kaimal spectrum) have been simulated. The chosen earthquake event was recorded at Tabas, Iran (1978), with a PGA of 0.8g. Load factors are estimated with the aim of characterizing the earthquake effect on the blade-root moments during operation. Below-rated wind speeds have higher load factors due to the earthquake during operation. The present study observed that the rotor speed does not frequently overshoot beyond the 10% threshold during an earthquake. The blade loads reveal the oscillations about the 2nd natural frequency of the tower At the same time, the blade loads increase by 2.3228 times near the rated-wind speed during operation of the wind turbine in the event of an earthquake. It is also noted that the effect of the earthquake are more pronounced at the lower wind speeds below the rated operational conditions. Counter-intuitively, the extreme loads experienced by the blades are reduced at higher wind speeds during an earthquake. The flap-wise moment is 0.8729 times lower at 16 m/s wind speed in the event of an earthquake. The present study emphasizes a re-evaluation of the extreme blade loads during operation in the event of an earthquake to ascertain structural safety.

Keywords: Wind turbines, Earthquake effects, Rotor over-speed, Blade-root moments, Coupled-modes, Load factors.

EFFECT OF MISALIGNED ROTOR-SHAFT ON MONOPILE-SUPPORTED OFFSHORE WIND TURBINE

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Abstract. Misaligned rotor-shaft appear in wind turbines due to faulty installation or during the lifetime of the structure. In this paper, an attempt is made to study the effect of the rotor-shaft tilt angle on the blade pitch angle, tip clearance, and tower loads for an NREL 5MW offshore wind turbine. These rotor-shaft tilt angles are necessary for avoidance of tower strike of blades. Therefore, in modern wind turbines, a nacelle offset is present. Three different rotor-shaft tilt angles, viz, 3º, 5º, and 8º are chosen for the study. A range of uniform wind speeds (seven values from below-rated to cut-out) is considered along with a significant wave height of 6m and peak period of 10s. The monopile with a rigid foundation (without soil effects) at the water depth of 20m is considered for the given turbine configuration. The present work focuses to analyse the tower base moments, tip clearance, and blade pitch angle for these degrees of misalignment at different wind speeds. In the process, the variation caused by this effect is shown. From the analysis, it is observed that the blade pitch angle is not much affected by the shaft misalignment, also it has been found that with an increase in the degree of misalignment tip clearance increases. The tower base roll moment and tower base torsion are significantly increased at the rated wind speed. The tower base torsion is significantly affected by shaft misalignment as compared to other loads and this loading effect is defined by the torsional load factor.

Keywords: Blade pitch angle, Offshore wind turbine, Tower base loads, Tip clearance, Misaligned shaft.

PREDICTION OF FLOW AND CAVITATION IN THE TIP VORTEX OF A SHIP PROPELLER

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Abstract. Prediction of flow and cavitation in the tip vortex of a ship propeller is challenging, for several reasons. The main reason is the need to accurately resolve high variation of velocity and pressure across the vortex, which requires an extremely fine numerical grid in the tip-vortex zone. In the paper the results of systematic grid refinement, adapted to the location of tip vortex, with control volumes as small as 1/1600th of propeller diameter are presented. The series of three grids enables an estimation of a grid-independent solution. Both non-cavitating and cavitating conditions are studied. In addition, the effect of turbulence model on predicted cavitation within tip vortex is presented. Without adaptive local grid refinement, cavitation within tip vortex may not appear at all. With a sufficiently fine grid, cavitation is predicted with any turbulence model, but eddy-viscosity types of models used when solving the Reynolds-averaged Navier-Stokes equations lead to a too soon decay of cavitation due to excessive turbulent viscosity within tip-vortex zone. Large-eddy simulations, irrespective of the used subgrid-scale model, lead to a realistic prediction of tip-vortex cavitation. Results of simulations are validated against data from experiments performed at SVA Potsdam on the Potsdam Propeller Test Case (PPTC) propeller, which was used as the test case at the smp'11 and smp'15 Workshops.

Keywords: Tip vortex, Cavitation, Adaptive grid refinement, Numerical simulation.

A STUDY ON THE UNDERWATER RADIATED NOISE EVALUATION METHOD INDUCED BY THE FLUCTUATING HYDRODYNAMIC PRESSURE OF A SUBMARINE HULL AND NON-CAVITATING PROPELLER

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Abstract. This paper aims to propose a numerical analysis methodology to evaluate Underwater Radiated Noise (URN) induced by the fluctuating hydrodynamic pressure of submarine hull and propeller under non-cavitating condition. For the purpose, Computational Fluid Dynamics (CFD) analysis using Large Eddy Simulation (LES) turbulence model has been adopted to analyse characteristics of the flow field around the obstacles in the fluid such as a circular cylinder and a submarine hull with a rotating propeller. Also, using CFD analysis results, Ffowcs Williams-Hawkings (FW-H) acoustic analogy has been applied to calculate time-domain acoustic pressures induced by the structures at arbitrary receiver positions. Furthermore, sound pressure levels (SPLs) in frequency domain have been investigated by Fast Fourier Transform (FFT) of time-domain data obtained by FW-H equation. Validity of FW-H acoustic analogy using CFD analysis results with LES turbulence model has been confirmed by numerical analyses for the 2-dimensional circular cylinder model. In addition, acoustic characteristics of the submarine hull with a rotating propeller under non-cavitating condition in free space have been investigated by evaluating time-domain acoustic pressures, SPLs and sound power levels (PWLs) in frequency domain, and directivity patterns derived by the ISO 3744 equivalent method.

Keywords: Underwater Radiated Noise (URN), Submarine, Non-cavitating propeller, Ffowcs Williams-Hawkings (FW-H) acoustic analogy, Computational Fluid Dynamics (CFD).

EXPERIMENTAL ASSESSMENT OF UNCERTAINTIES IN UNDERWATER SOUND MEASUREMENTS OF SHIPS

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Abstract. For six nominally identical road ferries, underwater sound level measurements have been performed by two different parties at two different locations. The first measurements were done using a mobile measurement setup, deployed for each ship trial, in the Black Sea, as part of the Sea Acceptance Trials. After delivery of the vessels to British Columbia, measurements were also performed at the static Underwater Listening Station in the Boundary Pass shipping lane on the route to the port of Vancouver. In this paper the uncertainty in measured underwater sound levels is assessed on basis of these measurements. The obtained statistics have been assessed to identify uncertainties in measuring underwater sound levels resulting from the use of different measurement procedures at different sound ranges and in different environmental conditions, recorded from nominally identical ships. The analysis was conducted for the underwater sound levels expressed in one third octave bands, as well as for frequency bands relevant for evaluation of the impact on the Southern Resident Killer Whale. The results of this assessment are compared with the claimed uncertainties on the basis of ISO 17208-1 and ANSI/ASA S12.64.

Keywords: Uncertainty, Variability, Underwater sound measurements.

PROPAGATION CHARACTERISTICS INVESTIGATION OF ACOUSTIC EMISSION SIGNALS FOR STRUCTURAL HEALTH MONITORING OF WIND TURBINE BLADES

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Abstract. Acoustic emission (AE) is considered as one of promising monitoring approaches for structural integrity management for wind turbine blades. However, there is not much work has been conducted on the investigation of propagation characteristics of AE signals in wind turbine blades though it plays an important role in explaining the generated AE waveform and optimizing the design of sensor layout scheme. This paper aims to investigate the propagation characteristics of AE signals in cross-section structure of wind turbine blade. A semi analytical finite element (SAFE) program is used to obtain the dispersion relations of composite and sandwich structures for wind turbine blades. Numerical simulation is then performed using ABAQUS in combination with modal acoustic emission theory to explore the propagation characteristics of AE signals in cap and trailing panel. The investigation is further broadened to examine the scattering of AE signals with shear web structure, and the reflection and transmission coefficients are calculated to quantify the scattering characteristics. The results show that AE signals undergo "T-shaped" transformation, mode conversion and amplitude attenuation when they pass through the shear web structure. The signal strength of the reflection signals is the strongest and the transmission signals is the weakest. This work investigates the propagation characteristics of AE signals in complex wind turbine blades, giving insight into the waveform interpretation of AE signals in practical engineering application.

Keywords: Acoustic emission (AE), Wind turbine blades, Propagation characteristics, Modal acoustic emission, Mode conversion.

RESEARCH INTO CONTAINER LOSS ABOVE THE DUTCH WADDEN ISLANDS AFTER THE MSC ZOE INCIDENT

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Abstract. In the evening and night of January 1 to 2 of 2019, the Ultra Large Container Ship (ULCS) MSC ZOE lost 342 containers north of the Dutch Wadden Islands in north-westerly storm conditions. This resulted in large-scale pollution of the sea and Wadden Islands. As independent research organisation, MARIN assisted the Dutch Safety Board with an extensive model test campaign. Based on these model tests, it was concluded that the most probable explanations for the loss of containers in the investigated shallow water conditions are: extreme (wave-frequency) ship motions and accelerations, ship contact with the sea bottom, impulsive loading on containers due to green water and slamming-induced impulsive loading on the hull. As a next step, the Dutch Ministry of Infrastructure and Water Management requested MARIN to investigate the behaviour of a wider range of container ships: Feeders (160-170 m), Panamax (290-300 m) and ULCS (390-400 m). Based on model tests, seakeeping calculations, Finite Element calculations on a 40 feet Container and analysis of the present status of cargo securing requirements, MARIN derived preliminary limiting wave heights for these ship types and routes. With wave heights above these limiting wave heights, the loading on the ships and their cargoes can exceed their capacity (safe values). The paper describes the methodologies applied, the results of the analysis and the reasoning behind the derivation of the limiting wave heights.

Keywords: Seakeeping, Container loss, Shallow water, Resonant roll, Green water, Bottom contact, FE analysis.

COUPLED ANALYSIS OF THE LNG OFFLOADING OPERATION BASED ON MULTIBODY DYNAMICS

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Abstract. The demand for LNG offloading operations in which Floating Liquefied Natural Gas (FLNG) delivers LNG to an LNG carrier is increasing in the process of LNG production. However, the analysis of the LNG offloading operation is very complex as ships are connected with offloading arms. Furthermore, the hydrodynamic interaction between the floating bodies should be considered at the same time. In this study, the dynamic analysis of LNG offloading operations with FLNG and LNG carrier considering the interaction of two floating bodies was conducted, and the joint forces exerted on the offloading arms were analyzed. Firstly, the multibody dynamics-based equations of motion were formulated for the analysis of the offloading arms. Subsequently, the external forces due to the hydrodynamic interaction of two floating bodies were calculated in the time domain and integrated with the multibody dynamics. Finally, the coupled analysis of the ships and the offloading arms was performed according to the various parameters of the offloading arms, such as the number, position, and length. As a result, the dynamic loads acting on the joints of the offloading arms were analyzed under various environmental conditions, and the safety regulations for the offloading operation were derived.

Keywords: LNG offloading, Multibody dynamics, Hydrodynamic interaction, Dynamic analysis.

CONNECTOR RESPONSE OF A MULTIBODY VLFS SUBJECT TO WAVE LOADING

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Abstract. The energy transition requires us to explore all options for generating non-fossil energy and offshore floating PV (OFPV) energy is gaining momentum with recent developments quite promising. The trend is to combine small individual floaters into a grid using connectors which can be made reasonably flexible. To address the challenges of offshore conditions the connectors need strength and flexibility. In this paper, the authors address the challenge of the conflicting demands of strength and flexibility for offshore floating structures. The first step is to assess the wave excitation loads between individual elements and how these loads influence the flexibility of a connection. A computational model is developed that uses a 3D BEM (Boundary Element Method) to calculate the linearized hydrodynamic coefficients and the wave diffraction and radiation forces. Meanwhile, the Froude-Krylov, hydrostatic, connector, and mooring forces are time and spatially dependent allowing nonlinearities to be captured. The time domain solution provides answers into the nonlinear interaction between the mechanical behaviour of compliant (flexible) connectors with hydromechanic behaviour of rigid floaters. After a successful validation, a three-floater OFPV system is subjected to typical sea-states representing 1 year and 100 year return on periods. The pitch motion response is compared for both sea-states and wave headings. Then, the forces and moments at the connectors are presented for two connector stiffnesses and sea-states. The head sea case has the greatest force in the axial direction and moment in vertical bending but then the forces and moments in the other DOF are greater in bow quarter seas. There is a decrease in forces but increase in moments when the stiffness of the connectors increases. The results also show the importance of dynamic amplification at sea-states with wave peak periods close to the natural frequency of the system. The connectors are shown to influence the natural frequency of the structure such that it behaves somewhere in between a single continuous structure and three independent floating modules. After successfully using the model to investigate the behaviour of a serially connected OFPV the next step will be to expand to a grid which is more representative of the future types of structures that will be deployed.

Keywords: Offshore Floating Solar, Multibody, Fluid-structure interaction, VLFS.

MOTION SIMULATION AND RISK ASSESSMENT OF DROPPED OBJECTS IN OFFSHORE OPERATIONS

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Abstract. Subsea pipelines are one of the most economic and reliable means of transporting hydrocarbons in offshore oil and gas development. However, some possible hazards, such as dropped objects, may cause damage to pipelines. In this paper, an online database of potential and actual dropped object incidents, called DORIS (Dropped Object Register of Incidents and Statistics) will be briefly introduced at first. Second, motion simulation methods of trajectories of dropped objects in different shapes will be mentioned. Then, the current classification rules about how to deal with the dropped objects in offshore operations will be reviewed. Finally, some ongoing research work about dropped cylindrical objects and container models at University of New Orleans (UNO) will be addressed.

Keywords: Dropped objects, Motion simulation, Risk assessment, Pipeline protection, Det Norske Veritas (DNV).

A REVIEW ON MARINE APPLICATIONS OF SOLAR PHOTOVOLTAIC SYSTEMS

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Abstract. The solar photovoltaic technology costs are continually decreasing. In recent years, efforts have been made towards implementation of solar photovoltaic technology in the marine environment. Currently, floating photovoltaic (FPV) plants for commercial (general purpose) use are installed on lakes and dams as well as on low-wave offshore sheltered locations. Recently, research efforts have been focused towards enabling installation of FPV systems in offshore locations with higher waves where significant wave heights up to 2 or 3 m can be expected. Such trends are beneficial in reducing the use of fossil fuels and consequently slowing down the climate changes as indicated in a number of recent review papers. This review is focused on current mathematical and numerical methods tailored to evaluate the environmental loads and responses of FPV systems installed at sea. For this purpose, available standards and recommendations are used as a guide to identify the main parts and requirements for such evaluations. The review gives recent advancements in the assessment of wind, waves, and sea current loads. The wave motions and mooring calculations are also covered along with the mismatch losses caused by the wave induced motions. On-site testing and field research that are relevant to the environmental loads and FPV responses are presented. Finally, the knowledge gaps are indicated, and possible future research directions are proposed to ensure safer FPV applications in the marine environment.

Keywords: Floating photovoltaic, Marine environment, Offshore locations, Environmental loads, Responses, Mismatch losses.

HYDRODYNAMIC LOADING AND MOORING FATIGUE ESTIMATION OF AN OFFSHORE OSCILLATING WATER COLUMN WAVE ENERGY CONVERTER

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Abstract. This paper summarizes the coupled hydro-mechanical modelling of a moored floating Oscillating Water Column device suitable for offshore wave energy exploitation. The device which is floating in finite depth waters, and it is exposed to the wave action of regular surface waves, consists of an exterior partially immersed toroidal body supplemented by a coaxial interior truncated cylinder, moored through tensioned tethers as a TLP platform. In the formed annulus area between the two solids, water oscillates pushing the dry air above the surface through an air turbine placed at the top of the device's chamber. The considered numerical implementation involves the hydrodynamic modelling of the floater through an analytical method that accounts for the mooring- and the air turbine- characteristics. Numerical results are presented in the frequency domain concerning the motion dynamics of the moored floater. Furthermore, since fatigue damage is known to be a significant issue for moored offshore floating structures, the strength in the mooring system based on the tension forces at the top of the tethers under different design environmental conditions, is simulated under deterministic and probabilistic approaches. The objective of the analysis is to investigate which sea states yield the dominating contribution to fatigue damage accumulation in the offshore OWC, based on wave records near Kassos Island, at the Aegean Sea.

Keywords: OWC device, TLP moorings, Fatigue Analysis, Deterministic, Probabilistic.

AN EXPERIMENT AND NUMERICAL STUDY ON THE CHARACTERISTICS OF MOTION AND LOAD FOR FLOATING SOLAR POWER FARM IN REGULAR WAVES

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Abstract. Recently, the demand for a floating solar power farm is rapidly increasing in lakes or coasts rather than on land. Various studies have been conducted to develop a numerical analysis technique considering the ocean conditions. Through this numerical analysis, structural stability and accurate motion response can be predicted when designing the floating solar farm. In this study, the model tests were at the Inha University Towing Tank (IUTT) to verify the numerical simulation results. The test model was designed as a floating solar farm composed of four units of two rows and two columns that can flexibly respond to external loads. Four motion capture cameras were used to measure the time-series motions of the floating units. Also, four tensiometers and a wave-height meter were installed at upstream points. The numerical results were verified comparing with the experimental data such as the motion characteristics and mooring force s. As a result, the heave and pitch movements were dominant in a head sea condition. When the wavelength was shorter than the total length of the two units, a difference was observed in the motion RAO of the first row and the second row. As the wavelength increased, the heave RAO increased linearly, and the pitch RAO converged. For oblique sea conditions, not only heave and pitch but also roll and yaw occurred, which leads to complex behaviours between the units. With the same wave condition, numerical simulation also showed similar results in motion RAO and mooring force in the head sea condition. Furthermore, various floating solar farms with more than two rows and columns are simulated to investigate in detail the complex interaction between floating units.

Keywords: Floating solar power farm, Wave-induced motion, RAO (Response Amplitude Operator), CFD, Model test.

STUDY ON MOTION CHARACTERISTICS OF FLOATING HAWT CONSIDERING THE COUPLING OF AERODYNAMICS AND HYDRODYNAMICS

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Abstract. Ocean wind energy provides an excellent alternative option due to the shortage of traditional energy resources and many environmental problems caused by carbon emission. Floating Horizontal Axial Wind Turbine (HAWT) has advantage of utilising wind energy at far and deep sea while floating HAWT have the challenge of evaluating the complex load characteristics due to interaction of wave load and wind load. This paper studies motion characteristics of a deep-sea floating HAWT by coupling aerodynamics and hydrodynamics using Computational Fluid Dynamics (CFD). We use CFD platform to calculate HAWT load in gas-liquid two-phase flow field. In the simulation process, the sliding mesh was used to simulate the rotating motion of blades, the overlapping mesh was used to simulate the 6-DOF motion of platform, the VOF method was used to capture the free liquid surface position accurately, and finally, the load characteristics of HAWT were obtained by using multi-mesh thinning technology. NREL-5MW model is selected. The motion response of the floating HAWT is found by analyzing the simulation results. It is indicated from research results that the motion analysis of HAWT under the impeller-platform movement coupling is realized. The methods studied in this paper provide a reference for floating HAWT engineering design.

Keywords: Floating HAWT, Motion characteristics, CFD, Aerodynamic, Hydrodynamic.

VALIDATION OF A FLUID STRUCTURE INTERACTION TOOL FOR FLEXIBLE PROPELLERS IN COMPOSITE MATERIALS

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Abstract. With their interesting mechanical properties, composite materials are a potential alternative to conventional metallic material for propellers. Indeed, in addition to the use of composite materials for their lightweight, lack of corrosion, dampening of vibration and noise, their flexibility offers some advantages to improve hydrodynamic efficiency. However, the design and the certification of flexible propellers are complicated and a hydro-structure coupling analysis is necessary to consider the relatively large deformation of blades. Unfortunately, there is a lack of proper design assessment tools for such flexible composite propellers. This article is about the validation of a design assessment tool known as ComPropApp which is designed by Cooperative Research Ships (CRS) partners within COMPROP Project. ComPropApp is a specially designed tool for the Fluid Structure Interaction (FSI) analysis of propeller made of composite materials. It is based on the explicit two-way coupling of a Boundary Element Method (BEM) solver and a Finite Element Model (FEM) solver which gives it an advantage over Reynolds Averaged Navier Stokes Equations (RANSE) solvers in terms of computation time, power and cost. Moreover, the coupling with the mechanical model is fully implemented in the tool, simplifying the mapping of hydrodynamic pressure along blades. Hence, it is suitable for the initial design stage and for the design review assessment. The validation study is based on numerical simulations using different FSI techniques such as one-way coupling and two-way coupling, implicit and explicit, and results are compared with ComPropApp. FSI simulations use commercial RANSE, STAR-CCM+ and FEM, FEMAP/Nastran solvers and are performed on a full-scale propeller made with carbon fibres coming from the French research project FabHeli. The paper describes the procedure used for the validation and compares results obtained with numerical simulations and ComPropApp. Discrepancies are in an acceptable range and reasons are explained as well as suggested improvements.

Keywords: Composite materials, Propeller, Fluid Structure Interaction (FSI), CFD analysis, BEM-FEM coupling.

GROUPING METHOD FOR LONG-TERM PREDICTION OF SLOSHING LOADS ON LNG CARGO

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Abstract. Sloshing has been a contentious issue in designing a liquefied natural gas (LNG) carrier. To assess sloshing loads, the experimental approach has been the main solution. Consideration of the design lifetime has been suggested to reduce the possible uncertainties of the experiment. However, it has not been a feasible option owing to the incalculable number of experimental cases. The present work proposes a viable solution to use this long-term approach of the sloshing experiment by reducing the number of test conditions. It suggests a grouping method that creates groups of the sea states and reduce the required number of test conditions for the long-term approach. Daewoo Shipbuilding and Marine Engineering Co., Ltd (DSME), Hyundai Heavy Industry Co., Ltd (HHI), Samsung Heavy Industry Co., Ltd (SHI), Korean Register (KR), and Seoul National University (SNU) have conducted an extensive series of joint industrial experiments of six-degree-of-freedom (6DoF) irregular sloshing model test. The second foremost cargo hold of the 174K S-LNGC provided by SHI is used. This series of the experiment constructs long-term analysis fulfilling all considerable sea states. Based on the experimental results, 16 different grouped sea states are proposed and their exceedance probabilities are individually obtained. Their long-term analysis results are compared with that of non-grouping sea states. From this validation, one of the grouping methods that shows the closest to the non-grouping long-term analysis result is presented.

Keywords: Sloshing, Long-term Approach, Sloshing Experiment, Grouping, LNG Design.

PREDICTION OF SLOSHING PRESSURE IN MEMBRANE TYPE LNG CCS

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Abstract. Due to the environmental regulations, the demand for LNG and LNG carriers has been increased. The LNG cargo containment system (LNG CCS) is one of the most important facilities in LNG carriers, and many membrane types of LNG CCS have been developed so far. Time series of sloshing pressures generated in the actual LNG tank is essential for structural health monitoring of LNG CCS. Since, there is still not enough information about the sloshing pressure time history occurring in real LNG tank, in this paper, a method of predicting the sloshing pressure generated on membrane from the stress response measured on hull structure was proposed. The impulse/space superposition method was newly proposed by discretizing the primary membrane where the sloshing pressure is generated. However, the impulse/space superposition method is used to predict the structural response of LNG CCS corresponding to a specific sloshing pressure. Thus, the inverse process of the impulse/space superposition method was established, and the sloshing pressure was predicted from the inner-deck stresses using the least square method. In order to validate the suggested method, a series of fluid-structure interaction simulations were performed. It can be concluded that the sloshing pressure prediction was properly made.

Keywords: Sloshing pressure, LNG CCS, Impulse superposition method, Fluid-structure interaction.

TIME-DOMAIN TEBEM FOR HYDROELASTIC RESPONSES OF A CONTAINER SHIP WITH FORWARD SPEED

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Abstract. In this paper, a numerical method for solving hydroelastic responses of a container ship with forward speed in regular waves is put forward. Firstly, Taylor Expansion Boundary Element Method (TEBEM) is generalized to the elastic modes which is used principally to solve the double body flow and unsteady flow boundary integral equation. The effect of forward speed on the underwater wetted grid is considered when the steady flow is solved by means of TEBEM. The infinity radiation condition is achieved by the Damping Zone Method. In the structure part, the Transfer Matrix Method is used to get the generalized structural mass, damping, stiffness and principal mode of displacement and rotation of vertical oscillation modes which will participate in the subsequent hydrodynamic calculation. In the hydrodynamic part, the first order wave force and hydrostatic restoring force are corresponding to the linear part and the slamming force is corresponding to the nonlinear part. Direct pressure integration on ship wetted surface is used to obtain the first order wave force and the momentum slamming theory is used to predict the slamming load. The fourth-order Runge-Kutta method is used to solve the hydroelasticity equations. Compared with the experimental results, an acceptable agreement can be obtained by TEBEM. Meanwhile, the effects of forward speed and slamming forces are analyzed.

Keywords: Hydroelastic, TEBEM, Time-domain, Slamming loads, Seakeeping.

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