



BOOK OF ABSTRACTS



Belgrade, Serbia
7–10 October 2026



**Book of Abstracts
of the 27th Symposium
on Theory and Practice of Shipbuilding
(SORTA 2026)**

7-10 October 2026, Belgrade, Serbia



University of Belgrade
Faculty of Mechanical Engineering

7-10 October 2026, Belgrade, Serbia

TITLE

Book of Abstracts of the 27th Symposium on Theory and Practice of Shipbuilding (SORTA 2026)

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PREFACE

This book presents the proceedings of SORTA 2026, the 27th Symposium on the Theory and Practice of Shipbuilding, held from 7 to 10 October 2026 in Belgrade, Serbia. The symposium is organized by the Department of Naval Architecture, Faculty of Mechanical Engineering, University of Belgrade, and is held in memory of Professor Leopold Sorta, whose name has become synonymous with one of the longest-standing scientific meetings in the field of shipbuilding, spanning more than five decades.

SORTA 2026 marked the symposium's return to Belgrade after more than four decades. The previous Belgrade edition took place in 1984 and was likewise organized by the Department of Naval Architecture, Faculty of Mechanical Engineering, University of Belgrade.

The long-standing tradition of SORTA demonstrates the enduring importance of shipbuilding science and practice for scientific progress and the sustainable development of the maritime industry. Continuing this tradition, SORTA 2026 brought together researchers, engineers, designers, classification societies, shipyards, and maritime professionals to exchange knowledge and discuss recent scientific and technological developments in shipbuilding and offshore engineering for both maritime and inland navigation.

The symposium program included keynote lectures, scientific and professional papers, and a panel discussion. The papers published in this volume cover a broad spectrum of topics, including ship structures and strength, hydrodynamics and stability, ship design, ship operation, maritime safety, offshore engineering, inland waterway transport, decarbonization, digitalization, artificial intelligence and deep learning applications, and other contemporary challenges. The proceedings reflect current research trends and practical engineering solutions and are intended for researchers, practicing engineers, and maritime professionals alike.

The Book of Abstracts is divided into sections. The first section contains the keynote lectures (invited lectures), while the technical sessions start from the second section. Since the contributions cover maritime ships, inland vessels, offshore structures, and various other types of waterborne structures, the sections are organized according to fundamental topics rather than types of structures. For instance, the second section, Strength, covers the strength of these structures, including loads, structural response, structural design, and related subtopics. The same approach is applied to the other sections: Hydrodynamics, Stability, Design, Operation, Decarbonization & Energy Efficiency & Pollution, Construction, and Education & Heritage. Finally, a poster section is included, along with a list of organizations supporting the conference.

Previous editions of the symposium were held in Zagreb (1974, 1976, 1978), Opatija (1980), Split (1982), Belgrade (1984), Pula (1986), Zagreb (1988),

7-10 October 2026, Belgrade, Serbia

Dubrovnik (1990), Opatija (1992), Dubrovnik (1994), Zagreb (1996), Zadar (1998), Rijeka (2000), Trogir (2002), Plitvice Lakes (2004), Rijeka (2006), Pula (2008), Lumbarda (2010), Zagreb (2012), Baška (2014), Trogir (2016), Split (2018), Rijeka (2020), Malinska (2022), and Zadar (2024).

We would like to express our sincere gratitude to all authors, reviewers, keynote speakers, members of the Scientific, Editorial and Organizing Committees, sponsors, and participants whose contributions made SORTA 2026 possible.

The Editors

SYMPOSIUM TOPICS

Main areas of interest include but are not limited to:

Ship design and hydrodynamics

Marine structures and strength

Offshore engineering and floating systems

Marine propulsion and energy systems

Emission reduction and decarbonization

AI and machine learning in marine engineering

Ship production, repair and retrofitting

Autonomous vessels and digital twins

Education, training, heritage, legal, logistics and

economic aspects of maritime transport

7-10 October 2026, Belgrade, Serbia



SYMPOSIUM PROGRAMME

7-10 October 2026, Belgrade, Serbia

Wednesday, 7 October 2026	
Time	Event
13:00 – 17:30	Shipyard Visit (<u>Argo Navis Shipyard, Belgrade</u>) <i>Bus departs at 13:00 from the main entrance of the Faculty of Mechanical Engineering (address: <u>Kraljice Marije 16</u>)</i>
19:00 – 21:00	Welcome Gathering with Cocktail Dinner <i>Faculty of Mechanical Engineering (address: <u>Kraljice Marije 16</u>), First floor, Library Room</i>

Thursday, 8 October 2026 (Part I)		Hall 211 (Second floor)
Venue: <u>Faculty of Mechanical Engineering (address: <u>Kraljice Marije 16</u>)</u>		
Time	Event	
08:00 – 09:00	Registration	
09:00 – 09:30	Opening Ceremony with Welcome Speeches <i>(Organizing Committee & Dean of the Faculty of Mech. Engineering)</i>	
09:30 – 10:00	Keynote & Invited Lecture (1): Behind the Scenes of CFD Validation: How are Measurements on Actual Ships Performed? <i>Dr. Dmitry Ponkratov (SIEMENS Digital Industries Software)</i>	
10:00 – 10:30	Keynote & Invited Lecture (2): Some Aspects of Hydro-Structure Interactions for Offshore and Naval Applications <i>Dr. Šime Malenica (Bureau Veritas)</i>	
10:30 – 11:00	Keynote & Invited Lecture (3): Review of Challenges in Developing Ships for Polar Waters <i>Prof. Dr. Pentti Kujala (Taltech, Estonian Maritime Academy)</i>	
11:00 – 11:30	Coffee Break	
11:30 – 12:40	Panel Discussion: What Kind of Naval Architects Do We Need for the Future? Moderator: <i>Marko Valčić</i> Panelists: <i>Dr. Dmitry Ponkratov (SIEMENS Digital Industries Software), Dr. Šime Malenica (Bureau Veritas) Prof. Dr. Pentti Kujala (Taltech, Estonian Maritime Academy)</i>	
13:00 – 14:00	Lunch Break	

7-10 October 2026, Belgrade, Serbia

Thursday, 8 October 2026 (Part II)		
Venue: <i>Faculty of Mechanical Engineering (address: Kraljice Marije 16)</i>		
Time	Event	
14:00 – 15:00	Registration Hall 211 (Second floor)	
15:00 – 16:40	Parallel Sessions	
	Hall 211 (Second Floor)	Library Room (First Floor)
	TOPIC: STRENGTH (I) Chairs: Joško Parunov and Jerolim Andrić	TOPIC: HYDRODYNAMICS (I) Chairs: Šime Malenica and Milica Vidić
15:00 – 15:20	Local Strength Analysis of Offshore Platform Deck Grillage Structures under Local Equipment and Storage Loading <i>Dai Zhijie, Ji Yuheng, Li Chuntong and Wang Deyu</i>	Numerical Assessment of Wing-Assisted Propulsion: Case Study <i>Matija Vasilev and Milan Kalajdžić</i>
15:20 – 15:40	Benchmarking Rapid Methods for Midship Vertical Wave Bending Moment Using a Frequency Independent Model Error Metric <i>Joško Parunov, Maro Čorak and Antonio Mikulić</i>	Assessment of the Scale Effects on the Nominal Wake of a Bulk Carrier Through Virtual and Real Fluid Approaches <i>Carlo Giorgio Grij, Nastia Degiuli and Ivana Martić</i>
15:40 – 16:00	Probabilistic Evaluation of MV Arvin Hull Girder Collapse in Black Sea Conditions <i>Nemanja Ilić, Stefan Rudaković and Nikola Momčilović</i>	Hydrodynamic Design of Wake-Adapted Ducted Propellers based on Self-Propulsion CFD Analysis <i>Andriy Pechenyuk and Dean Vučinić</i>
16:00 – 16:20	Structural Design of River Cruise Ships <i>Jerolim Andrić, Josip Andrišić, Stanislav Kitarović, Mateja Tomičić, Dominik Banjedvovec and Luka Jozić</i>	Reconstruction and CFD Validation of Series 60 Hull Forms as a Basis for Bow and Stern Modification Studies <i>Ines Ivković, Matija Vasilev and Milan Kalajdžić</i>
16:20 – 16:40	Comparative Analysis of European Inland Passenger Vessel Panel Buckling Stresses Obtained Using Rule-Based Formulas and Finite Element Analysis <i>Zoran Stanojčić</i>	Quasi-Parametric Local Hull Geometry Optimization <i>Inno Gatin, Robert Keser and Vuko Vukčević</i>
16:40 – 17:10	Coffee Break Room 210 (Second floor)	

7-10 October 2026, Belgrade, Serbia

Thursday, 8 October 2026 (Part III)		
Venue: <i>Faculty of Mechanical Engineering (address: Kraljice Marije 16)</i>		
Time	Event	
17:10 – 18:30	Parallel Sessions	
	Hall 211 (Second Floor)	Library Room (First Floor)
	TOPIC: STRENGTH (II) Chairs: Wang Deyu and Li Chuntong	TOPIC: HYDRODYNAMICS (II) Chairs: Nastia Degiuli and Dean Vučinić
17:10 – 17:30	Structural Assessment of Tender Lifting Points by FEA and Proof Testing <i>Nemanja Ilić and Milan Kalajdžić</i>	A Validated CFD–ROM–FEM Framework for Near Real-Time Thermal Assessment of Cryogenic Hydrogen Carriers <i>Marco La Valle, Tommaso Rosolen, Emiliano Costa, Rodolfo Taccani, Ronelly José De Souza, Nicola Demo, Andrea Martini and Davide Miotti</i>
17:30 – 17:50	Integrated Methodology for Determining the Shear Properties of the Foam Core of Sandwich Panels <i>Davor Bolj, Albert Zamarin, Marko Hadjina and Marino Brčić</i>	Numerical Investigation of Parametric Rolling in Conical Wave-Energy Buoys <i>Anton Turk, Marijana Marjanović, Marko Hadjina and Jasna Prpić-Oršić</i>
17:50 – 18:10	Experimental and Numerical Analysis of Additively Manufactured Polymer Sandwich Structures under Bending and Tension <i>Marino Brčić, Davor Bolj, Martin Brcković, Dominik Roginek and Heshuai Yu</i>	Experimental Studies of the Motion Responses of an Offshore Wind Platform and Supply Vessels in Projects EAGLE and AEROGANP <i>Milica Vidić, Anne Gosset and Marcos Míguez González</i>
18:10 – 18:30	Insights into Offshore Cranes Studies: A Review <i>Andro Dragović, Ana Petrović, Nikola Momčilović, Milan Kalajdžić and Nenad Zrnić</i>	

7-10 October 2026, Belgrade, Serbia

Friday, 9 October 2026 (Part I)		
Venue: <i>Faculty of Mechanical Engineering (address: Kraljice Marije 16)</i>		
Time	Event	
08:15 – 09:00	Registration	
09:00 – 10:20	Parallel Sessions	
	Hall 211 (Second Floor)	Library Room (First Floor)
	TOPIC: STABILITY Chairs: Tomasz Hinz and Stefan Rudaković	TOPIC: DESIGN Chairs: Pentti Kujala and Artur Karczewski
09:00 – 09:20	Impact of Hull Shape on Ships' Vulnerability to Excessive Acceleration: a Parametric Analysis in the Context of the Second Generation Intact Stability Criteria <i>Tomasz Hinz, Karolina Bierkowska, Przemysław Krata, Grzegorz Mazerski and Henrique Gaspar</i>	Regression Models for Estimating Cruise Ship Main Dimensions in the Early Stages of Design <i>Francesco Mauro, Ahmed Salem, Enrico Del Piero, Luca Braidotti, Serena Bertagna and Vittorio Bucci</i>
09:20 – 09:40	A Novel Framework for Stability Assessment of River-Sea Ships <i>Stefan Rudaković and Igor Bačkalov</i>	Empirical Estimation of Interior Outfit Density for Preliminary Design of Floating Residential Units <i>Artur Karczewski and Natalia Wcisło</i>
09:40 – 10:00	Development of Stability Metamodels for the Concept Design of Hard-Chine Small Motor Yachts <i>Enrico Del Piero, Matteo Del Monte, Niccolò Scanavino, Luca Braidotti, Francesco Mauro, Serena Bertagna and Vittorio Bucci</i>	Closing the 3D–2D Gap in Ship Structural Design <i>Aleksa Suvačarov</i>
10:00 – 10:20	Assessment of Yacht Stability Code Limitations through the Bayesian Sinking Case Study <i>Marko Perković, Maciej Gucma, Peter Vidmar and Jure Srše</i>	From Design to Planing: Hull Development and Water Trials of a 6 m Electric Wing-in-Ground Vehicle <i>Zorana Milošević, Daniel Bajo Collados and Sergio Dominguez</i>
10:20 – 10:50	Coffee Break	Room 210 (Second floor)

7-10 October 2026, Belgrade, Serbia

Friday, 9 October 2026 (Part II)		
Venue: <i>Faculty of Mechanical Engineering (address: Kraljice Marije 16)</i>		
Time	Event	
	Parallel Sessions	
	Hall 211 (Second Floor)	Library Room (First Floor)
10:50 – 12:30	TOPIC: DECARBONISATION & ENERGY EFFICIENCY & POLLUTION (I) Chairs: Marijana Marjanović and Josip Orović	TOPIC: OPERATION Chairs: Maciej Gucma and Aqsa Yaseen
10:50 – 11:10	From Dual-Fuel Retrofit to Methanol Newbuildings: A Fleet-Renewal Strategy for Small Passenger Ships <i>Marko Novaselić, Tomislav Bukša and Marko Valčić</i>	Towards Autonomy Crew Transfer and Service Vessels in Offshore Wind Farms: Technologies, Challenges, and Research Gaps <i>Marvin Roshan Crompton Ramesh, Aqsa Yaseen, Inga Zaitseva-Pärnaste and Pentti Kujala</i>
11:10 – 11:30	Impact of Fuel Additives on Passenger Ship Energy Efficiency <i>Vlatko Knežević, Josip Orović, Zoran Pavin and Miroslav Vukičević</i>	A Review: Learning-Based Collision Avoidance Methods for Autonomous Vessels (2021–2025) <i>Aqsa Yaseen, Marvin Roshan Crompton Ramesh, Karl Janson and Pentti Kujala</i>
11:30 – 11:50	Are Container Ships Becoming More Energy Efficient? <i>Matija Vasilev, Milan Kalajdžić, Nikola Momčilović and Filip Miltenović</i>	Digital Twin Applications in Marine Engines <i>Marko Kopic, Dean Bernečić, Goran Vukelić and Tomislav Senčić</i>
11:50 – 12:10	The Impact of Heavy Ballast on the Energy Efficiency of Bulk Carriers <i>Veljko Perović and Milan Kalajdžić</i>	Digital Twin Concepts for Decision-Making in Retrofit, Repair and Maintenance of Hybrid Maritime Power Plants <i>Valentin Bratkov and Pentti Kujala</i>
12:10 – 12:30	Energy System of Methanol Fuelled Ships <i>Ivan Gospić, Luka Grbić, Nastia Degiuli, Mate Barić and Đani Duka</i>	Assessment of Main Engine Replacement on a Seismic Survey Vessel <i>Luka Mijatović, Nemanja Ilić, Matija Kovačević and Milan Kalajdžić</i>
12:45	Group Photo Faculty hall (entrance)	
13:00 – 14:00	Lunch Break	

7-10 October 2026, Belgrade, Serbia

Friday, 9 October 2026 (Part III)		
Venue: <i>Faculty of Mechanical Engineering (address: Kraljice Marije 16)</i>		
Time	Event	
14:00 – 14:40	POSTER SESSION	
	Hi4TrAining: Physics-Based VR Training for Gas and Alternative Fuel Ships - Integration of CFD, Reduced-Order Models and AI into Immersive Maritime Safety Training Environments <i>Marco La Valle, Emiliano Costa, Gianluigi Rozza and Stefano Burigat</i>	
	Integrated Methodology for Determining the Shear Properties of the Foam Core of Sandwich Panels <i>Davor Bolf, Albert Zamarin, Marko Hadjina and Marino Brčić</i>	
	Experimental and Numerical Analysis of Additively Manufactured Polymer Sandwich Structures <i>Marino Brčić, Davor Bolf, Martin Brcković, Dominik Roginek and Heshuai Yu</i>	
	Mapping the Onset of Forced Parametric Resonance in a Conical Wave-Energy Buoy: A Time-Domain Parametric Survey <i>Anton Turk, Marijana Marjanović, Jasna Prpić-Oršić and Marko Hadjina</i>	
	From Dual-fuel Retrofit to Methanol Newbuildings – A Fleet-Renewal Strategy for Small Passenger Ships <i>Marko Novaselić, Tomislav Bukša and Marko Valčić</i>	
	Development of OCX-Based XR Inspection Tool and On-Site Validation in a Shipyard Environment <i>Mladen Radonić and Jan Obić</i>	
	Technological Preparation for Ship Launching After Extended Construction Downtime <i>Jan Obić, Alen Grijak, Marko Hadjina and Anton Turk</i>	
14:40 – 15:40	Confluence Belgrade: 2017-2026 <i>Luka Đoković</i>	
	The Future of Confluence Belgrade <i>Stefan Maletić and Janko Miličević</i>	
	Parallel Sessions	
14:40 – 15:40	Hall 211 (Second Floor)	Library Room (First Floor)
	TOPIC: DECARBONISATION & ENERGY EFFICIENCY & POLLUTION (II) Chair: Marko Valčić	TOPIC: CONSTRUCTION (I) Chairs: Marko Hadjina and Davor Bolf
14:40 – 15:00	Assessment of Propeller-Induced Bottom Wash and Sediment Resuspension of Large Container Ships in Shallow Port Areas <i>Jure Srše, Lucjan Gućma and Marko Perković</i>	Technological Preparation for Ship Launching After Extended Construction Downtime <i>Jan Obić, Alen Grijak, Marko Hadjina and Anton Turk</i>
15:00 – 15:20	A Data-Driven Framework for Biofouling Modelling: Toward a World Biofouling Database <i>Andrej Erceg and Neven Hadžić</i>	Offshore Wind Turbine Nacelle Transport Frame Construction Technology <i>Jan Obić and Alen Grijak</i>
15:20 – 15:40	Evaluation of Air Pollution Constituents, Mitigation Strategies, and their Effectiveness in Apapa and Tin Can Island Seaports, Lagos State, Nigeria <i>Okechukwu Julius Anyanwu, Vivian Ikeogu and Catherine Obasi</i>	Development of OCX-Based XR Inspection Tool and On-Site Validation in a Shipyard Environment <i>Mladen Radonić and Jan Obić</i>
15:40 – 15:50	Coffee Break Room 210 (Second floor)	

7-10 October 2026, Belgrade, Serbia

Friday, 9 October 2026 (Part IV)		
Venue: <i>Faculty of Mechanical Engineering (address: Kraljice Marije 16)</i>		
Time	Event	
15:50 – 16:50	Hall 211 (Second Floor)	Library Room (First Floor)
	TOPIC: EDUCATION & HERITAGE Chair: Vedran Slapničar	TOPIC: CONSTRUCTION (II) Chair: Boris Ljubenkov
15:50 – 16:10	From Software Proficiency to Adaptability: Emerging Competence Paradigms in Mechanical Engineering and Naval Architecture Education <i>Vedran Slapničar and Smiljko Rudan</i>	Analysis of the Application of Arc Stud Welding in a Ship Outfitting <i>Tino Šeparović, Boris Ljubenkov, Ratko Mimica and Ines Bezić</i>
16:10 – 16:30	Naval Architecture in Serbia: Seven Decades of Academic and Professional Collaboration <i>Dejan Radojčić</i>	Application of Artificial Intelligence in the Digitalisation of Shipbuilding Production Processes <i>Meri Skitarelić and Dora Vojnić</i>
16:30 – 16:50	The Bridge on the Barges (A Case of Unconventional Use of Finite Element Method in Ship Hydrostatic Calculation) <i>Milorad Motok</i>	Quality and Quantity Control System for Shipbuilding and Offshore Facilities <i>Marin Dobrović</i>
17:00 – 17:40	Meeting of the SORTA Standing Committee (Closed Session) 104a (First floor)	
17:45 – 18:15	Closing Ceremony Hall 211 (Second Floor)	
20:00 – 23:30	Symposium Dinner Restaurant “IMA DANA” Address: Skadarska 38 (Skadarlija, Belgrade)	

Saturday, 10 October 2026	
Time	Event
09:00 – 13:00	Visit to Shipyard Vahali (Sremska Mitrovica) <i>Bus departs at 09:00 from the main entrance of the Faculty of Mechanical Engineering building</i>
13:00 – 17:00	Excursion to Fruška Gora, Winery Visit & Lunch <i>Bus returns to Belgrade</i>

TABLE OF CONTENTS

KEYNOTE LECTURES	1
Behind the Scenes of CFD Validation: How are Measurements on Actual Ships Performed?	2
<i>Dmitry Ponkratov</i>	
Some Aspects of Hydro-Structure Interactions for Offshore and Naval Applications	3
<i>Šime Malenica</i>	
Review of Challenges in Developing Ships for Polar Waters	4
<i>Pentti Kujala</i>	
STRENGTH	5
Local Strength Analysis of Offshore Platform Deck Grillage Structures under Local Equipment and Storage Loading	6
<i>Dai Zhijie, Ji Yuheng, Li Chuntong and Wang Deyu</i>	
Benchmarking Rapid Methods for Midship Vertical Wave Bending Moment Using a Frequency Independent Model Error Metric	7
<i>Joško Parunov, Maro Čorak and Antonio Mikulić</i>	
Probabilistic Evaluation of MV Arvin Hull Girder Collapse in Black Sea Conditions	8
<i>Nemanja Ilić, Stefan Rudaković and Nikola Momčilović</i>	
Structural Design of River Cruise Ships	9
<i>Jerolim Andrić, Josip Andrišić, Stanislav Kitarović, Mateja Tomičić, Dominik Banjedvorec and Luka Jozić</i>	
Comparative Analysis of European Inland Passenger Vessel Panel Buckling Stresses Obtained Using Rule-Based Formulas and Finite Element Analysis	10
<i>Zoran Stanojčić</i>	
Structural Assessment of Tender Lifting Points by FEA and Proof Testing	11
<i>Nemanja Ilić and Milan Kalajdžić</i>	

7-10 October 2026, Belgrade, Serbia

Integrated Methodology for Determining the Shear Properties of the Foam Core of Sandwich Panels	12
<i>Davor Bolf, Albert Zamarin, Marko Hadjina and Marino Brčić</i>	

Experimental and Numerical Analysis of Additively Manufactured Polymer Sandwich Structures under Bending and Tension	13
<i>Marino Brčić, Davor Bolf, Martin Brcković, Dominik Roginek and Heshuai Yu</i>	

Insights into Offshore Cranes Studies: A Review	14
<i>Andro Dragović, Ana Petrović, Nikola Momčilović, Milan Kalajdžić and Nenad Zrnić</i>	

STABILITY 15

Impact of Hull Shape on Ships' Vulnerability to Excessive Acceleration: a Parametric Analysis in the Context of the Second Generation Intact Stability Criteria	16
<i>Tomasz Hinz, Karolina Bierkowska, Przemysław Krata, Grzegorz Mazerski and Henrique Gaspar</i>	

A Novel Framework for Stability Assessment of River-Sea Ships	17
<i>Stefan Rudaković and Igor Bačkalov</i>	

Development of Stability Metamodels for the Concept Design of Hard-Chine Small Motor Yachts	18
<i>Enrico Del Piero, Matteo Del Monte, Niccolò Scanavino, Luca Braidotti, Francesco Mauro, Serena Bertagna and Vittorio Bucci</i>	

Assessment of Yacht Stability Code Limitations through the Bayesian Sinking Case Study	19
<i>Marko Perković, Maciej Gucma, Peter Vidmar and Jure Srše</i>	

HYDRODYNAMICS 20

Numerical Assessment of Wing-Assisted Propulsion: Case Study	21
<i>Matija Vasilev and Milan Kalajdžić</i>	

Assessment of the Scale Effects on the Nominal Wake of a Bulk Carrier Through Virtual and Real Fluid Approaches	22
<i>Carlo Giorgio Grlj, Nastia Degiuli and Ivana Martić</i>	

Hydrodynamic Design of Wake-Adapted Ducted Propellers based on Self-Propulsion CFD Analysis	23
<i>Andriy Pechenyuk and Dean Vučinić</i>	

Reconstruction and CFD Validation of Series 60 Hull Forms as a Basis for Bow and Stern Modification Studies	24
<i>Ines Ivković, Matija Vasilev and Milan Kalajdžić</i>	
Quasi-Parametric Local Hull Geometry Optimization	25
<i>Inno Gatin, Robert Keser and Vuko Vukčević</i>	
A Validated CFD–ROM–FEM Framework for Near Real-Time Thermal Assessment of Cryogenic Hydrogen Carriers	26
<i>Marco La Valle, Tommaso Rosolen, Emiliano Costa, Rodolfo Taccani, Ronelly José De Souza, Nicola Demo, Andrea Martini and Davide Miotti</i>	
Numerical Investigation of Parametric Rolling in Conical Wave-Energy Buoys	27
<i>Anton Turk, Marijana Marjanović, Marko Hadjina and Jasna Prpić-Oršić</i>	
Experimental Studies of the Motion Responses of an Offshore Wind Platform and Supply Vessels in Projects EAGLE and AEROGANP	28
<i>Milica Vidić, Anne Gosset and Marcos Míguez González</i>	
DESIGN	29
Regression Models for Estimating Cruise Ship Main Dimensions in the Early Stages of Designs	30
<i>Francesco Mauro, Ahmed Salem, Enrico Del Piero, Luca Braidotti, Serena Bertagna and Vittorio Bucci</i>	
Empirical Estimation of Interior Outfit Density for Preliminary Design of Floating Residential Units	31
<i>Artur Karczewski and Natalia Wcisło</i>	
Closing the 3D–2D Gap in Ship Structural Design	32
<i>Aleksa Suvačarov</i>	
From Design to Planing: Hull Development and Water Trials of a 6 m Electric Wing-in-Ground Vehicle	33
<i>Zorana Milošević, Daniel Bajo Collados and Sergio Dominguez</i>	

OPERATIONS

34

Towards Autonomy Crew Transfer and Service Vessels in Offshore Wind Farms: Technologies, Challenges, and Research Gaps

35

Marvin Roshan Crompton Ramesh, Aqsa Yaseen, Inga Zaitseva-Pärnaste and Pentti Kujala

A Review: Learning-Based Collision Avoidance Methods for Autonomous Vessels (2021–2025)

36

Aqsa Yaseen, Marvin Roshan Crompton Ramesh, Karl Janson and Pentti Kujala

Digital Twin Applications in Marine Engines

37

Marko Kopic, Dean Bernečić, Goran Vukelić and Tomislav Senčić

Digital Twin Concepts for Decision-Making in Retrofit, Repair and Maintenance of Hybrid Maritime Power Plants

38

Valentin Bratkov and Pentti Kujala

Assessment of Main Engine Replacement on a Seismic Survey Vessel

39

Luka Mijatović, Nemanja Ilić, Matija Kovačević and Milan Kalajdžić

DECARBONISATION & ENERGY EFFICIENCY & POLLUTION

40

From Dual-Fuel Retrofit to Methanol Newbuildings: A Fleet-Renewal Strategy for Small Passenger Ships

41

Marko Novaselić, Tomislav Bukša and Marko Valčić

The Impact of Heavy Ballast on the Energy Efficiency of Bulk Carriers

42

Veljko Perović and Milan Kalajdžić

Are Container Ships Becoming More Energy Efficient?

43

Matija Vasilev, Milan Kalajdžić, Nikola Momčilović and Filip Miltenović

Impact of Fuel Additives on Passenger Ship Energy Efficiency

44

Vlatko Knežević, Josip Orović, Zoran Pavin and Miroslav Vukičević

Energy System of Methanol Fuelled Ships

45

Ivan Gospić, Luka Grbić, Nastia Degiuli, Mate Barić and Đani Duka

Assessment of Propeller-Induced Bottom Wash and Sediment Resuspension of Large Container Ships in Shallow Port Areas

46

Jure Srše, Lucjan Gućma and Marko Perković

A Data-Driven Framework for Biofouling Modelling: Toward a World Biofouling Database	47
<i>Andrej Erceg and Neven Hadžić</i>	

Evaluation of Air Pollution Constituents, Mitigation Strategies, and their Effectiveness in Apapa and Tin Can Island Seaports, Lagos State, Nigeria	48
<i>Okechukwu Julius Anyanwu, Vivian Ikeogu and Catherine Obasi</i>	

CONSTRUCTION	49
---------------------	----

Technological Preparation for Ship Launching After Extended Construction Downtime	50
<i>Jan Obić, Alen Grijak, Marko Hadjina and Anton Turk</i>	

Offshore Wind Turbine Nacelle Transport Frame Construction Technology	51
<i>Jan Obić and Alen Grijak</i>	

Development of OCX-Based XR Inspection Tool and On-Site Validation in a Shipyard Environment	52
<i>Mladen Radonić and Jan Obić</i>	

Analysis of the Application of Arc Stud Welding in a Ship Outfitting	53
<i>Tino Šeparović, Boris Ljubenkov, Ratko Mimica and Ines Bezić</i>	

Application of Artificial Intelligence in the Digitalisation of Shipbuilding Production Processes	54
<i>Meri Skitarelić and Dora Vojnić</i>	

Quality and Quantity Control System for Shipbuilding and Offshore Facilities	55
<i>Marin Dobrović</i>	

EDUCATION & HERITAGE	56
---------------------------------	----

From Software Proficiency to Adaptability: Emerging Competence Paradigms in Mechanical Engineering and Naval Architecture Education	57
<i>Vedran Slapničar and Smiljko Rudan</i>	

7-10 October 2026, Belgrade, Serbia

Naval Architecture in Serbia: Seven Decades of Academic and Professional Collaboration	58
<i>Dejan Radojčić</i>	

The Bridge on the Barges (A Case of Unconventional Use of Finite Element Method in Ship Hydrostatic Calculation)	59
<i>Milorad Motok</i>	

POSTERS 60

Hi4TrAIning: Physics-Based VR Training for Gas and Alternative Fuel Ships - Integration of CFD, Reduced-Order Models and AI into Immersive Maritime Safety Training Environments	61
<i>Marco La Valle, Emiliano Costa, Gianluigi Rozza and Stefano Burigat</i>	

Integrated Methodology for Determining the Shear Properties of the Foam Core of Sandwich Panels	62
<i>Davor Bolf, Albert Zamarin, Marko Hadjina and Marino Brčić</i>	

Experimental and Numerical Analysis of Additively Manufactured Polymer Sandwich Structures	63
<i>Marino Brčić, Davor Bolf, Martin Brcković, Dominik Roginek and Heshuai Yu</i>	

Mapping the Onset of Forced Parametric Resonance in a Conical Wave-Energy Buoy: A Time-Domain Parametric Survey	64
<i>Anton Turk, Marijana Marjanović, Marko Hadjina and Jasna Prpić-Oršić</i>	

From Dual-fuel Retrofit to Methanol Newbuildings – A Fleet-Renewal Strategy for Small Passenger Ships	65
<i>Marko Novaselić, Tomislav Bukša and Marko Valčić</i>	

Confluence Belgrade: 2017-2026	66
<i>Luka Đoković</i>	

The future of Confluence Belgrade	67
<i>Stefan Maletić and Janko Miličević</i>	

SUPPORTING ORGANIZATIONS 68

SECTION I

KEYNOTE LECTURES

Behind the Scenes of CFD Validation: How are Measurements on Actual Ships Performed?

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Abstract. When you launch a CFD run to compare and validate your case against a ship-scale benchmark, what comes to mind about sea trial measurements? Can you imagine performing sea trials on a cruise liner with 4000 passengers on board? Can you imagine performing sea trials on a tanker in the piracy risk area? And what about night sea trials to illuminate seawater particles and hence measure the flow coming to the propeller? Join Dr Dmitry Ponkratov lecture to learn about these and other hidden stories associated with gaining ship operation data for CFD validation. Dr Ponkratov organised the first scientific project to collect such comprehensive datasets and attended all the sea trials for the vessels in the famous JoResJoint Research Project.

Keywords. Seatrials, CFD, performance, research, joresproject.

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Some Aspects of Hydro-Structure Interactions for Offshore and Naval Applications

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Abstract. Evaluating the structural response of the floating body subjected to water waves represents an essential step in the design process. The practical procedure of design verification considers two main structural failure modes namely the yielding and buckling in extreme conditions and the cracks initiated by fatigue. Even though these two failure modes are fundamentally different, the hydro structure interaction tools and methodologies have many points in common. The structural response basically means the stress distribution as a consequence of the external loading. Various physical phenomena can be of importance depending on the wave conditions and on the structural characteristics of the body. Numerical models need to be able to take those effects into account consistently, which requires rather complex numerical models where the competencies of relevance to both marine hydrodynamics and structural dynamics need to be combined wisely. Strictly speaking, the structural response can be classified into two main categories: static and dynamic. However, in the context of marine structures, there is often a certain misunderstanding observed regarding this separation. The misunderstanding occurs mainly because both the static and the dynamic structural responses are induced by the time varying (i.e. dynamic) loading. However, the fundamental difference in between the static and dynamic structural response lies in the fact that the static response does not account for the structural dynamics (vibrations) while the dynamic response does. At the same time the different variants of the static and dynamic responses are sometimes introduced and denoted as quasi-static or quasi-dynamic, where the term “quasi” is related to the structural loading which is considered to be independent of the structural response (in “quasi-***” approach). In addition, very often the denomination one-way, two-way, full, loose... coupling procedure are used and the clear separation in between these procedures is sometimes confusing. The purpose of the present lecture is to discuss these different aspects of hydro-structure interactions, by considering the practical examples of relevance for marine industry.

Keywords. Hydro-structure interactions, diffraction-radiation analysis, quasi-static and dynamic structural response.

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Review of Challenges in Developing Ships for Polar Waters

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Abstract. Shipping activities in ice-covered water and the design of such ships date back to over one century ago. With ongoing climate change, the number of polar ships is on the increase. Ships sailing through ice-covered regions should be powerful enough to overcome the additional resistance due to ice, and meanwhile strong enough to bear the impact with ice. The methodology of designing polar ships, therefore, differs from that for open-water ships. The keynote talk concentrates on the main challenges related to the design of ships for these harsh environmental conditions. The main topic of the presentation is how to determine adequate ice-strengthening for polar ships through rule-defined scenarios for ice conditions, ice-induced loads, and scantling requirements. This approach has provided a practical and widely accepted basis for polar and ice-going ship design. However, ice class rule based polar ship design has limitations such as: limited ability to account for diverse operational profiles in varying ice conditions, ship varying speed and maneuvering modes are not taken into account, stochasticity of ice loads is not taken into account and current rules cannot distinguish consequence differences among ship types. All these topics will be covered in detail in the keynote and advanced solutions will be presented to overcome the challenges.

Keywords. Ship hull, ice-strengthening, ice class rules, ice loads.

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SECTION II

STRENGTH

Local Strength Analysis of Offshore Platform Deck Grillage Structures under Local Equipment and Storage Loading

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Abstract. Offshore platform decks are frequently subjected to localised equipment and storage loads during module installation, equipment layout, maintenance operations, and temporary deck storage. The loaded area and loading position can significantly affect the stress distribution and deformation response of deck grillage structures. With reference to a typical steel deck grillage used in offshore platform topside structures, a finite element model of a local deck grillage is established in this study. The local equipment/storage load is idealised as a uniformly distributed static pressure acting over a rectangular area, and the maximum von Mises stress, vertical deflection, and safety factor of the structure are investigated under different loaded areas and loading positions. The results show that, for a constant load weight, a smaller loaded area leads to a higher equivalent local pressure and more pronounced stress concentration and local deformation, whereas increasing the supporting area can effectively reduce the structural response. The loading position changes the load-transfer path; the response is most unfavourable in regions without direct support from primary supporting members, while the strength margin is markedly improved when the load is located close to primary supporting members or their intersections. The findings provide a reference for equipment arrangement, temporary deck storage planning, and local strength assessment of offshore platform decks.

Keywords. Offshore platform deck, equipment/storage load, loaded area, loading position, finite element analysis.

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Benchmarking Rapid Methods for Midship Vertical Wave Bending Moment Using a Frequency Independent Model Error Metric

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Abstract. Rapid ship seakeeping methods are particularly attractive when computational efficiency is of primary importance or when detailed hull geometry is unavailable. However, even under these constraints, ensuring a reasonable level of accuracy remains essential. This study compares two widely used rapid methods for estimating transfer functions of the vertical wave bending moment (VWBM) at midship, namely Sikora's method and a closed-form expression (CFE). The comparison is carried out using the Frequency Independent Model Error (FIME) as a measure of model uncertainty, obtained by benchmarking both methods against model-scale experimental data. The results indicate the consistently better performance of Sikora's method for the considered dataset, particularly by demonstrating reduced variability in the model error.

Keywords. Wave bending moments, transfer functions, model uncertainty.

Acknowledgment. This work was supported by the Croatian Science Foundation under the project HRZZ-IP-2022-10-2821.

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Probabilistic Evaluation of MV Arvin Hull Girder Collapse in Black Sea Conditions

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Abstract. This paper extends previous research on the structural failure of the river-sea tanker MV Arvin by introducing a probabilistic assessment of hull girder collapse under Black Sea environmental conditions. Ultimate strength values obtained through the nonlinear finite element method (NLFEM) are adopted as the structural resistance of the vessel, whereas wave-induced bending moments are evaluated by means of linear seakeeping theory for 146,090 representative environmental and operational conditions. A reliability assessment is then performed to evaluate the probability of hull girder failure for each simulated sea state, assuming the loading condition corresponding to the time of the accident. For each realization, the total vertical bending moment is compared with the ultimate hull girder strength to determine whether structural collapse occurs. The proposed methodology enables the quantification of collapse risk under different sea states and provides an overall estimate of the vessel's structural reliability under representative environmental conditions. The results contribute to a better understanding of the structural vulnerability of river-sea vessels operating in exposed maritime environments.

Keywords. Probabilistic assessment, structural reliability, Black Sea environment, MV Arvin, river-sea vessel.

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Structural Design of River Cruise Ships

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Abstract. The structural design of inland cruise ships faces numerous challenges, primarily due to their operational and architectural demands. With limited draft and beam constraints imposed by inland waterways, these vessels must maintain adequate structural strength while incorporating passenger-centric features such as large glass windows, expansive superstructures, and open decks. The paper discusses and highlights the basic challenges in the structural design and analysis of large inland cruise vessels. Inland cruise ships are multi-deck ships characterized by large superstructure side openings generating complex hull-superstructure structural interaction. The length and height of the superstructure is approximately equal to the length and height of the lower hull and its influence on longitudinal strength is very important and should be taken into consideration during the determination of structural elements in the very early design phase. The main results and challenges of 80/110/135m long inland cruise vessels have been briefly presented for all three structural design phases : (1) Concept design phase: design challenges in structural scantling definition of midship section based on prescribed Rule calculation and partial 3D FE model have been described; (2) Preliminary design phase: Global response analysis and verification of longitudinal strength and feasibility calculation (yielding and buckling) has been performed based on the global full ship FE model; (3) Detail design phase: Detail response stress analysis have been performed based on fine mesh FE models of critical details embedded into the global full ship FE model.

Keywords. Inland cruise ship, structural design, hull-superstructure interaction, longitudinal strength.

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Comparative Analysis of European Inland Passenger Vessel Panel Buckling Stresses Obtained Using Rule-Based Formulas and Finite Element Analysis

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Abstract. In recent years large inland waterway (IW) passenger vessel designs are oriented to reduce draft. Vessel structure is therefore further optimized by using thinner plating where acceptable, making buckling criteria more dominant than before. Different classification societies provide different approaches in estimating plate buckling capacity. Also, plate buckling capacity can be estimated using non-linear analysis on sub-models of the vessels where different load combinations, thicknesses and boundary conditions are considered. The objective of the study is to compare the results and limitations of three approaches for assessing plate buckling: (i) a gross scantling-based rule approach, (ii) a net scantling-based rule approach, and (iii) a non-linear finite element analysis (NLFEM) approach. Panels are loaded to mimic stresses resulting from global loads combined with anticipated local loads. The scantlings of the plating, stiffeners, and girders are based on typical European IW passenger vessels built by Vahali Shipyards. For the analyzed case, both the net-based and gross-based rules show good agreement with the analytical solution at larger length-to-width ratios, whereas noticeable deviations among the different approaches are observed at smaller ratios. While the NLFEM approach accounts for factors such as lateral pressure and manufacturing imperfections, the predicted buckling stress is highly sensitive to the assumed imperfection shape and magnitude. However, the method can also reveal additional buckling capacity beyond that predicted by simplified approaches, although at the expense of increased modeling effort and computational cost.

Keywords. Inland passenger vessel, non-linear FEA, buckling, structural design.

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Structural Assessment of Tender Lifting Points by FEA and Proof Testing

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Abstract. Safe launch and recovery operations of man riding tenders depend on lifting arrangements capable of withstanding both operational and proof-test loads while meeting applicable safety regulations. This paper presents the structural assessment and verification of lifting point supporting structures installed on a 6.4 m tender intended for service aboard a commercial yacht. The lifting arrangement consists of three lifting points, one located at the bow and two at the stern, supported by welded stainless-steel structures manufactured from AISI 316L steel. Load distribution among the lifting points was determined using static equilibrium calculations based on the fully loaded condition of the tender, including fuel, equipment, and personnel. The supporting structures were subsequently assessed through finite element analysis (FEA) using detailed 3D models. The analyses considered elastic-plastic material behaviour and were performed in accordance with the requirements of the IMO Life Saving Appliances (LSA) Code and Shipping Notice 04/2021 governing man riding tender lifting arrangements. The numerical assessment identified a localized area within one stern support assembly where the required factor of safety was not achieved. To satisfy the statutory requirements, design optimization was performed by increasing the thickness of the critical structural component. The modified arrangement significantly reduced the maximum von Mises stress and increased the factor of safety above the minimum required value. To validate the analytical results, a full-scale static proof load test was carried out in the presence of an attending surveyor. The tender was loaded in accordance with regulatory requirements and suspended from its lifting arrangement for a specified holding period. Measured loads confirmed the intended loading condition, while post-test inspections revealed no signs of permanent deformation, cracking, or structural damage. The study demonstrates how the combination of finite element analysis, design optimization, and proof-load testing can provide a reliable methodology for verifying lifting arrangements on man riding tenders and ensuring compliance with flag-state and statutory safety requirements.

Keywords. Man riding tender, finite element analysis, structural verification, lifting arrangements, static load testing.

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Integrated Methodology for Determining the Shear Properties of the Foam Core of Sandwich Panels

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Abstract. The paper presents a methodology for determining the shear properties of the foam core of composite sandwich panels and selecting an appropriate material model for use in ship structures, thus enabling a more systematic and reliable application of sandwich panels in shipbuilding. The methodology defines the path from experimental determination of material properties to the selection of an appropriate calculation method and material model. In the experimental part, the ASTM C273 and ASTM C393/C393M procedures are analysed, defining the conditions for their application, their limitations, and the criteria for selecting a suitable testing method. In the numerical part, classification-society tools and the finite element method are considered, with emphasis on selecting the optimal material model in the LS-DYNA software package. The Analytic Hierarchy Process (AHP) multi-criteria decision-making method is applied to evaluate and compare several LS-DYNA material models based on experimentally accessible and literature-based parameters. The results show that the MAT_012/013 model is the most favourable among the observed alternatives for marine sandwich-panel cores. The contribution of this work is threefold: (i) it proposes an integrated workflow that links the choice between ASTM C273 and ASTM C393/C393M with the intended structural application, (ii) it formalises the transfer of experimental shear data into classification-society tools and finite element models, and (iii) it provides a transparent AHP-based procedure for selecting a material model that balances accuracy with practical parameter availability.

Keywords. Sandwich panel, shear test, ASTM C273, FEA, testing methodology, LS-DYNA, AHP method, calculation methodology.

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Experimental and Numerical Analysis of Additively Manufactured Polymer Sandwich Structures under Bending and Tension

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Abstract. This paper consolidates two complementary research studies on 3D-printed polymer sandwich structures into a single manuscript focused on the structural response under bending and tension loading, as an extension of previous work on composite sandwich panels and 3D-printed polymer structures. One study examined three-point bending of sandwich specimens with honeycomb, trapezoidal, and triangular cores, followed by numerical verification and evaluation of hybrid acrylonitrile butadiene styrene (ABS)/polylactic acid (PLA) sandwich configurations. The other investigated tensile behaviour of trapezoidal-core sandwich structures and base polymer specimens made of PLA, ABS, polyethylene terephthalate-glycol (PET-G), and acrylonitrile styrene acrylate (ASA), along with finite element modelling and low-cycle fatigue assessment. By combining these works, the paper establishes a unified design and analysis framework for mechanically interlocked multi-material sandwich panels manufactured by fused-filament fabrication. The combined analysis shows that core geometry, material layout, and joining strategy strongly affect stiffness, stress distribution, and experimental repeatability. In bending, triangular PLA sandwich cores gave the best response among single-material core geometries. At the same time, for hybrid trapezoidal configurations, the PLA–ABS–PLA arrangement was mechanically more favorable than ABS–PLA–ABS because it produced higher reaction force and lower core stress at a given displacement, a trend consistent with typical performance differences between corrugated and honeycomb cores. In tension, the adopted trapezoidal mechanically interlocked concept enabled systematic comparison of mixed-material combinations, and nonlinear numerical simulations reproduced the measured trends with acceptable agreement while also revealing stress concentrations in the interlocking zones. The results support the use of additively manufactured sandwich structures as customisable lightweight components and, by relating the measured behaviour to established sandwich design principles from the literature, highlight the need for careful selection of core topology, material sequence and joining method in future structural applications, in line with design recommendations for composite sandwich structures in the literature.

Keywords. 3D printed sandwich structures, corrugated core geometry, FFF polymer composites, three-point bending and tension, finite element analysis.

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Insights into Offshore Cranes Studies: A Review

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Abstract. Offshore cranes (OCs) are increasingly employed in offshore engineering applications, including marine construction, cargo handling, and the installation and maintenance of offshore platforms, vessels and renewable energy systems. Driven by the expansion of offshore construction activities around the world, increasing safety requirements, and growing scientific interest, the number of publications related to OCs has increased during the last decade, covering a broad range of topics associated with their design, operation, and performance. However, review studies remain limited. Therefore, this study presents a review of more than 100 relevant publications with the aim of examining the development of OCs research, and identifying potential research gaps. OCs operate at the interface between shipbuilding and crane engineering, where differing regulatory frameworks and numerical approaches have resulted in limited research on the global response of crane–vessel systems. In contrast to ship structures and land-based cranes, for which advanced structural and direct calculation procedures are well established, corresponding methodologies for OCs have received less attention in both studies and regulations. The review indicates that most studies focus on operational dynamics to describe crane motions. Few studies address structural behavior, with most focusing on local strength, such as fatigue and buckling of components. The global structural response, including nonlinear behavior, ultimate strength, the influence of movable foundations, and reliability in a coupled OCs–marine environment, remains largely unexplored. These findings identify potential directions for future research on the structural assessment and reliability of OCs.

Keywords. Offshore cranes (OCs), systematic analysis, offshore engineering, global strength.

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SECTION III

STABILITY

Impact of Hull Shape on Ships' Vulnerability to Excessive Acceleration: a Parametric Analysis in the Context of the Second Generation Intact Stability Criteria

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Abstract. The International Maritime Organisation's Second Generation Intact Stability Criteria address complex dynamic failure modes, including excessive acceleration. While Level 2 vulnerability assessments significantly improve safety, they remain computationally intensive during the early stages of ship design. Previous research has demonstrated that surrogate models, particularly Artificial Neural Networks, can provide rapid assessment of these criteria with high predictive accuracy conducting a systematic parametric analysis to quantify the influence of specific hull-geometry parameters on vulnerability to excessive acceleration. Utilising a dataset of 5,000 unique hull configurations generated via parametric CAD modelling (CAESSES) and evaluated using automated stability software, the research examines the sensitivity of the long-term probability index C to variations in both primary dimensions and local hull features. Analysed parameters include Length Between Perpendiculars, beam, bilge radius, deadrise, and flare angle. The results identify critical geometric thresholds for SGISC compliance, providing naval architects with a clearer understanding of the design space. By moving beyond "black-box" AI predictions toward a transparent evaluation of geometric influences, this work offers actionable guidance for optimising vessel safety during the conceptual design phase.

Keywords. Stability, SGISC, geometry, design.

Acknowledgment. We gratefully acknowledge the permission to use the computational resources provided by the Academic Computer Centre in Gdansk (CI TASK).

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A Novel Framework for Stability Assessment of River-Sea Ships

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Abstract. This paper proposes a novel approach to intact stability assessment of river-sea ships, grounded in the Second-Generation Intact Stability Criteria (SGISC) - regulatory framework currently under development by the International Maritime Organization. Due to their distinctive hull characteristics, river-sea ships are identified as vulnerable specifically to the Dead ship condition and Excessive acceleration failure modes, making roll motion in beam wind and waves the central focus of the research. Several important modifications to the SGISC procedures are introduced and justified: the adaptation of environmental conditions to reflect the actual operational areas of river-sea ships, a correction to the eddy damping component of the Simplified Ikeda's Method, and the development of regression-based prediction models for the natural roll period and effective wave slope coefficient as replacements for the SGISC standard methods. The concept of operational limitations with respect to maximum significant wave height is introduced as well. The results demonstrate that, with the proposed modifications, river-sea ships can be effectively assessed within the modified SGISC framework, and that an extended operability range can be achieved while maintaining an adequate level of safety.

Keywords. River-sea ships, ship safety, stability assessment, regulations, ship dynamics, SGISC.

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Development of Stability Metamodels for the Concept Design of Hard-Chine Small Motor Yachts

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Abstract. Hard-chine hulls, characterized by an angular intersection between the bottom and the topsides, are widely adopted in motor yachts, patrol vessels, and workboats for their balance between speed, fuel efficiency, comfort, and operational range. However, valid models for stability assessment developed for displacement and planning vessels are inadequate for hard-chine hulls, given their different hull shapes. This paper presents the development of metamodels to predict intact and damage stability parameters of hard-chine small motor yachts, intended for use during concept design and within multi-criteria decision-making frameworks. Starting from a database of real hull forms, a representative hull dataset was generated using Design of Experiments, employing a Central Composite Design. Stability evaluations were conducted in accordance with the Red Ensign Group Yacht Code 2024. Numerical results were processed using Response Surface Methodology to derive polynomial regression models as functions of non-dimensional geometric parameters. The proposed metamodels show good accuracy within their validity ranges, enabling rapid estimation of stability limits and significantly reducing the need for computationally intensive analyses in early-stage yacht design.

Keywords. Concept design, hard-chine, motor yacht, intact stability, damage stability, multiple linear regression.

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Assessment of Yacht Stability Code Limitations through the Bayesian Sinking Case Study

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Abstract. Although modern sailing yachts are generally designed in accordance with established stability criteria and safety regulations, recent accidents have raised concerns about the effectiveness of these methods in extreme conditions. This paper presents a case study analysis of the sinking of the sailing yacht *Bayesian* off the coast of Sicily. The vessel reportedly encountered an intense downburst or waterspout before capsizing and sinking. A reverse-engineering approach was employed using Maxsurf naval architecture software to reconstruct the vessel geometry and evaluate its intact stability characteristics under various loading and centerboard configurations. The study examines the applicability and limitations of current yacht stability criteria when assessing vessels with exceptionally high rigging, large sail areas, and elevated vertical centers of gravity. Attention is given to aerodynamic heeling moments, rapid wind loading and transient dynamic effects, which are not fully represented in conventional static stability assessment methods. Preliminary findings suggest that compliance with existing stability regulations may not guarantee sufficient resilience against extreme localized meteorological phenomena. The sinking of the sailing yacht *Bayesian* provides an important reference point for discussing potential improvements to stability assessment procedures for modern large sailing yachts with unconventional proportions and high-performance design characteristics.

Keywords. Yacht stability, Bayesian, sailing yacht, capsizes, stability criteria, Maxsurf, reverse engineering, severe weather, naval architecture.

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SECTION IV

HYDRODYNAMICS

Numerical Assessment of Wing-Assisted Propulsion: Case Study

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Abstract. This paper presents a numerical investigation by using Computational Fluid Dynamics (CFD) of a wing-assisted propulsion system intended to reduce the fuel consumption of a RO-RO vessel. The study evaluates a stern-mounted hydrofoil as an Energy Saving Device (ESD) by comparing the original vessel configuration with several wing geometries and angles of attack. Two hydrofoil profiles were considered: a conventional NACA-type profile and a high-lift profile. The assessment combined calm water resistance calculations and self-propulsion simulations using an actuator-disk approach across representative vessel drafts and speeds. The results show that the wing increases viscous resistance because of its added wetted area, but selected geometries reduce pressure resistance, improve dynamic trim, reduce stern-wave amplitude and can generate useful forward thrust. The best performance occurred for the high-lift profile at negative angle of attack, with the optimum indicated at approximately -3 degrees. For the investigated arrangement, fuel oil consumption was reduced by up to 7.7% at design draft and 18 kn, while operation at lower draft showed limited or negative benefit. The findings indicate that wing-assisted propulsion can be an effective ESD when the foil profile, angle of attack and vertical position are matched to the vessel operating envelope.

Keywords. CFD, ESD, energy efficiency.

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Assessment of the Scale Effects on the Nominal Wake of a Bulk Carrier through Virtual and Real Fluid Approaches

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Abstract. The nominal wake is a key parameter in propeller design, as it directly determines the inflow conditions to the propeller and consequently affects propulsion characteristics. Numerical simulations have proven to be a reliable tool for predicting ship hydrodynamic characteristics, and the nominal wake can be extracted from CFD simulations of the resistance test. However, the nominal wake is susceptible to scale effects because the boundary layer developing around the model is relatively thicker than that of the full-scale ship. This study investigates the scale effects on the nominal wake of the Japan Bulk Carrier by means of numerical simulations performed at several model scales and at full scale using the real fluid. The numerical predictions are validated against available experimental measurements and benchmark data from the NMRI workshop. An additional numerical simulation at model scale is conducted using the virtual fluid method in order to simultaneously satisfy Reynolds and Froude similarities. The scale effects on the nominal wake are analysed using contours of the dimensionless axial velocity over the propeller disc, the radial distribution of the circumferentially averaged dimensionless axial velocity, and its integral value. The results demonstrate significant differences between the nominal wakes obtained at model scale and those obtained at full scale with real fluid. In contrast, the nominal wake predicted at model scale using the virtual fluid shows very good agreement with the results obtained at full scale with real fluid.

Keywords. CFD, Japan bulk carrier, scale effects, virtual fluid, Froude similarity, Reynolds similarity.

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Hydrodynamic Design of Wake-Adapted Ducted Propellers based on Self-Propulsion CFD Analysis

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Abstract. Ducted propellers are an efficient type of thruster for vessels operating with high specific power loading. The earliest experiments with ducted propellers involved installing existing marine propellers in makeshift nozzles. Since then, propellers and nozzles specially designed to operate together have been developed. In particular, the Ka-screw series of the NSMB and their modifications, such as the Kv-screw series designed by A. Vučinić (Superina), have played, and still play, an important role in ship design. Further improvement of their hydrodynamic efficiency remains promising, especially under realistic behind-hull operating conditions, where the local characteristics of the wake velocity field may lead to intensive cavitation and vibration. A known approach for addressing similar problems in isolated propellers is hydrodynamic adaptation to the wake velocity field based on lifting-line theory. However, this well-established method cannot be applied directly to ducted propellers, because the nominal wake is significantly modified by the nozzle. An alternative, which is combining individually designed wake-adapted nozzles with standard propellers, provides only a partial effect and considerably complicates production of such asymmetrical nozzles. In the present paper, the authors propose a hydrodynamic design approach for adapting ducted propeller blades based on indirect analysis of the wake velocity field inside the nozzle. The method uses the distribution of thrust forces obtained from self-propulsion CFD analysis. The proposed approach therefore follows the logic of conventional wake-adapted propeller design, but its implementation relies on detailed CFD data that are not accessible through model experiments or other classical methods.

Keywords. Ducted propeller, wake-adapted propeller, CFD, self-propulsion simulation, nozzle-propeller interaction, ship propulsion.

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Reconstruction and CFD Validation of Series 60 Hull Forms as a Basis for Bow and Stern Modification Studies

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Abstract. Experimental investigations of the Series 60 hull forms carried out during the 1950s and 1960s remain one of the most comprehensive hydrodynamic databases available for merchant ship hulls. At that time, available propulsion power was relatively limited and costly, making hull-form optimization one of the most effective ways to improve ship performance. Consequently, systematic experiments covering a wide range of block coefficients were conducted and have remained a benchmark for ship hydrodynamics ever since. Despite their continued use for CFD validation, these hull forms no longer represent contemporary merchant ship geometry, limiting their applicability for investigating modern design concepts. This study aims to reconstruct and validate an extended numerical Series 60 database that preserves direct comparability with the original experimental results while providing a reference platform for future hull-form development. Three-dimensional models of the original Series 60 parent forms were reconstructed from the published geometric definitions, while additional hull forms with block coefficients of 0.55, 0.85, and 0.90 were generated to extend the original series. CFD simulations were performed using Simcenter STAR-CCM+ under conditions corresponding to the historical towing tank experiments, and the numerical predictions of resistance and free-surface wave patterns were compared with the available experimental data. The validated database represents the first stage of a broader research programme aimed at systematically investigating the hydrodynamic effects of contemporary stern and bow modifications while maintaining continuity with one of the most widely recognized experimental benchmark series in ship hydrodynamics.

Keywords. Series 60, computational fluid dynamics (CFD), hull-form reconstruction, hydrodynamic resistance, towing tank validation, merchant ships, hull-form optimization, bow and stern modifications.

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Quasi-Parametric Local Hull Geometry Optimization

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Abstract. Fully parametrized hull geometry model is a powerful tool increasingly used in the ship design process. It facilitates hull geometry optimization both locally and globally, both in terms of hydrodynamic performance as well as other aspects, such as cost and weight. However, generating fully parametric models requires significant effort, know-how, and/or expensive specialized software. This prohibits its use in many ship design projects with limited budgets. In this work, a quasi-parametric description of local hull geometry changes is proposed. This approach describes certain local geometry changes of the existing surface geometry, by using a small number of independent parameters. Low-cost software is utilized for this purpose, namely the Rhinoceros 3D software together with its plug-in Grasshopper. A formal Bayesian optimization is conducted with the use of a surrogate model representing the parameter space. Parameter space evaluation is carried out using RANS CFD to predict calm water resistance or propulsion power for different parameter sets. The initial parameter set is generated using the Design of experiments approach. The proposed workflow produces significant improvements in hydrodynamic hull performance by reducing hull resistance and powering.

Keywords. Hull form parametrization, hull form optimization, Bayesian optimization, CFD.

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A Validated CFD–ROM–FEM Framework for Near Real-Time Thermal Assessment of Cryogenic Hydrogen Carriers

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Abstract. The design of cryogenic hydrogen carriers presents significant thermal and structural challenges due to the extreme operating conditions associated with liquid hydrogen storage ($-253\text{ }^{\circ}\text{C}$). Accurate prediction of temperature distributions within hull structures is essential to ensure structural integrity, material selection and compliance with safety regulations. However, conventional approaches based on simplified analytical models and iterative finite element (FEM) procedures often suffer from limited accuracy in the estimation of convective heat transfer coefficients and high computational costs. This work presents a validated multi-fidelity framework integrating high-fidelity computational fluid dynamics (CFD), reduced-order Models (ROM) and FEM for the thermal assessment of ship structures containing cryogenic tanks. Parametric CFD simulations based on Conjugate Heat Transfer (CHT) are used to generate a database of thermal and convective fields under varying environmental conditions. These data are employed to train data-driven ROMs based on Proper Orthogonal Decomposition (POD) and interpolation techniques, enabling rapid reconstruction of heat transfer coefficients and temperature fields. The ROM outputs are coupled with FEM analyses, replacing traditional iterative procedures. Compared to conventional workflows requiring up to 1–2 days per loading condition, the proposed approach enables near real-time assessments, reducing computational time by more than one order of magnitude. The framework is validated through experimental campaigns and applied to a liquid hydrogen carrier design, including vacuum loss scenarios. Results demonstrate good accuracy and computational efficiency, supporting safer and more efficient cryogenic ship design.

Keywords. Cryogenic hydrogen carriers, thermal analysis, Computational Fluid Dynamics (CFD), Reduced Order Models (ROM), Finite Element Method (FEM).

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Numerical Investigation of Parametric Rolling in Conical Wave-Energy Buoys

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Abstract. A preliminary numerical investigation is presented for the deliberate excitation of parametric rolling in a conical wave-energy buoy operating in regular longitudinal waves. In conventional ship design, parametric resonance is an undesirable dynamic instability to be suppressed. Here the logic is reversed, and the phenomenon is intentionally induced as a mechanism to enhance the energy captured by an ocean wave-energy conversion (OWEC) device. The buoy is modelled as a simple conical form whose hydrostatic and inertial properties are available in closed analytical form, thus enabling efficient and systematic surveys of the geometric conditions most favourable to parametric resonance. Buoy responses are computed in six degrees of freedom (6 DOF) using a nonlinear time-domain seakeeping solver. The restoring coefficients are evaluated for the instantaneous wetted hull at each time step and the equations of motion are integrated with a fourth-order Runge-Kutta scheme, while roll damping is estimated using Miller's method. Simulations were carried out over a range of wave heights (2-6 m) and wavelength-to-length ratios (0.75-2.25). Parametric rolling is found to develop when the wavelength is approximately twice the buoy length, with roll amplitudes reaching about 18° and increasing almost linearly with wave height. Onset occurs at wave heights as low as 2.5 m, well within realistic sea states. The results demonstrate the feasibility of forcing parametric resonance in an unrestrained buoy and motivate further work coupling the device with mooring and power take-off (PTO) systems.

Keywords. Parametric rolling, wave energy conversion, conical buoy, roll damping, ocean wave energy converter, parametric resonance.

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Experimental Studies of the Motion Responses of an Offshore Wind Platform and Supply Vessels in Projects EAGLE and AEROGANP

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Abstract. Floating offshore wind turbines (FOWTs) are one of the pivotal elements of sustainable energy generation with their main advantage being the possibility to install them in areas with stronger and more consistent winds. This, however, also generates challenges, among which are those related to inspection and maintenance operations, during which human crews may be exposed to safety risks. Unmanned aerial vehicles (UAVs) have emerged as a promising alternative for such operations, enabling remote inspection and reducing personnel exposure to hazardous conditions. Nevertheless, their use introduces new operational issues: FOWTs and offshore supply vessels are both subject to wave-induced motions which complicate close-range flights, increase the risk of collision, and make landings more demanding for the UAV. This contribution presents two projects that address the aforementioned challenges. The project EAGLE, financed by the Spanish Ministry of Science, Innovation and Universities, focused on the development of algorithms for autonomous UAV-performed inspection operations and landing. In the second, still ongoing INTERREG POCTEP project AEROGANP, a specialized motion-compensating UAV landing platform is designed for installation on supply vessels to improve landing safety and reliability. In both projects, the development of the corresponding algorithms and control strategies depended on the accurate characterization of the platform and vessel motion responses in mild and moderate wind and wave conditions typical for inspection and maintenance operations. To this end, three experimental campaigns were carried out in the towing tank of the University of A Coruña, providing the motion time series and crucial motion statistical descriptors.

Keywords. Offshore wind, seakeeping, experimental testing, UAV landing, ship motions.

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SECTION V

DESIGN

Regression Models for Estimating Cruise Ship Main Dimensions in the Early Stages of Designs

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Abstract. Cruise ships are complex object to design, requiring the knowledge of multiple aspects of naval architecture and marine engineering. During the concept phase of design, the first step consists in estimating the ship main dimensions as a function of the desiderata of the ship owners. Therefore, it is necessary to provide designers with suitable tools for a fast estimation of the principal ship parameters. The literature reports the availability of simple regression methods and the application of modern machine learning techniques for assessing this issue. The present paper focuses on the traditional regression methods, providing for the first time on cruise ships multiple linear regressions that could be directly applied by designers in the early stages of design. Starting from a database of modern cruise vessels, models have been developed not only for the main dimensions but also for other relevant preliminary attributes like the deadweight, displacement and installed power. The results highlights how the multiple linear regressions provide a good estimate for all the considered parameters, giving to designers an instrument easy to apply.

Keywords. Ship design, regression models, cruise ships, multiple linear regressions.

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Empirical Estimation of Interior Outfit Density for Preliminary Design of Floating Residential Units

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Abstract. The growing popularity of floating residential units and houseboats has created a demand for simplified preliminary design methods supporting rapid estimation of displacement and mass during early-stage naval architectural calculations. One of the key challenges in conceptual design is the estimation of the interior outfit mass, which depends on furnishing arrangements, finishing materials, and the functional layout of accommodation spaces. This paper presents an empirical method for estimating the interior outfit density of floating residential units intended for preliminary design applications. The study is based on a database of 30 contemporary European houseboats produced by 12 manufacturers from Poland, Lithuania, Finland, and the Netherlands. The analysed units were classified according to principal dimensions, residential area, interior layouts, furnishing configurations, and finishing materials. Based on the identified furnishing and finishing solutions, mass calculations were carried out for accommodation spaces, sanitary compartments, kitchen areas, and living spaces. The obtained results were used to derive size-dependent density coefficients and a power-law regression relationship between residential area and interior outfit density. The proposed approach enables simplified prediction of interior outfit mass without the need for detailed interior modelling during conceptual design stages and may support feasibility studies and early-stage optimization of floating residential units.

Keywords. Floating residential units, houseboats, preliminary design, outfit weight estimation, empirical modelling.

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Closing the 3D–2D Gap in Ship Structural Design

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Abstract. Traditionally, ship structural design is developed through a sequence of 2D drawings from which the corresponding 3D model is subsequently created. Modern CAD-based design is gradually reversing this workflow, with the 3D model increasingly serving as the primary design representation and 2D production drawings being derived from it. In practice, however, this transition remains incomplete. Although the structural 3D model exists, 2D drawings are still frequently maintained separately and manually updated whenever structural members are revised, layer conventions change, or new details emerge. The consequence extends beyond increased labour: when the cost of propagating a design change to drawings is high, engineers are implicitly discouraged from iterating. Decisions get committed earlier than the design warrants, the gap between intent and documentation widens, and the manufacturing phase absorbs what the design phase did not resolve. This work describes an approach to closing that gap through purpose-built code for Rhinoceros 3D that provides a hierarchical modelling framework and automates the derivation of 2D section drawings and manufacturing outputs from the organized structural model. Topics covered include the implementation of drafting standards through rule-based automation, consistent generation of drawings across projects, the practical balance between automated output and engineer-controlled annotation, and the current limitations of the approach. The objective is not to replace engineering judgement, but to ensure that engineers focus their effort on designing the vessel rather than maintaining its documentation.

Keywords. Rhinoceros 3D, RapiDraft, ship structural design, structural drawing automation, section drawings, shipbuilding.

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From Design to Planing: Hull Development and Water Trials of a 6 m Electric Wing-in-Ground Vehicle

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Abstract. Wing-in-Ground (WIG) vehicles combine the efficiency of marine transportation with the speed of aircraft by operating in ground effect, close to the water surface. Since the pioneering work of Finnish engineer Toivo Kaario in the 1930s and large-scale Soviet ekranoplan programs of the 1960s-1980s, WIGs have demonstrated their potential, yet publicly available experimental data on their performance remains scarce. The SEAWINGS project is developing an electric WIG vehicle demonstrator. This work presents the hull design methodology and the initial water test campaigns. The prototype features a floating fuselage, a high rectangular wing with four electric motors, and a T-tail. It has a length of 6 m, a wingspan of 5.5 m, and a maximum take-off weight of 160 kg, with a total installed power of 24 kW. The hull was designed following established seaplane design guidelines. Water trials were conducted under representative operating conditions. The first campaign occurred in May 2026 at El Burguillo reservoir near Madrid, with short runs of 50 m. It revealed excessive hydrodynamic drag from the floaters and water spray ingestion by the propellers. The design was subsequently modified: spray rails were added and floaters were raised. A second campaign followed in July 2026 at the Montemor-o-Velho nautical center in Portugal, with runs of up to 300 m. The vehicle reached planing mode with good lateral stability, and propeller spray ingestion was eliminated. These results provide experimental data for small-scale WIG development and validate SEAWINGS hull design ahead of next test phase: water take-off.

Keywords. Wing-In-Ground vehicle, WIG, ekranoplan, hull design, planning, water trials, SEAWINGS.

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SECTION VI

OPERATIONS

Towards Autonomy Crew Transfer and Service Vessels in Offshore Wind Farms: Technologies, Challenges, and Research Gaps

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Abstract. The expansion of the offshore wind farms has increased the need for safe and efficient operations of vessels such as Service Operation Vessels (SOVs) and Crew Transfer Vessels (CTVs) which support offshore operation and maintenance (O&M) activities. Traditional vessel operations remain largely manual, constrained by human limitations and environmental conditions. There are major gaps in understanding emerging technologies such as autonomous SOVs and CTVs, ice strengthened offshore vessels and challenges in operating them. To address these gaps, this review brings forward recent advancements in sensor technologies, vessel automation, and risk assessment methods. Autonomous vessels have the potential to improve operational efficiency, enhance safety, and reduce operating costs in comparison with conventional CTVs and SOVs. However, practical validation of these systems remains limited. This review identifies the key enabling technologies and operational challenges while outlining priorities for future research and development of autonomous CTVs and SOVs.

Keywords. Crew transfer vessels, service operation vessels, wind farms, autonomous vessels.

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A Review: Learning-Based Collision Avoidance Methods for Autonomous Vessels (2021–2025)

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Abstract. Autonomous vessel collision avoidance has become a critical research area in response to the growing development of Maritime Autonomous Surface Ships (MASS) and the increasing complexity of maritime traffic environments. In recent years, machine learning techniques have gained significant attention due to their ability to support adaptive decision-making, trajectory prediction, and situation awareness under uncertain operating conditions. This paper presents a focused review of machine learning approaches for autonomous vessel collision avoidance published between 2021 and 2025. A systematic literature review was conducted across four major scientific databases, resulting in 832 initial records. Following duplicate removal and relevance screening, 445 studies were selected for detailed analysis. To accurately capture methodological diversity, hybrid frameworks were decomposed into individual techniques, yielding 891 method occurrences. From these, 179 machine learning and artificial intelligence methods were identified and analyzed. The results reveal a rapid increase in the adoption of machine learning approaches after 2022, with reinforcement learning emerging as the dominant paradigm. Deep Reinforcement Learning (DRL), Proximal Policy Optimization (PPO), and Deep Q-Network (DQN)-based approaches were the most frequently reported methods. The findings highlight current research trends, identify key challenges related to real-world deployment, and provide insights into future developments of machine learning-driven autonomous vessel collision avoidance systems.

Keywords. Maritime Autonomous Surface Ships (MASS), collision avoidance, intelligent navigation, Machine Learning (ML), Artificial Intelligence (AI), situation awareness.

Acknowledgment. The research was conducted using the research infrastructure “Marine Technology and Hydrodynamics Research Infrastructure MarTech” funded by the Estonian Research Council (TARISTU24-TK6). This activity was also supported as part of DIGIMARIS, an Interreg Central Baltic Programme 2021-2027 project co-funded by the European Union

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Digital Twin Applications in Marine Engines

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Abstract. Digital twin (DT) technology is gaining attention in marine engineering, as it may improve the operation of marine engines under variable loads, harsh operating conditions, and strict emission limits. This study covers research from 2017 to 2025 dealing with the application of the digital twin concept to marine engines. Based on that, a framework for building a marine engine DT is developed and it comprises five elements: physical asset, data collection, digital model, data processing and analytics, and user interface. DTs founded upon that framework are useful for condition monitoring, fault diagnosis, and performance improvement. Additionally, a SWOT analysis has been conducted to assess the main strengths, weaknesses, opportunities, and threats of introducing the DT concept into marine engines. The possibility of applying the DT technology in the existing marine diesel engine is assessed through the project “The development of Marine Diesel Engine Digital Twin (TwinMarine)”, and the results of the initial study are presented. Overall, it can be concluded that DT technology has clear potential, but further development is still needed before it can be used more widely in everyday marine engine operation.

Keywords. Digital twin, marine engine, condition monitoring, predictive maintenance, emission control, maritime digitalization.

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Digital Twin Concepts for Decision-Making in Retrofit, Repair and Maintenance of Hybrid Maritime Power Plants

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Abstract. This paper examines how digital Twin concepts can support retrofit, repair, and maintenance decision-making in hybrid maritime power plants. It addressed the increasing complexity of hybrid and multi-fuel ship power systems, where subsystem interdependence, operational variability, fragmented lifecycle information, and hydrogen-related safety and maturity constraints make lifecycle interventions more difficult to interpret and justify than in conventional maritime power plants. The results showed that Digital Twin support is strongest where lifecycle decision difficulty is primarily informational in nature. Monitoring and diagnostics were found to be most relevant for improving system visibility and interpretation of anomalies, prediction was relevant mainly for maintenance timing and bounded continued operation reasoning, and simulation was most relevant for comparative retrofit reasoning. At the same time, the study showed that Digital Twin does not remove structural complexity, eliminate uncertainty, or replace engineering judgement. Its contribution remains incomplete where lifecycle decision-making is limited by fragmented data, limited interoperability, organisational readiness, and technological and regulatory immaturity with respect to hydrogen.

Keywords. Digital Twin, hybrid maritime power plants, lifecycle decision-making, retrofit, repair, maintenance, system complexity, predictive maintenance, hydrogen integration, maritime digitalisation.

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Assessment of Main Engine Replacement on a Seismic Survey Vessel

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Abstract. This paper presents a study of main engine replacement onboard a seismic survey vessel following a severe overspeed incident that resulted in catastrophic engine damage. Technical assessment confirmed that the engine was beyond economic repair, making complete renewal the only viable option. The primary challenge was the highly constrained engine room arrangement, typical of offshore seismic vessels, where machinery is installed within a compact space offering limited access for major maintenance activities. To evaluate replacement possibilities, a comprehensive 3D laser scanning survey of the engine room was performed. The acquired point cloud data were used to develop an accurate as-built structural model, including the engine foundations, surrounding hull structure, decks, and adjacent equipment. This digital model enabled assessment of several engine removal concepts while considering the existing geometric and structural constraints. Three alternatives were investigated: vertical extraction through deck openings, lateral removal through a side-shell cut-out, and removal of a dedicated hull section incorporating the engine foundation. Each concept was evaluated from structural, operational, and practical perspectives. The analysis demonstrated that conventional extraction methods would require extensive structural modifications and introduce significant operational challenges. In contrast, removal of a predefined hull section was shown to be technically feasible while maintaining structural integrity through temporary reinforcement arrangements. The selected solution allows the engine and foundation structure to be extracted as a single unit, enabling replacement and alignment activities to be carried out in a controlled workshop environment. The proposed approach improves accessibility, installation accuracy, and safety while reducing risks associated with onboard operations. The study demonstrates the value of integrating 3D laser scanning, digital modelling, and engineering assessment when developing practical solutions for complex ship repair and machinery renewal projects.

Keywords. Engine renewal, hull section removal, ship repair, 3D scanning, structural assessment.

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SECTION VII

DECARBONISATION & ENERGY EFFICIENCY & POLLUTION

From Dual-Fuel Retrofit to Methanol Newbuildings: A Fleet-Renewal Strategy for Small Passenger Ships

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Abstract. A large share of Croatia's coastal passenger fleet consists of small, ageing vessels below 5,000 GT, the threshold at which the European Union's main climate instruments for shipping, the Emissions Trading System and the FuelEU Maritime Regulation, currently apply. For now, temporary exemptions covering scheduled island links keep these smaller ships outside the binding targets. That grace period, however, will expire before the decade is out, and as the oldest units approach replacement, their operators will face the tightening greenhouse-gas (GHG) agenda of the International Maritime Organization and the EU with little slack left. Against this backdrop, the study puts methanol at the centre of fleet renewal and appraises it through a ship-design lens. Two routes are set side by side: dual-fuel conversion of in-service vessels, and purpose-built methanol newbuildings. Each is examined for its well-to-wake GHG intensity across grey, bio- and e-methanol, for the design consequences of a low-flashpoint fuel (tank volume, energy-density penalty, onboard safety), and for its fit with maturing class rules and IMO instruments. Preference goes not to what merely clears a single near-term threshold, but to configurations that remain defensible as limits are ratcheted down. From this, a staged renewal framework is distilled for sub-5,000 GT passenger ships that ties each choice to its regulatory deadline, its achievable emission cut, and the best-matched propulsion option, from early retrofit to eventual newbuilding. For operators, yards, and the national administration, it turns the remaining exemption window into an opportunity to prepare for decarbonisation rather than to postpone it.

Keywords. Passenger ships, fleet renewal, methanol, well-to-wake analysis, alternative marine fuels.

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The Impact of Heavy Ballast on the Energy Efficiency of Bulk Carriers

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Abstract. The increasing focus on maritime energy efficiency and emission reduction has placed greater importance on understanding the operational impact of ballast conditions on ship performance. This paper examines the influence of heavy ballast on the energy efficiency of bulk carriers, with particular emphasis on its role as a non-preferential, last-resort operational measure due to its significant hydrodynamic and engineering drawbacks. A marine engineering approach is adopted to evaluate how heavy ballast affects the operational draft, resulting in an increase in wetted surface area and consequently higher hydrodynamic resistance. As a result, propulsion power demand increases, leading to higher fuel consumption during voyage operations. Although heavy ballast may be required to ensure stability and safe operation under specific conditions, it introduces substantial penalties in terms of energy efficiency and overall vessel performance. The Admiralty Constant is used as a simplified performance indicator to evaluate the relationship between speed, displacement, and required power under different ballast conditions. The comparative assessment shows that increased ballast generally reduces energy efficiency despite its operational benefits for maintaining seaworthiness and stability. Operational measures such as route selection and voyage planning under favorable meteorological conditions can often provide a more energy-efficient alternative to sailing with heavy ballast in adverse weather. In many cases, avoiding severe sea states through route optimization is more effective than increasing ballast to improve seakeeping. Overall, heavy ballast should be regarded as a last-resort operational measure, while integrated strategies combining weather routing and ballast minimization offer greater potential for improving the energy efficiency of bulk carrier operations.

Keywords. Heavy ballast, bulk carriers, energy efficiency, Admiralty Constant, hydrodynamic resistance, wet surface area, voyage optimization.

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Are Container Ships Becoming More Energy Efficient?

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Abstract. Container shipping has been subjected to increasing pressure to reduce greenhouse gas emissions and improve energy efficiency. The IMO's short-term measures have accelerated this process and thus significantly influenced both ship design and operation. However, an important question remains largely unanswered: have container ships become genuinely more energy efficient, or have the observed improvements been achieved primarily through reduced operating speeds? In this context, this work presents trends in the development of container ships, ranging from small feeder vessels to ultra-large container ships. Changes in principal dimensions, deadweight, propulsion power, propeller diameter, speed, and energy-efficiency indicators are given to identify the key drivers behind the evolution of container ship design. The results show that, although the overall energy efficiency of container ships has improved, compliance with IMO energy-efficiency regulations has generally declined. The predominant strategy for achieving compliance remains slow steaming, resulting in significant speed reductions across the investigated fleet, achieved through the application of Engine Power Limitation (EPL). As operating speeds continue to decline, the remaining potential for further efficiency improvements through conventional measures becomes limited.

Keywords. Container ships, decarbonization, energy efficiency.

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Impact of Fuel Additives on Passenger Ship Energy Efficiency

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Abstract. The maritime sector is facing increasing regulatory and environmental pressures to reduce greenhouse gas (GHG) emissions while maintaining operational efficiency and economic sustainability. Although alternative marine fuels are widely recognized as a key strategy for maritime decarbonization, their large-scale implementation remains constrained by substantial capital investment requirements, fuel storage and handling limitations. In this context, fuel additives represent a potentially viable short- to medium-term measure for improving the environmental and operational energy efficiency of ships. This research is part of the project Smart Emissions, which aims to reduce exhaust gas emissions and optimize the energy efficiency of passenger ships. The initial exhaust gas measurements were concluded on one stationary marine diesel engine for research tests. Furthermore, this research assesses the potential impact of fuel additive implementation on key maritime energy-efficiency indicators and regulatory frameworks, including the Carbon Intensity Indicator (CII), the Ship Energy Efficiency Management Plan (SEEMP), and the Energy Efficiency Operational Indicator (EEOI). The results demonstrate the potential of fuel additives as an operational measure to enhance energy efficiency, reduce fuel consumption, and support greenhouse gas emission reduction objectives in passenger ship operations.

Keywords. Energy efficiency, fuel additives, exhaust emissions, passenger ships.

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Energy System of Methanol Fuelled Ships

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Abstract. The global shipping industry is increasingly embracing a decarbonisation agenda aimed at reducing greenhouse gas (GHG) emissions through the adoption of modern, energy efficient systems powered by alternative low-carbon fuels, such as natural gas, methanol, ethanol, and carbon-free ammonia. This paper focuses on ship energy systems fuelled by methanol or ethanol as primary fuels. It provides a review of suitable marine dual fuel diesel engines and an analysis of the associated fuel systems, including fuel storage, supply, and distribution subsystems. To this end, contemporary marine dual-fuel engine technologies and their corresponding fuel system configurations are presented in a concise manner. The implementation of methanol fuelled energy systems in the maritime sector is gaining momentum, particularly in container, passenger, and Ro-Ro vessels, driven by regulatory requirements, environmental considerations, and techno-economic incentives. Available data indicate that the widespread adoption of methanol fuelled ships is currently constrained by economic barriers, primarily higher capital investment costs compared with conventional fuel oil-based propulsion systems. These additional costs are largely associated with the technological solutions required for methanol (or ethanol) storage, handling, and utilisation, including specialised fuel-system equipment and safety measures. Nevertheless, future prospects remain favourable, supported by anticipated technological advancements, economies of scale, and policy mechanisms such as subsidies and incentives promoting maritime decarbonisation.

Keywords. Decarbonisation, methanol, ethanol, ship energy systems, marine dual-fuel engines, economic barrier.

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Assessment of Propeller-Induced Bottom Wash and Sediment Resuspension of Large Container Ships in Shallow Port Areas

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Abstract. The continuous growth in the size of container vessels has significantly increased the hydrodynamic impact in shallow and restricted port areas. Although the main engines of modern Ultra Large Container Ships (ULCS) are often operated at reduced power during port maneuvers, the limited under-keel clearance and confined geometry of the basin may still generate intense propeller-induced bottom wash and substantial sediment resuspension. These processes can negatively impact port infrastructure, water quality, sediment transport dynamics, and the redistribution of potentially contaminated seabed material. This paper presents an integrated methodological approach to assessing the effects of bottom wash in shallow port environments, using the Port of Koper as a representative case study. The research combines real maneuver observations, AIS-based traffic analysis, sediment sampling, and numerical hydrodynamic modeling using the MIKE 3 framework. Attention is given to the interaction between vessel propulsion regimes, under-keel clearance, basin geometry, and tug assistance during maneuvering operations. Measured and reconstructed maneuvering scenarios were also implemented in a full-mission bridge simulator to evaluate the potential for operational optimization and reduce environmental impacts through modified maneuvering strategies. The study shows that, even with reduced propulsion power, large container ships can generate significant near-bed flow velocities that can cause sediment erosion and resuspension in shallow port basins. The results obtained contribute to an improved understanding of the hydrodynamic impacts of ships in modern ports, supporting the development of environmentally sustainable maneuvering practices, port planning measures, and advanced simulation-based decision-support tools.

Keywords. Bottom wash, sediment resuspension, container ships, Port of Koper, shallow water, propeller wash, maneuver optimization, MIKE 3, ship simulation, environmental impact.

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A Data-Driven Framework for Biofouling Modelling: Toward a World Biofouling Database

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Abstract. Biofouling development on marine vessel hulls significantly affects hydrodynamic resistance, fuel consumption, emissions and maintenance. Conventional engineering approaches typically represent this process through simplified roughness increments, thereby neglecting the underlying complex biological processes and variability of biofouling formation. In this context, the present work highlights the need for a structured, data-driven biofouling growth modelling approach and introduces the concept of a World Biofouling Database as a foundation for improved prediction and management of hull biofouling. The proposed database is envisioned as a comprehensive repository of species-specific and environment-dependent parameters, including settlement intensity, growth rates, lifespan, and seasonal dynamics. By integrating dispersed experimental results, historical datasets, and literature sources into a standardized framework, the database would enable consistent characterization of biofouling processes across different regions and operational conditions. This, in turn, facilitates comparability between studies and provides normalized input data for advanced modelling techniques. The establishment of such a global data infrastructure represents an important step toward bridging marine biology and naval architecture, supporting informed decision-making in hull maintenance, antifouling strategies, and lifecycle optimization, while simultaneously reducing operational costs and environmental impact.

Keywords. Marine growth, biofouling modeling, vessel performance, ship and offshore structure maintenance, sustainable shipping.

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Evaluation of Air Pollution Constituents, Mitigation Strategies, and their Effectiveness in Apapa and Tin Can Island Seaports, Lagos State, Nigeria

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Abstract. Air pollution generated by shipping, cargo-handling equipment, heavy-duty vehicles, and industrial activities has become a major environmental and public health concern in Nigeria's busiest seaports. This study assessed the constituents of air pollution and evaluated the effectiveness of mitigation measures in Apapa and Tin Can Island Seaports, Lagos State, Nigeria. A mixed-methods research design was adopted, combining experimental air quality monitoring with a descriptive survey of 343 respondents drawn from port operators, terminal operators, regulatory agencies, and other stakeholders. Air quality parameters were measured using calibrated environmental monitoring equipment, while questionnaire data were analyzed using descriptive and inferential statistics at the 0.05 level of significance. Results showed mean carbon monoxide (CO) concentrations of 26.15 ppm in Apapa and 25.74 ppm in Tin Can Island, exceeding both the World Health Organization (WHO) guideline (4.00 ppm) and the Nigerian National Ambient Air Quality (NAAQ) standard (8.73 ppm). Nitrogen dioxide (NO₂) and sulphur dioxide (SO₂) concentrations were below NAAQ limits but above WHO guideline values, while carbon dioxide (CO₂) and hydrocarbons (HC) reflected continued emissions from port activities. Mitigation measures, including truck traffic management, cleaner fuel initiatives, equipment maintenance, environmental monitoring, vehicle inspections, and regulatory enforcement, contributed to improved air quality but were limited by weak enforcement, aging infrastructure, inadequate monitoring facilities, and poor compliance with environmental regulations. The study concludes that current mitigation measures are inadequate for sustainable air quality management. It recommends strengthening regulatory enforcement, implementing Emission Control Areas (ECAs), and enhancing stakeholder collaboration to improve environmental sustainability in Nigerian seaports.

Keywords. Air constituents, mitigation measures, Apapa Seaport, Tin Can Island Seaport, air quality.

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SECTION VIII

CONSTRUCTION

Technological Preparation for Ship Launching After Extended Construction Downtime

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Abstract. The paper addresses the investigation and description of the preparation of a ship for launching after an extended period of construction downtime, due to shipyards financial collapse and client's subsequent contract termination. The research is based on the specific case of the vessel Yard 526 at the Uljanik Shipyard, whose construction had been suspended. The construction stoppage required a detailed assessment of the current condition of the slipway and associated equipment. Particular attention was given to determining the vessel's settlement on the slipway and establishing its actual position on the blocks. As part of the analysis, a thorough inspection of the blocks and launching equipment was conducted, with special emphasis on identifying and rectifying inadequate or damaged blocks. Factors influencing the ship's keel height relative to the slipway line were analyzed, as this relationship has a significant impact on safety during the launching process. Due to the novel circumstances, a revision of the launching methodology was performed, and the timelines for all phases of pre-launch activities were accordingly adjusted and described.

Keywords. Shipbuilding delays, ship launching, livestock carrier, corrosion, preparatory works.

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Offshore Wind Turbine Nacelle Transport Frame Construction Technology

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Abstract. The fabrication of the transport frame for an offshore wind turbine substructure relies on precise welding procedures, strict dimensional control, and optimized resource management. Central to the process is the elimination of any additional machining and hot work for and after flange installation, while clearly defining pre-welding methods. Used welding method is gas metal arc welding. The process requires high precision, allowing a maximum addition of +1 mm per joint element, which can be trimmed after assembly if necessary. Each weld is ground flush with the parent material. Visual and non-destructive testing control is emphasized at every stage. According to the welding procedure specification, two or four welders work simultaneously on diametrically opposed positions, ensuring uniform heat distribution and minimal distortion. After welding the main structure, inspection focuses exclusively on dimensional accuracy and the positioning of the flange substructure. Dimensional inspection is conducted along 11 defined control lines and 18 control points. Any deviations are corrected strictly by cold pressing if necessary. Gap tolerances are limited to 3 mm for full penetration fillet welds and 0 mm for butt welds, ensuring full contact and structural integrity. The primary task and objective achieved was to assemble the flange without the need for final metal machining and additional hot work. It was also ensured that the structure itself, prior to flange installation, levels and aligns without dimensional deviations, by using a minimal over-dimension approach combined with carefully prepared WPS lists. In the end this method proved to be more cost-effective, but slower and somewhat more complex.

Keywords. Offshore, wind turbine, nacelle transport, WPS list, welding procedures optimization.

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Development of OCX-Based XR Inspection Tool and On-Site Validation in a Shipyard Environment

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Abstract. This paper presents the current development state and on-site validation of a novel extended reality (XR)-based inspection tool designed to support on-site inspection processes in shipbuilding industry. The system is primarily based on the Open Class 3D Exchange (OCX) standard, enabling integration of shipbuilding engineering data along with an interactive, spatially aligned XR environment. The proposed solution addresses limitations of conventional inspection workflows, which typically rely on 2D documentation and manual interpretation of spatial information under demanding industrial conditions. The developed system was evaluated in representative inspection use cases defined in collaboration with a partner shipyard. These included practical tasks such as 3D model alignment, locating inspection points, identifying structural elements, verifying construction features, and recording detected issues. Validation was conducted under real shipyard construction site conditions with participation of practicing engineers and technical staff. Evaluation focused on usability, task performance, and operational feasibility within realistic working environments. Observations from on-site usage indicate improved situational and spatial awareness, more efficient access to relevant information, and reduced reliance on traditional paper-based documentation. The system functions as a support tool for engineers, enhancing decision-making rather than replacing human expertise, consistent with emerging human-centric approaches in industrial digitalization. The paper discusses system architecture, implementation challenges, validation methodology, and insights from real-world deployment, providing a basis for further development towards fully integrated digital inspection workflows in shipbuilding.

Keywords. 3D, hull structure, visualization, inspection, XR, AR, MR, headset, OCX, interoperability, innovation.

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Analysis of the Application of Arc Stud Welding in a Ship Outfitting

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Abstract. Shipbuilding is a complex and demanding technological process that involves a large amount of materials, information and people. At the same time, shipyards are in a global market where they can survive if they meet the conditions of competitiveness, which include parameters such as costs, deadlines and quality. It is in the interest of every shipyard to try to shorten the duration of the entire process in any way possible, and to reduce production costs. The shipbuilding process is divided into sub-processes, and one of the most demanding sub-processes is the ship outfitting, especially when the shipyard's production program is oriented towards complex vessels. The improvement of the sub-process of ship outfitting can be achieved by introducing the procedure of Arc stud welding, which belongs to highly productive procedures. This will affect the increase in productivity and the reduction of costs in the shipbuilding process. The paper will analyze the application of Arc stud welding in ship outfitting with ventilation ducts. First, the usual work procedure for ship outfitting will be presented, and then a new work procedure using Arc stud welding will be proposed. Using the example of a selected ship, the work methods will be compared according to parameters such as the number of activities, material costs, and the duration of the outfitting process. In conclusion, the advantages and disadvantages of applying Arc stud welding method in ship outfitting will be stated and the steps of future work on the development of the method will be defined.

Keywords: Arc stud welding, ship outfitting, productivity.

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Application of Artificial Intelligence in the Digitalisation of Shipbuilding Production Processes

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Abstract. Artificial intelligence is modifying our environment day by day and changing the way we approach certain problems in and out of work hours. It is currently used in shipbuilding to improve efficiency, reduce costs and increase safety. This paper examines the possible uses of artificial intelligence (AI) to digitalise shipbuilding production processes, identifying opportunities to improve efficiency, quality, and sustainability across design and manufacturing stages. We investigate different strategies for optimising placement of polygons on a discrete grid (nesting) implemented in Python and guided by large language models (LLM). The strategies include evolutionary algorithms, gradient-free and gradient-based solvers and metaheuristic methods. Empirical evaluation examines solution quality, runtime, and scalability. The study also explores the potential application of artificial intelligence in robotic welding systems. The focus is placed on enhancing process execution through real-time adaptation, intelligent control, and automated quality assurance. A conceptual framework of an AI-driven robotic welding system is presented, integrating sensor data acquisition, data preprocessing, and machine learning models for defect detection and weld quality prediction. The paper surveys two complementary domains and proposes their integration as future work. The integration of artificial intelligence into shipbuilding production processes represents a key step toward fully automated and data-driven manufacturing systems, providing a strong foundation for the development of intelligent and interconnected production environments.

Keywords. Artificial intelligence, nesting, Python, robotic welding, production optimization.

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Quality and Quantity Control System for Shipbuilding and Offshore Facilities

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Abstract. To fulfil the contract requirements during ship/offshore facility construction, an efficient quality control system is needed for document control and materials traceability, planning and monitoring of welding and NDT control, as well as for (pre)commissioning and start-up activities. According to the contract requirements for the construction of the offshore gas production platforms, a system of specific database applications has been developed and further integrated into the PROFF software. The software provides real-time data for efficient project management and quality control. It enables the integration of fabrication information and better coordination of work. Finally, it enables the reduction of man-hours spent, timely completion of the work, and an efficient handover procedure.

Keywords. Ship, offshore facility, project management, EPC, quality, construction, commissioning, welding, NDT, software.

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SECTION IX

EDUCATION & HERITAGE

From Software Proficiency to Adaptability: Emerging Competence Paradigms in Mechanical Engineering and Naval Architecture Education

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Abstract. Recent international labour market analyses indicate a substantial transformation in employer competence expectations. While engineering education has traditionally emphasised immediate software proficiency and operational readiness, contemporary employer-based surveys consistently prioritise adaptability, analytical thinking, communication, and systems-level understanding. This paper presents a structured synthesis study of five major international labour-market and skills reports combining employer surveys and workforce analytics (World Economic Forum 2023 and 2025; McKinsey Global Institute 2021; OECD Skills Outlook 2023; NACE Job Outlook 2024). The analysis demonstrates strong convergence around transferable competences and limited emphasis on software-specific tool mastery. These findings are further supported by established engineering education research. Based on this synthesis, the paper proposes curriculum redesign implications for mechanical engineering and naval architecture programmes, particularly through increased elective flexibility in master-level studies. It contributes to ongoing discussions on employability, curriculum innovation, and university–industry alignment within technical higher education.

Keywords. Engineering education, employability, transferable competences, adaptability, curriculum redesign, naval architecture.

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Naval Architecture in Serbia: Seven Decades of Academic and Professional Collaboration

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Abstract. The Department of Naval Architecture at the Faculty of Mechanical Engineering, University of Belgrade, established in 1948, is the only higher education institution in Serbia dedicated to the education of naval architects. For more than seven decades, it has played a central role in the development of the national shipbuilding industry through education, research, and cooperation with industry. The Department has educated more than 550 naval architects whose expertise has contributed to the design and construction of over 2,500 vessels operating worldwide. Its graduates have built successful careers in shipyards, design offices, classification societies, research institutions, and universities in Serbia and abroad. Today, the Department combines a strong tradition with modern engineering education, advanced computational methods, and international scientific collaboration. Its study program is accredited by the Royal Institution of Naval Architects (RINA), confirming compliance with internationally recognized standards of naval architecture education. Building on this foundation, the curriculum integrates knowledge of both seagoing and inland waterway vessels within a unified framework. Inland waterway design, while not a separate specialization, is reinforced through cooperation with the Society of Naval Architects of Serbia (SNAS), partnerships with local shipyards, and participation in European research projects involving Department staff. These collaborations extend academic expertise into applied practice and ensure continuity in inland waterway innovation. Within the Danube region, the Department is distinguished as one of the few institutions maintaining sustained engagement in this field, thereby strengthening the link between education, professional practice, and industry needs. Closely associated with the Department since its establishment, SNAS (Društvo Brodograđevnih Inženjera i Tehničara “Belgrade”, DBIT), founded in 1969, has become the leading professional organization in Serbia in the field of naval architecture and marine engineering. Through lectures, seminars, conferences, and international activities, including membership in the Confederation of European Maritime Technology Societies (CEMT), SNAS has promoted lifelong learning, professional networking, and enhanced the visibility of Serbian naval architecture in Europe. Together, the Department and SNAS have made a lasting contribution to the advancement of naval architecture and to the international recognition of the Serbian naval architecture community.

Keywords. Naval architecture education, University of Belgrade, shipbuilding industry, inland waterway vessels, Danube region, Society of Naval Architects of Serbia, SNAS – DBIT, professional development, Confederation of European Maritime Technology Societies.

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The Bridge on the Barges (A Case of Unconventional Use of Finite Element Method in Ship Hydrostatic Calculation)

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Abstract. At one point in time, more than 20 years ago, the pontoon bridge, or so called The Bridge on the Barges, consisting of longitudinally connected standard inland barges, was to be built on the river Danube. The first step of the design was to evaluate vertical displacements and forces at the points of hinge connection of the barges, for various cases of traffic load distribution along the bridge. Instead of performing standard hydrostatic calculations of immersion and trim of the vessels, whole structure was modeled as a chain of rigid beams elastically supported by buoyancy – and analyzed using the finite element method. Besides some practical benefits in calculation time saving, applied technique did not bring any true theoretical novelty. However, it introduced rather original method and stands as an interesting Case of Unconventional Use of Finite Element Method in Ship Hydrostatic Calculation.

Keywords. Finite element method, pontoon bridge, barge.

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SECTION X

POSTERS

Hi4TrAlning: Physics-Based VR Training for Gas and Alternative Fuel Ships

Integration of CFD, Reduced-Order Models and AI into immersive maritime safety training environments

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Motivation

- Increasing complexity of LNG, LH₂ and alternative fuels
- Limited real-world training
- High risk in emergency scenarios

Training in real conditions is unsafe and costly

Solution Concept

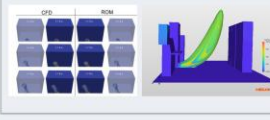
Hi4TrAlning integrates a multi-layer architecture:

- High-fidelity **CFD** simulations
- Reduced Order Models (**ROM**)
- Immersive **VR** environments
- AI-based interaction

Immersive VR Training Environment



Physics-based training scenarios derived from CFD and ROM models and integrated into immersive VR environments



Training Scenarios

- Methane dispersion in confined spaces
- Oxygen depletion in TCS environments
- Emergency response and alarm handling
- Human interaction under stress conditions

User Validation

Metrics:

- SUS
- NASA-TLX
- IPQ
- SSQ

Results:

- SUS ≈ 70 (good usability)
- Low simulator sickness (SSQ)
- Strong user immersion (IPQ)
- Measurable learning improvement

Industrial Impact

- Safe training
- Scalable scenarios
- Applicable to LNG, H₂, NH₃
- Reduced costs

Ship Environments & Scenarios



Key Results

- ROM enables near real-time interaction
- High realism of VR environments
- Repeatable and scalable training
- User validation confirms effectiveness
- TRL 8 achieved

Conclusion

From simulation to experience:
bridging engineering and human training



7-10 October 2026, Belgrade, Serbia



Experimental and Numerical Analysis of Additively Manufactured Polymer Sandwich Structures

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ABSTRACT & AIM

Two complementary studies on 3D-printed FFF polymer sandwich structures are unified: (1) three-point bending of honeycomb, trapezoidal and triangular-core beams with hybrid ABS/PLA configurations; (2) tensile and low-cycle fatigue testing of trapezoidal mechanically interlocked specimens in PLA, ABS, PET-G and ASA.

Core geometry, material layout, and joining strategy strongly affect stiffness, stress distribution, and repeatability. 3D-printed sandwich structures combine low mass with high stiffness and enable rapid fabrication of complex internal cores via FFF. Core topology, face-core bonding, and material selection strongly influence stiffness, failure modes, and structural efficiency.

Multi-material combinations raise questions on layer adhesion, residual stresses, and joining robustness. This paper synthesises two studies into a unified design and analysis framework.

3D printed sandwich • corrugated core • FFF polymers

METHOD OVERVIEW

CAD (Autodesk Inventor) → FFF printing (Raise3D Pro2 for bending; Bambu Lab X1 Carbon for tensile) → experimental testing → FEA (Abaqus). Three core geometries (Fig. 1) and two printers (Figs. 4–5) used.



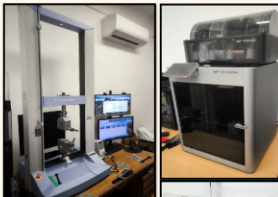
Fig. 1. Core concepts: (a) honeycomb, (b) trapezoidal, (c) triangular corrugated.



Fig. 2. 3D models of trapezoidal-core sandwich tensile specimen with dovetail-type interlock and standard tensile specimen for base material testing. Dovetail-type mechanical interlock (0.1 mm tolerance) replaced adhesive bonding, eliminating bond-layer variability and enabling reliable multi-material assembly.

EXPERIMENTAL SETUP

- 3-point bending: Raise3D Pro2-printed PLA beams (span adjusted per geometry)
- Tension: SHIMADZU AGS-X, 10 kN, 10 mm/min — 84 specimens (48 standard + 36 sandwich)
- Low-cycle fatigue: selected materials at multiple force amplitudes



Figs. 3. Experimental setup and 3D printers used for specimen fabrication: • SHIMADZU AGS-X (upper left) • BambuLab X1 Carbon (3D printer; upper right) • Raise3D Pro2Plus (3D printer; bottom right)

BENDING TESTS & RESULTS

Three-point bending on PLA beams (honeycomb, trapezoidal, triangular). Triangular core gave highest stiffness and best load-displacement behavior. Hybrid ABS/PLA variants compared in two stacking sequences.



Fig. 4. Three-point bending test setup for sandwich beams.

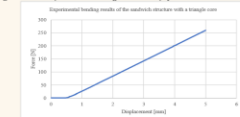


Fig. 5. Load-displacement curve example: sandwich structure with a triangle core.

Hybrid ABS/PLA Configuration Results:

ABS-PLA-ABS	PLA-ABS-PLA ✓
127.53 N	148.51 N
33.05 MPa	27.32 MPa

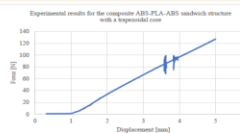


Fig. 6. Bending curves for ABS-PLA-ABS vs. PLA-ABS-PLA hybrid configurations

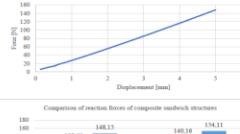


Fig. 7. FEA von Mises stress distribution in PLA-ABS-PLA trapezoidal sandwich beam under 3-point bending.

FINITE ELEMENT ANALYSIS — BENDING

Abaqus FEA reproduced experimental bending response. PLA-ABS-PLA showed lower peak von Mises stress (27.32 MPa) vs. ABS-PLA-ABS (33.05 MPa) — consistent with classical sandwich theory: stiffer material in outer layers reduces core stress.

TENSILE TESTS & RESULTS

SHIMADZU AGS-X, 10 kN. Base materials (PLA, ABS, PET-G, ASA) characterised first, then sandwich combinations (PLA-ABS, PLA-PET-G, ASA-PET-G) tested. Mechanical interlock provided stable, reproducible failure in gauge section.

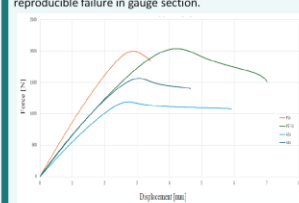


Fig. 8. Tensile force-extension curves for PLA, ABS, PET-G and ASA standard specimens.

LOW-CYCLE FATIGUE (LCF)

Cyclic tests at multiple force amplitudes on selected materials and sandwich configurations. Results show progressive stiffness degradation and hysteresis evolution — the mechanically interlocked concept is suitable for fatigue-oriented testing.

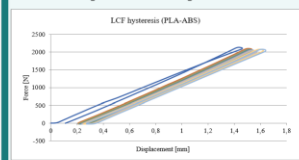


Fig. 9. Example LCF diagram: progressive stiffness degradation and hysteresis evolution under cyclic loading.

CONCLUSIONS

- ▶ Triangular PLA core is the best single-material geometry under 3-point bending; PLA-ABS-PLA hybrid is the most favourable composite configuration.
- ▶ Placing the stiffer polymer in the outer layers increases global stiffness and reduces core stress — confirmed by both experiments and FEA.
- ▶ Dovetail mechanical interlocking replaces adhesive bonding, enabling robust multi-material assembly and reproducible failure at tensile testing.
- ▶ Nonlinear FEA reproduces experimental trends and reveals stress concentrations at interlock zones not accessible experimentally.
- ▶ Framework applicable to 3D-printed marine sandwich components: interior outfitting, superstructures, non-critical hull elements.

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Mapping the Onset of Forced Parametric Resonance in a Conical Wave-Energy Buoy: A Time-Domain Parametric Survey

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INTRODUCTION

Parametric rolling is normally treated as a dangerous dynamic instability of ships in longitudinal waves: transverse stability varies periodically between wave crest and trough and, when this variation occurs at about twice the natural roll frequency, roll is strongly amplified. **For a wave-energy converter (WEC) the logic can be reversed**, i.e. the same resonance can be deliberately induced and exploited to capture wave energy.

Aim of the study: map the conditions under which forced parametric resonance can be induced in a freely floating conical buoy in regular longitudinal waves.



SHIP
Parametric roll = hazard
→ suppress
(anti-roll tanks, fins, hull-form changes)



WEC BUOY
Parametric roll = resource
→ induce & exploit
(tune roll to $\approx 2 \times$ wave encounter period)

METHODOLOGY

A conical form is used because its hydrostatic and inertial properties (VCG, KB, BM, GM, mass moments of inertia, GZ) are available in **closed analytical form**, so geometric and sea-state parameters can be varied quickly and systematically. Motions are resolved in all six degrees of freedom (6 DOF) in a nonlinear time-domain framework.

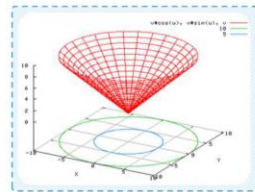


Figure 1. Conical buoy in parametric form.

Table 1. Main particulars of the conical buoy.

Parameter	Value
Length, L_{BP}	20.00 m
Breadth, B_{DWL}	20.00 m
Depth, D	20.00 m
Draught, T_{DWL}	10.00 m
Displacement, Δ_{DWL}	1046 t
Block coefficient, C_B	0.66
Metacentric height, GM_1	5.00 m
Natural roll period, T_{44}	22.78 s
Speed, U	0 kn

Numerical procedure (per time step)

- Analytical geometry**
hull, mass & inertia tensor in closed form
- Hydrodynamic coefficients**
added mass, damping, wave excitation (strip theory)
- Nonlinear restoring**
recomputed on the instantaneous wetted hull
- Roll damping**
Miller's method, iterated to converged roll
- 6-DOF time integration**
4th-order Runge-Kutta

RESULTS

Simulation grid:

Wave height: 2-4.5 m

$\lambda/L = 0.75-2.25$

head seas, 0 kn

regular waves

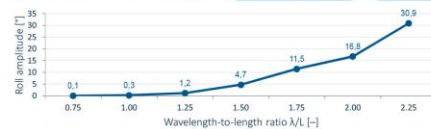


Figure 2. Roll amplitude vs. λ/L ($H_w = 4.5$ m): onset at $\lambda/L = 1.5$

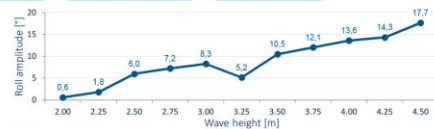


Figure 3. Roll amplitude vs. H_w ($\lambda/L = 2$, $T_w = 5.06$ s): onset at $H_w = 2.5$ m.

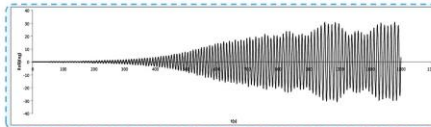


Figure 4. Development of parametric rolling, $\lambda/L = 2$, $H_w = 4.5$ m ($n_4 = 18^\circ$).

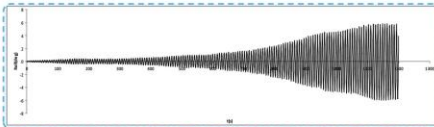


Figure 5. Onset of parametric rolling at $H_w = 2.5$ m, $T_w = 5.06$ s ($n_4 = 6^\circ$).

CONCLUSION

$\approx 18^\circ$
roll amplitude at
 $\lambda/L = 2$, $H_w = 4.5$ m

2.5 m
wave height at onset
of parametric roll

$\lambda \approx 2L$
resonant wavelength
($T_w = 5.06$ s)

Parametric rolling, normally a hazard to be suppressed on ships, can be deliberately induced in a freely floating conical buoy in regular longitudinal waves. Resonance develops as the wavelength approaches twice the buoy length, with roll amplitudes of about 18° and onset at wave heights as low as 2.5 m. The near-linear growth of roll amplitude with wave height is encouraging for predictable power output and a natural starting point for coupling the device with mooring and power take-off (PTO) systems.

ACKNOWLEDGEMENT

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METHANOL AS A MARINE FUEL • SORTA 2026

From Dual-Fuel Retrofit to Methanol Newbuildings

A Fleet-Renewal Strategy for Small Passenger Ships

Marko Novaselić • Tomislav Buksa | Jadrolinija • Marko Valčić | University of Zadar

Jadrolinija d.d., Rijeka, Croatia • University of Zadar, Department of Mechatronics and Robotics, Zadar, Croatia



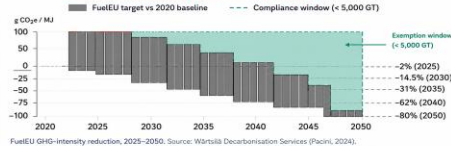
1 Context & the regulatory ratchet

Croatian island mobility runs on small, ageing ferries, most below 5,000 GT and still outside binding climate rules. IMO targets net-zero by ~2050; FuelEU tightens fuel GHG intensity from ~2% to ~80% (2025–2050). The exemption window is time to prepare, not postpone.

54 vessels • 40+ ports • 11.4 M pax/yr • ~20 yr avg age

Threshold of (non-)regulation: < 5,000 GT

FuelEU GHG-intensity reduction trajectory



FuelEU GHG-intensity reduction, 2025–2050. Source: Wärtsilä Decarbonisation Services (Pacini, 2024).

2 Methanol: ship design meets well-to-wake



Dual-fuel methanol conversion (Stena Germanica). Source: Wärtsilä (Pacini, 2024); Stena RoRo (Tretlow, 2024).

STENA GERMANICA METHANOL CONVERSION

- Conversion of Stena Germanica to liquid methanol in 2024
- Cylindrical tanks integrated for optimal volume use and stability
- Dual-fuel engines with methanol as primary fuel and MGO as backup
- Energy efficiency maintained with proven engine technology
- Efficiency level in line with Stena Germanica's service profile and conversion goals
- Daily consumption ~35 t methanol (MGO)

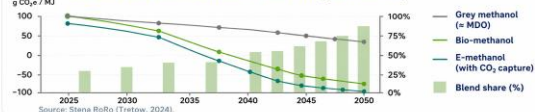
Liquid at ambient conditions, sulphur-free, low PM/NOx. Trade-offs: a low flashpoint (IGF-Code) and about half the energy density of fuel oil. How it is made decides everything: grey ≈ MDO, while bio- and e-methanol can deliver major GHG cuts.



3 Grey vs green: blending as a compliance dial

Blending conventional with green methanol keeps a vessel compliant as limits fall. E-methanol (well-to-tank ≈ -67 gCO₂e/MJ with captured CO₂) turns the dial furthest; grey methanol alone tracks marine diesel.

FUEL MIX AND CARBON INTENSITY OVER TIME (ILLUSTRATIVE)



Source: Stena RoRo (Tretlow, 2024).

4 The solution space for small passenger ships

Each pathway fits a different duty. For mid-range island RoPax, methanol offers the best balance of maturity, handling and cost; batteries suit the shortest crossings, HVO drops in as a bridge, and ammonia/hydrogen remain longer-horizon options.

ALTERNATIVE MARINE FUELS (Green Fuel Price = 2026)									
Fuel	Readiness (2026)	CO ₂ (g/MJ)	Methanol Blending	Bioequivalents	HVO Drop-in	Hydrogen (2026)	Ammonia (2026)	Electricity (2026)	Zero Fuel Conversion
E-methanol	***	10.9	0–100%	***	–	–	3.4–4.5	3–5h	3–5h
Bio-methanol	***	10.9	0–100%	***	–	–	3.4–4.5	3–5h	3–5h
HVO (iso-dec)	***	37.1	0–100%	***	***	–	1.3–1.5h	1.3–1.5h	1.3–1.5h
Batteries	***	–	–	–	–	–	–	1–2h	1–2h
Ammonia (NH ₃)	**	18.0	–	***	–	18.9	1.7–2.3	1.9–2.9h	1.9–2.9h
Hydrogen (H ₂)	*	12.0	–	–	–	12.0	–	1.9–2.9h	1.9–2.9h

5 Two routes to a staged fleet renewal

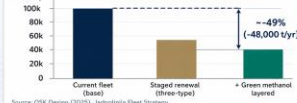
Route A - Retrofit

Fast, low-CAPEX bridge, Stena proof: ballast tanks → ~400 m³ (5-day range). 6-week docking, dual-fuel conversion kit.

Route B - Newbuilding

Diesel-electric, multi-fuel, battery-ready; tanks optimised from the keel up. The future-proof endpoint.

FLEET CO₂ FOOTPRINT: CURRENT VS RENEWED FLEET



Source: OSK (Design, 2023); Jadrolinija Fleet Strategy.

A three-type renewal alone cuts fleet CO₂ by ~49% (~48,000 t/yr). Layered with green methanol, one e-methanol vessel offsets a six-ship FuelEU pool, moving from early retrofit to eventual newbuilding.

6 Conclusions

Favour configurations that stay defensible as limits tighten, not those that merely clear the next threshold. Retrofit now as a bridge; build multi-fuel / methanol as the endpoint; secure green-methanol supply and shore power. For operators, yards and the administration, the time to act is inside the window.

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7-10 October 2026, Belgrade, Serbia

SORTA 2026 - 27th Symposium on Theory and Practice of Shipbuilding

CONFLUENCE BELGRADE: 2017–2026

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SAVA

Sava was the boat that represented Confluence Belgrade in the Lightweight race at Hydrocontest, a prestigious international student competition held in St. Tropez that gathered teams from leading universities around the world.

Built with a slender, streamlined form optimized for high speeds, Sava earned the team 2nd place in the lightweight cargo transport category in 2017.

As one of the team's first major projects, Sava was designed and built by the students themselves, from concept to construction, under the mentorship of professors from the Department of Naval Architecture, and it laid the foundation for everything that followed.

Its hull later became the design inspiration for SavaECO, the team's solar-powered catamaran developed for collecting floating waste.



TEAM

Confluence Belgrade was formed around the Department of Naval Architecture at the Faculty of Mechanical Engineering, University of Belgrade, bringing together students united by a shared love of water and nautical sciences.

From its earliest days, the team has drawn members from every level of study, from undergraduate to doctoral, including experienced sailors, divers, fishermen, and simply dreamers hoping to one day become one.

A number of team members have come from Montenegro over the years, further proving the quality of the study program and the faculty training the next generation of naval architects in Belgrade.

The Naval Architecture program itself is accredited by the Royal Institution of Naval Architects (RINA), the world's most prestigious institution in the field, giving the team's projects, from Sava and Dunav to SavaECO, a foundation recognized well beyond Serbia's borders.



DUNAV

Dunav was Confluence Belgrade's second boat, built for the Mass Transport race at Hydrocontest.

Unlike Sava's slender profile optimized for speed, Dunav was a larger monohull vessel designed to carry heavier loads while maintaining energy efficiency, a fundamentally different engineering challenge than the one Sava was built to solve.

In 2018, Dunav brought the team its greatest success yet, winning 1st place and the championship title in the mass transport category, competing against more experienced and better-funded teams from around the world.

The experience of designing and building Dunav gave students hands-on insight into higher-capacity vessel design, sparking ideas about potential career paths within the broader naval architecture and maritime industry.



SavaECO

SavaECO is a developmental environmental project that drew the most attention from the team's booth at the Belgrade Nautical Fair – a catamaran measuring 2.54 x 1.48m, designed for the efficient collection of floating waste from water surfaces.

The prototype was presented in 2023 at the Third International Maritime Science Conference in Kotor (KIMC), where it was very well received.

The hulls, modeled after the award-winning Sava hull (2nd place at Hydrocontest 2017), are joined together by a solar panel and powered by solar energy.



ZAGREB 2025

IWR25

Last year we set our sights on a long-standing student shipbuilding competition, the International Waterbike Regatta (IWR), held in Zagreb, hoping to finally get back on the water after a long absence.

Due to a series of internal challenges and insufficient team alignment during that period, we weren't able to organize ourselves in time, and in the end we had to skip the competition.

This generation deeply regrets not having achieved what we had hoped for back then, but valuable lessons were drawn from that experience, leaving the next generation a stronger and better foundation than we had at the start.

We remain hopeful that this very foundation will be the basis for competitions and projects to come...

SORTA 2026 - 27th Symposium on Theory and Practice of Shipbuilding

The Future of Confluence

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About us

We are the new generation of Confluence Belgrade, a team of young and enthusiastic students supported by experienced former members who are eager to share their knowledge and contribute to the development of new competition vessels.

What we want to accomplish

Our ambition is not only to compete at the highest level, but also to innovate, challenge conventional approaches, and pioneer new vessel concepts that push the boundaries of what is expected;

The competitions we aim to participate in include HydroContest, Njord: The Autonomous Ship Challenge, and the Monaco Energy Boat Challenge. Through these events, we seek to test our engineering capabilities, gain international experience, and benchmark our vessel designs against other leading student teams.



Autonomous surface cleaning vessel

Using an integrated network of sensors and AI-powered vision systems, we aim to develop a fully autonomous vessel capable of following a predefined navigation pattern, identifying and distinguishing waste from surrounding objects, and selectively collecting it. Once the vessel reaches its storage capacity, it will automatically navigate to a designated point, unload the collected waste, and then resume its cleaning.



Aquatic weed harvesting vessel

We identified a recurring problem in marinas and harbors, where floating weeds tend to accumulate around stationary and moored vessels. To address this issue, we aim to develop a specialized autonomous vessel capable of navigating through these areas, collecting excess vegetation, and keeping the water around docked boats clear and accessible.

SECTION XI

SUPPORTING ORGANISATIONS

7-10 October 2026, Belgrade, Serbia



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