THE NAVAL ARCHITECT

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OCT 2023

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October 2023

FEATURES

THE NAVAL ARCHITECT

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Printed in Wales by Stephens & George Magazines.

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A 2023 subscription to The Naval Architect costs:

THE NAVAL ARCHITECT SUBSCRIPTION (10 issues per year)			
LOCATION	PRINT ONLY	DIGITAL ONLY	PRINT + DIGITAL
UK	£232	£232	£296
Rest of Europe	£245	£232	£308
Rest of World	£261	£232	£325
	Includes P+P	Inclusive of VAT	

The Naval Architect Group (English Edition)
Average Net Circulation 8,195 (total)
1 January to 31 December 2022
ISSN 03060209

LISW RETURNS, FOR THE MANY, NOT THE FEW

By **Daniel Johnson**

September saw the return of the London International Shipping Week (LISW). Now in its tenth year of operation, LISW appears to be maturing into a key waypoint in the global maritime calendar, as was evidenced by this year's breadth of events, calibre of speakers and record-breaking attendance. With more than 350 events taking place across various venues in London, *The Naval Architect*'s diligent editorial team certainly burned the shoe leather over the week to get an inside track on a diverse array of topics that are shaping the future of global shipping.

Without doubt, the big-ticket topic of LISW 2023 was decarbonisation. Having had a little time to digest the outcomes of July's MEPC 80, and after years of uncertainty about how strict the targets would be, the industry seems to be broadly welcoming of the IMO's revised GHG strategy in ambition to reach net-zero emissions from shipping by 2050. However, despite the generally upbeat nature of the conference streams and panel discussions focused on reducing carbon emissions and adopting eco-friendly practices and technology, conversations on the sidelines did indicate a rising level of scepticism concerning the future targets in general and the 2030 targets in particular; a common thread being serious doubt about the supply and cost of future green fuels, a subject that is covered elsewhere in this issue of *TNA* (page 12).

Away from decarbonisation, several events were connected with skill development, training and future skills needed for a changing industry landscape. A takeaway from here was of a skills shortage tsunami due to hit the maritime industry sometime soon. One reason for this is a very obvious negative public perception of the industry, which forms a barrier to attracting new talent, especially in the context of high demand for advanced STEM skills.

One event of note for the UK shipbuilding sector was the launch of the UK Shipbuilding Skills Taskforce's (UKSST) report *A Step Change in UK Shipbuilding Skills* and a supporting toolkit for shipbuilding employers *How to Leverage UK Skills Systems*.

UKSST was established in July 2022 on the back of the UK government's refresh of its 2017 National Shipbuilding Strategy (NSbS), which sets out a package of government measures aimed at fostering a shipbuilding renaissance across the UK. The Taskforce was charged with building a picture of UK shipbuilding's skills needs and making recommendations to resolve skills shortages, particularly those related to new and emerging technologies and zero-emissions shipping. Its membership is drawn from across the UK, with expertise spanning shipbuilding employers, key educators, academic researchers and trade unions.

In his speech at the launch, UKSST chair Dr Paul Little, principal of City Glasgow College, noted that pathways into the industry need to be widened "for the many, not the few", and went on to outline the Taskforce's key recommendations for industry, educators and government. These include: establishing a new, sector-wide narrative for shipbuilding to promote it as a vibrant and inclusive sector; helping the sector engage more productively with the existing skills system (supported by the toolkit); forecasting the impact of technological change in the sector on skills; and setting up an industry-led skills delivery group to oversee and drive delivery of the recommendations, and to be a voice for skills for shipbuilding.

LISW 2023 EVENTS DREW RECORD CROWDS

The report makes clear that UK shipbuilding will only thrive, both now and in the future, with a sustained pipeline of skilled and highly motivated people to support the industry to become more competitive. A key theme is the importance of continued co-operation and communication between governments across the UK, industry employers, trade unions and training and education providers. According to Dr Little, this co-operative approach will enable the UK's skills systems to rapidly respond to changing employer requirements as technology advances and grow the supply of STEM skills that the shipbuilding sector needs to succeed.

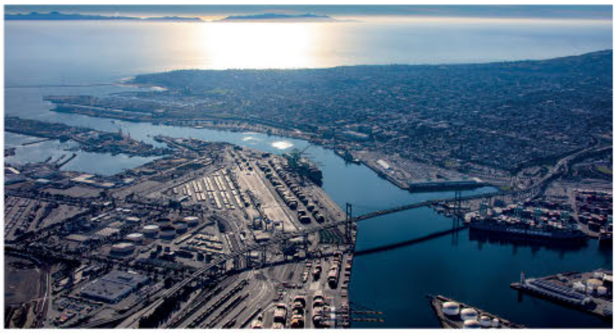
He also noted: "Ultimately, skills gaps and skills shortages will persist and hold us back unless and until we nationally embrace a skills economy with the same fervour with which we embraced a knowledge economy."

Publication of the report isn't the end of the journey for UKSST. The Taskforce will continue working until December 2023, engaging with industry, educators and government on its recommendations, aiming to secure buy-in and initiate recommended activity. The UK government will publish a response to the report in the coming months. It is to be hoped that the report's recommendations are heeded to help pave the way for coming generations to secure the future of UK shipbuilding. ■

NEWS

DECARBONISATION

PLAN FOR FIRST TRANS-PACIFIC GREEN SHIPPING CORRIDOR OUTLINED



PORT OF LOS ANGELES

Plans for the creation of the first-ever green shipping corridor across the Pacific have been unveiled by the Port of Los Angeles, Port of Long Beach and Port of Shanghai.

The ports, together with other stakeholders, including some of the largest carriers in the world, deem the Green Shipping Corridor Implementation Plan as a significant step towards accelerating emissions reductions on one of the world's busiest container shipping routes across the Pacific Ocean.

The plan intends to highlight cutting-edge goods movement technology, decarbonisation applications, and best management practises to improve efficiency.

As part of the proposals, the carrier partners will begin deploying reduced or zero lifecycle carbon capable ships on the Shanghai-San Pedro Bay green shipping corridor by 2025, and work together to demonstrate by 2030 the feasibility of deploying the world's first zero lifecycle carbon emission container ships.

Carrier partners include CMA CGM, COSCO Shipping Lines, Maersk and ONE. Core partners include the Shanghai International Port (Group) Co. Ltd, the China Classification Society and the Maritime Technology Co-operation Center of Asia.

Gene Seroka, executive director of the Port of Los Angeles, says: "This trans-Pacific green corridor will be a model for the global co-operation needed to accelerate change throughout the maritime industry. Reducing emissions in this corridor will yield substantial reductions.

"For perspective, most of the emissions associated with moving cargo by ship occur in the mid-ocean part of the journey between ports. This corridor will help reduce mid-ocean emissions while continuing the work we have done to cut emissions within our ports."

WIND POWER

BOUND4BLUE'S WAP SYSTEMS GET FINANCIAL BOOST

European developer of wind-assisted propulsion (WAP) systems bound4blue has secured €22.4 million in new funding from several key investors as well as the European Commission.

A total of €15.9 million comes from a Series A funding round led by GTT Strategic Ventures, with the participation of the EIC (European Innovation Council) Fund and the Sustainable Ocean Alliance.

The financing is further complemented by a €4.1 million grant from the Innovation Fund Programme, awarded by CINEA (European Climate, Infrastructure and Environment Executive Agency) in 2022, and an additional grant of €2.4 million previously awarded in 2021 by the EIC Accelerator Programme.

The EIC Fund operates within the EIC's mandate to identify and support high-impact innovations within the EU. Its support for bound4blue reflects a strategic decision to participate in the success of the European shipping decarbonisation strategy and builds upon its commitment to the grant component.

According to boud4blue, the funds raised will be used to help the company roll out its suction sail system eSAIL, as well as scale up to meet demand for zero-emission propulsion solutions in shipping.

THE FUNDS RAISED WILL BE USED TO HELP ROLL OUT AND SCALE UP THE ESAIL SUCTION SAIL SYSTEM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TANKERS

FIRST DUAL-FUEL VLCC CERTIFIED BY GREEN AWARD

The LNG dual-fuel-powered very large crude carrier (VLCC) *Antonis I. Angelicoussis* has been certified by the Green Award Foundation.

The 330m-long, 320,916dwt tanker is the first LNG dual-fuel VLCC to join the Green Award programme. The certification includes the Green Award greenhouse gas (GHG) labels CO_2 (level 1) and CH4.

The Greek-flagged ship is managed by Maran Tankers Management, the oil shipping arm of Greece's Angelicoussis Group, which manages over 140 vessels. Built by Samsung Heavy Industries in South Korea, the *Antonis I. Angelicoussis* was delivered to Maran Tankers earlier this year, along with sister ships *Maria A. Angelicoussis*, *Maran Danae* and *Maran Dione*.

All four LNG dual-fuel ships are part of Maran Tanker's fleet expansion programme, which also includes eight newbuild LNG dual-fuel Suezmax tankers on order. The four VLCCs are the lowest emission vessels of their type in the world today.

Green Award was first established in 1994 as a non-profit, independent, international quality mark for high performing vessels. Governed by key industry representatives, it represents a network of ports, ship managers, charterers, maritime service providers and authorities in over 30 countries. Since its inception it has certified more than 1,000 vessels.

VLCC *ANTONIS I. ANGELICOUSSIS*

The Angelicoussis Group has been participating in the Green Award programme for over 27 years. In recent years, three Maran Tankers managed oil tankers were certified by Green Award, as well as four LNG tankers operated by sister company Maran Gas Maritime.

CRUISE SHIPS

MSC ORDERS TWO NEW HYDROGEN-POWERED SHIPS FROM FINCANTIERI

EXPLORA JOURNEYS' FIRST SHIP, *EXPLORA I*, WAS DELIVERED BY FINCANTIERI IN JULY 2023

The Cruise Division of MSC Group has confirmed firm orders for two hydrogen-powered vessels for its luxury travel brand Explora Journeys with the Italian shipbuilder Fincantieri.

MSC has also pledged to continue its push towards a 2050 net-zero carbon emissions target by investing in new environmental technologies for the luxury ships. The deal completes a total investment of €3.5 billion in six luxury ships for Explora Journeys.

The *Explora V* and *Explora VI* will have new efficiency measures and will also be capable of using alternative fuels such as bio and synthetic gas and methanol. MSC's Cruise Division will work with Fincantieri in future to equip the ships with future technologies including carbon capture, and more advanced waste management systems.

The two new vessels on order will be delivered in 2027 and 2028.

"This new contract with MSC is a sign of the growing vitality of the cruise sector, in line with what we had predicted. In strategic terms, our future will depend on our ability to lead the evolution of the sector towards all energy and digital transition technologies with the entrepreneurship required to validate, industrialise and commercialise new solutions," says Pierroberto Folgiero, chief executive officer, Financantieri.

Explora V and *Explora VI* will use liquid hydrogen with fuel cells for their hotel operations while docked in ports to eliminate carbon emissions with the vessels' engines switched off. The ships will also feature a new generation of LNG engines that will further tackle the issue of methane slip with the use of containment systems.

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IN BRIEF

CARBON CAPTURE & STORAGE

LCO2 CARRIERS FOR CCS PROJECTS

Mitsui O.S.K. Lines (MOL), Petronas CCS Ventures and MISC Berhad have reached an agreement for the potential establishment of a joint venture to invest in developing and monetising liquefied carbon dioxide (LCO2) carriers for carbon capture and storage (CCS) projects. MOL and Petronas received four approvals in principle for the conceptual design of the LCO2 carriers from classification societies DNV and ABS earlier this year.

NUCLEAR POWER

EMERGENCY NUCLEAR POWER SHIP CONCEPT

American shipowner Crowley and BWX Technologies have signed a memorandum of understanding (MoU) to jointly develop a ship concept that will have nuclear microreactors to provide power to remote locations in emergencies. The 115m shallow-draught vessel will be equipped with modular reactors that are able to supply energy to shore facilities such as military bases in remote island locations, backup utility grids after disasters, and provide power in other scenarios where traditional electricity sources have been damaged or are not available.

ALTERNATIVE FUELS

GREEN FUEL PARTNERSHIP

Global shipping giants Maersk and CMA CGM have announced a collaborative effort to work towards developing alternative green fuels for container ship propulsion. The work will include developing high standards for green fuels, establishing a framework for mass production of green methane and green methanol, including analysis of full lifecycle and related greenhouse gases, and taking a more direct approach to regulatory conversations.

AUTONOMOUS SHIPS

AUTONOMOUS ZERO-EMISSION BOXSHIP ENTERS DESIGN PHASE

Zulu Associates, the Belgian short-sea shipping company, has contracted Conoship International to advance the design of the Zulu Mass 200TEU container vessel.

The new 100m-long vessel will be powered by zero-emission propulsion technology and provide a short-sea platform initially for direct container and feeder flows. It will be able to operate on both rivers and in coastal environments and will be capable of carrying 180 containers.

Zulu Mass will be designed for standardised assembly line production and feature modularity in its equipment to allow ease of maintenance and technical upgrades. It will also be designed to be unmanned as a part of a Maritime Autonomy System, which will allow it to compete with fossil-fuelled vessels.

The vessel concept, which has received approval in principle (AiP) from Lloyd's Register, is planned to be initially operational with Anglo Belgian Shipping Company on green corridors between the European Continent and the United Kingdom.

Zulu Mass will be fully electrical and powered by modular energy containers provided by established energy storage companies using batteries and/or hydrogen-based power systems. In addition to zero-emission electrical propulsion, the vessel will be equipped with auxiliary wind propulsion, and the feasibility of wave propulsion will be investigated.

Belgium established a legal framework for unmanned vessel pilot projects in the North Sea in 2021. Recently, Belgium, the UK and Denmark came together to sign an agreement that eliminates the need for separate permit applications, greatly simplifying the regulatory process, according to Zulu Associates.

RENDER OF ZULU MASS. SOURCE: ZULU ASSOCIATES

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NEWS ANALYSIS

FUTURE FUELS AND SOME UNCOMFORTABLE TRUTHS

By **Malcolm Latarche**, correspondent

Future fuels were a topic for much discussion throughout September with both DNV and Lloyd's Register publishing studies on the subject, Maersk naming the world's first methanol-fuelled container ship and entering into partnership with Equinor to secure a supply of green methanol and it also being a theme of the London International Shipping Week (LISW) during the middle of the month.

The question of future and alternative fuels is a fraught one and there are probably as many opinions on how things will pan out as there are decision makers within the maritime industry. From the environmentalists' point of view and similarly from some in the industry as well, financial incentives – or more accurately disincentives – are the answer. Tax shipping for being a dirty industry and it will clean up goes the argument. Except perhaps it probably will not.

It is a widely held view that people power and action by 'green' leaders among cargo interests to use only ships that can show a lower carbon footprint will encourage shipowners to decarbonise at a more rapid rate. The more pragmatic view is that while organisations like to trumpet green credentials, their own customers want things to be sold – and therefore moved across oceans – at the lowest possible cost. It is the latter view or something akin to it that seems to be gaining the upper hand in many countries as people and politicians start to question the economic cost and popularity of green measures.

Maersk's christening of its new feeder vessel *Laura Maersk* by EU President Ursula von der Leyen was a publicity success and another demonstration by Maersk of its willingness to innovate. It has previously looked at biofuels and has stated that methanol is a stepping stone to ammonia in its long-term strategy. However, Maersk's plan to potentially convert or have built over 170 ships powered by methanol revealed the size of the problem facing shipping.

Before the christening of *Laura Maersk*, an agreement was signed between the owner and Norwegian energy company Equinor for a secure supply of green methanol during the initial months of operation from September 2023 and into the first half of 2024. Long term the plan is for the ships to run on e-methanol produced in Denmark. By 2030, Maersk will need approximately five million tons of green fuels for its ships and today's global production of green methanol is below 100,000tons. And Maersk is only one owner. There are already several vessels running on methanol and more in the pipeline for other owners. COSCO has 12 methanol-fuelled mega container ships on order and Wilhelmsen has the same number of PCTCs on order.

LAURA MAERSK NAMING CEREMONY. SOURCE: MAERSK

The studies produced by the two classification societies reveal some interesting facts that may have been overlooked in the push for shipping to decarbonise. In the foreword to the DNV report Maritime Forecast to 2050, DNV Maritime CEO Knut Ørbeck-Nilssen highlighted that "meeting the IMO GHG goal for 2030 will require shipping to secure 30–40% of the estimated annual global supply of carbon-neutral fuels by then – a daunting, nearly impossible task considering that other sectors will compete for the same fuel supply".

Lloyd's Register's *The future of maritime fuels. What you need to know* carries a similar warning about another highly tipped future fuel ammonia. It says, e-ammonia emerges as the most highly adopted maritime fuel in the long term – on average the market share of e-ammonia is 35% in 2050. However, there is a large variation across the scenarios because of the different assumptions on future prices and the ability to scale fuel infrastructure at the required pace. Most of the scenarios provide a range between 20% and 50% of the market, while the most optimistic outlier scenario projects a market share for e-ammonia of approximately 80% by 2050.

This would make the shipping industry the largest user of ammonia relative to other sectors (such as fertiliser and power generation). What also has to be considered is that shipowners are not in a position to dictate the scale of non-fossil fuel production and except in a few rare cases neither are national governments.

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GREEN MARINE PARTNER

NEWS EQUIPMENT

DECARBONISATION

BABCOCK GETS APPROVAL FOR NEW GAS SUPPLY AND CO_2 CARGO HANDLING SYSTEMS

Babcock's LGE business, specialising in liquefied gas solutions, has received approval in principle (AiP) from Lloyd's Register (LR) for its multi-fuel gas supply and CO_2 cargo handling systems, ecoFGSS-FLEX and ecoCO2.

LR PRESENTS BABCOCK'S LGE BUSINESS WITH AN AIP FOR ECOCO2

The new ecoFGSS-FLEX system is based on Babcock's pre-existing ecoFGSS LPG fuel gas system. The fundamentals of both systems are the same. However, the new, larger eco-FGSS-FLEX system enables the use of ammonia as a fuel for future application when engine technology and global supply chains are established, with minimal or no disruption to the fuel gas supply system.

Both systems allow operators to use one of two different fuel types on a broad range of vessels. This will allow shipowners to reduce the emissions from their fleets.

Babcock's ecoCO2 CO_2 cargo handling system is designed for the full carbon capture, utilisation and storage (CCUS) value chain.

The system accounts for a range of operating parameters including shipping profiles, loading and discharge terminal parameters, cargo composition and cargo volumes.

"The solutions offered by Babcock's LGE business matter more now than ever and in ecoFGSS-FLEX, we have a product which will allow shipowners to decarbonise quickly and efficiently in an ever-changing and complex market," says Neale Campbell, managing director of Babcock's LGE business.

"With ecoCO2, we have a product which has been designed using tried and tested equipment and adheres to industry safety standards and environmental legislation," he adds.

CRANES & CARGO EQUIPMENT

MACGREGOR WINS MULTI-MILLION-EURO CRANE ORDER

MacGregor, part of Cargotec, has received an order to fit out 10 x 84,500dwt multipurpose vessels being built in Asia with general cargo cranes.

THE CRANES ARE SCHEDULED TO BE DELIVERED BETWEEN 2024 AND 2026. SOURCE: MACGREGOR

The order, valued at more than €25 million, was booked into Cargotec's 2023 third quarter orders received. The cranes are scheduled to be delivered between the fourth quarter of 2024 and the first quarter of 2026.

The order includes a total of 40 cranes with a lifting capacity of 75tonnes. All of the cranes are connected to the latest worldwide service support and equipped with an active safety system for the highest possible secure operation, according to MacGregor.

The company adds that it was selected as the supplier of these general cargo cranes thanks to its well-known design capabilities and long-term good co-operation with the customer.

"I'm very proud of the confidence that the shipyard has shown in choosing us to supply cranes for this important project. We look forward to providing our customer with our high-class equipment and services," says Magnus Sjöberg, Macgregor's senior vice president, Merchant Solutions.


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AIR LUBRICATION

KUMIAI PICKS ALFA LAVAL'S AIR LUBRICATION TECH FOR LPG TANKER

Alfa Laval's OceanGlide technology has been selected by Southeast Asian LPG tanker and bulk carrier company Kumiai Navigation for installation onboard one of its LPG tankers as a retrofit.

The company's decision to leverage fluidic air lubrication technology is rooted in its ambition to reduce the vessel's energy consumption, improve its overall performance and comply with environmental regulations.

The OceanGlide system uses fluidic technology to create and control streamlined air layer sections on the vessel's flat bottom, each with its own fluidic band. The independent steering of each band allows a more controlled airflow to reduce friction between the hull and water. These individually controlled sections serve to minimise drag and ensure maximum coverage, eliminating passive cavities along the vessel's underside.

According to Alfa Laval, the technology is proven to reduce specific drag by 50-75% and provide fuel savings of up to 12% under real-life conditions. The actual amount of fuel savings achieved can vary depending on vessel operations and operator priorities.

The technology also supports compliance with EEDI/EEXI and CII requirements laid down by the International Maritime Organization to reduce greenhouse gas emissions, the company adds.

Tomo Kuroyanagi, managing director, Kumiai Navigation, says: "OceanGlide serves our goal of adopting advanced new sustainable technologies to remain competitive in this challenging market. We are excited to take advantage of the fluidic air lubrication technology to help us decarbonise and contribute towards our carbon reduction roadmap."

PROPULSION

ABB POWERS SAMSKIP'S NEW HYDROGEN-FUELLED CONTAINER VESSELS

ABB has signed a contract with global logistics company Samskip Group, based in Rotterdam, the Netherlands, to supply a comprehensive power, propulsion and automation system for two newbuild short-sea container ships.

The vessels will be among the world's first of their kind to use hydrogen as a fuel.

The two vessels will be built by Cochin Shipyard Ltd, the largest shipbuilding and maintenance facility in India. The 135m ships are due for delivery in 2025 and are planned to operate between Oslo Fjord and Rotterdam, a distance of approximately 700nm.

In addition to the integration of hydrogen fuel cells, ABB's package includes a new compact version ABB Onboard DC Grid power distribution. The vessels will also feature ABB Ability System 800xA automation technology to allow seamless operation of onboard equipment. Using ABB Ability remote diagnostic systems, the vessels will also receive 24hr remote safety and performance support.

The two vessels will be powered by a 3.2MW hydrogen fuel cell each, with diesel generators installed for back-up. Samskip, which aims to achieve net zero by 2040, anticipates that each vessel will be able to avoid around 25,000tonnes of CO_2 emissions a year when powered by fuel cells and by using green shore power at the port of call.

"Samskip's level of ambition on emissions requires partners like ABB, with similar objectives for innovation and the willingness to invest in the future," says Erik Hofmeester, head of fleet management, Samskip Group. "These ships are a milestone for the maritime industry, delivering hydrogen fuel cells as a clean and renewable technology."

The project is co-funded by Norwegian state enterprise ENOVA. Operating under Norway's Ministry of Climate and Environment, ENOVA promotes a shift towards more environmentally friendly energy consumption and production, as well as the development of energy and climate technology.

SAMSKIP'S NEWBUILDS ARE DUE FOR DELIVERY IN 2025. SOURCE: NAVAL DYNAMICS

SOUTH KOREA

HANWHA DEVELOPS ENERGY STORAGE SYSTEMS FOR LARGE OCEAN-GOING VESSELS

By **Tom Barlow-Brown**

The most recent acquisition by South Korea-based technology and engineering conglomerate Hanwha Group has had a rocky start. Formerly known as Daewoo Shipbuilding and Marine Engineering (DSME), the newly rebranded Hanwha Ocean posted losses of KRW159.1 billion (US$120 million) in Q2 2023.

However, the company now seems to have turned a new leaf after its full incorporation into the Hanwha brand in May this year. Since then, the research and development team has got to work on several different projects, both for the commercial and defence sectors. The latter of which Hanwha has previously specialised in.

The latest product announcement is a new series of energy storage systems (ESS) that can be used for large vessels, in particular LNG carriers. ESS systems allow for energy generated by a power source to be stored for later use. Combined with renewable energy sources onboard a maritime vessel they can form a hybrid system to allow for the optimisation of the vessel's power supply, thus reducing emissions and increasing fuel efficiency.

"The successful completion of this project is the result of synergy resulting from the industry-leading expertise and experience of both companies," according to the head of Hanwha Ocean R&D Institute, Joong Kyoo Kang. "With this success, we will continue to deliver advanced eco-friendly and digital solutions to shipowners with our cutting-edge technologies."

Hanwha Ocean has previously developed ESS for submarines and smaller vessels, such as workboats, but with this current venture is branching out into large ships. The technology developed by the company is a megawatt-hour class energy storage system that can be adequately integrated into the power supply of vessels such as LNG carriers or container ships.

As it is a joint venture between Hanwha Ocean and the already well-established Hanwha Aerospace, the latter will also take steps to develop the technology for use in the urban aerospace mobility (UAM) sector. The ESS uses lithium-ion batteries and features containerised packaging that consolidates the system. As a result, this reduces the amount of space the system takes up. It is also fitted with an automatic fire extinguishing function which allows for swift detection and fire suppression, increasing overall safety.

"The packaging and safety technology of ESS, which is essential for global decarbonisation, is critical not only in the defence sector but also in the aviation and maritime

THE NEW ESS TECHNOLOGY IS AIMED AT THE RAPIDLY GROWING 'ECO-FRIENDLY' VESSEL MARKET. SOURCE: HANWHA OCEAN

industries," says Seung Hak Moon, head of E-Propulsion Business Group at Hanwha Aerospace. "We're taking a holistic approach to maximise synergy through collaboration among affiliates, consistently placing the environment at the focus of all our activities."

Hanwha Ocean also recently partnered with French classification society Bureau Veritas in a joint development project (JDP) to assess the construction of independent LNG fuel tanks for ultra-large container ships. The project aims to enhance the design process of independent LNG fuel tanks by looking at how they are attached to the internal structure of a vessel.

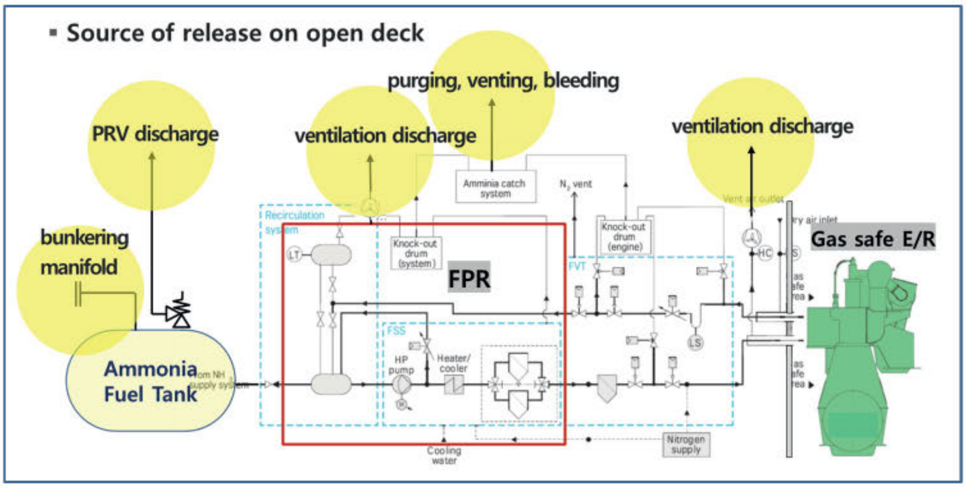
In its previous iteration as DSME, the company had specialised in the production of LNG vessels. It delivered the world's first and only LNG regasification vessel that supplied natural gas to disaster areas in the aftermath of Hurricane Katrina in the US in 2005. Among other accomplishments, the company has also produced 15 LNG icebreaker carriers for use in Arctic operations and, in 2020, delivered *HMM Algeciras*, at the time the world's largest 23,000TEU container ship.

Additionally, Hanwha Ocean has been granted approval in principle for cargo hold designs for ultra-large liquefied carbon dioxide (LCO2) carriers and an ammonia-fuelled gas turbine LNG carrier design from DNV and ABS, respectively.

It seems that Hanwha Ocean is now on its way to becoming a major player in the South Korean naval architecture field. The company plans to invest approximately KRW600 billion (US$450 million) to develop an eco-friendly propulsion system based on ammonia, methanol and hydrogen, as well as smart ship technology and autonomous vessels.

OVERCOMING THE TOXICITY CHALLENGE OF AMMONIA AS A SHIP FUEL: A TECHNICAL PERSPECTIVE

Both innovation and caution are key to mastering the hazards of ammonia and enabling its use as a clean marine fuel, according to South Korean classification society KR



SOURCE: KOREAN REGISTER

As the maritime industry pivots toward more environmentally friendly solutions, ammonia has emerged as a promising alternative fuel under the International Maritime Organization's (IMO) Global Greenhouse Gas (GHG) Strategy. While ammonia's carbon-neutral profile offers a clean option, it also introduces a new set of complications, notably its toxic nature.

Regulatory landscape and safety concerns

Traditionally, maritime fuel regulations primarily address flammability. With ammonia, toxicity becomes an equally crucial parameter. According to the existing International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) and MARPOL Annex VI/18, the use of toxic substances like ammonia as a fuel is currently prohibited.

CHOI Wooseok, principal surveyor of the Korean Register (KR) Machinery Rule Development Team, states: "The maritime industry has not yet seen a toxic gas like ammonia being used as a primary fuel. Its toxicity makes it a subject of numerous safety and health regulations. This creates an entirely new set of challenges that the existing frameworks don't currently address."

The use of ammonia as a fuel presents the industry with two main questions: Can ammonia leaks be effectively controlled within the maritime environment? If control measures fail, how can we safeguard crew members from harmful exposure?

The unique maritime environment

The maritime industry can glean insights from ammonia's use in land-based applications and its transport as cargo on ships. However, the maritime context presents several unique challenges that distinguish it from terrestrial applications where ammonia is used:

- Limited Space: The confined space on a ship complicates immediate remedial action and limits escape routes and evacuation measures in case of a leak.
- Lack of External Support: Unlike land-based scenarios, ships often cannot rely on quick external assistance for rapid incident management, placing the onus of safety solely on the onboard crew.
- System Integration: During maritime operation, ammonia is not merely stored; it is actively transported to the engine room for combustion, increasing exposure risks for the crew.

Risk assessment: the first step

Before ammonia can be considered a viable maritime fuel, comprehensive risk assessments must be conducted. These should include identification of all potential leak points and failure scenarios. CHOI Wooseok advises that: "The safe adoption of ammonia as a maritime fuel is dependent on comprehensive risk assessments and multi-layered safety measures. These assessments should go beyond individual ship systems to include a systemic view of potential risks."

Exposure limits and alarm systems

In the design phase for ammonia engines and fuel supply systems, manufacturers propose concepts that closely align with those for low flash-point fuels. This foundational design allows for the identification of all potential leakage scenarios, which must be addressed by implementing safety measures based on two key factors: concentration for toxicity and concentration for flammability, also known as the lower explosive limit (LEL).

To establish a safe environment onboard, it's crucial to determine the permissible exposure limit (PEL), a concentration level that poses no health risks, considering both the frequency and duration of exposure. While there are established concentration reference values for various terrestrial conditions, these existing guidelines for toxic substances in industrial environments provide some direction for maritime applications. CHOI Wooseok notes: "While land-based guidelines offer a starting point, we need marine-specific standards that consider the unique challenges of the sea."

One value under consideration for maritime applications is the PEL-time weighted average (PEL-TWA) of 25 parts per million (ppm), as defined by the National Institute for Occupational Safety and Health (NIOSH). This is a concentration level deemed to have no serious health impacts after repeated exposure over an eight-hour period. Additionally, it's crucial to identify the concentration that could cause serious health effects even during short-term exposure. A reasonable figure for this IDLH concentration is 300ppm as also defined by NIOSH.

So, how can a maritime environment ensure avoidance of long-term exposure to an ammonia concentration of 25ppm and short-term exposure to 300ppm? The straightforward solution involves the strategic placement of gas detectors in areas where hazardous gases may be present. These detectors would be configured to trigger an alarm system, calibrated to the identified limits, and emergency protocols can include gas treatment and shutdown systems set to trigger at predetermined concentrations, such as the suggested IDLH concentration of 300ppm.

Design safeguards

The design specifications can provide insights into various aspects of each potential leakage scenario, including the quantity of leaked material. To ensure the safety of seafarers, specific safety measures can be implemented for key sources of leakage, as detailed below:

- Machinery Space: Following the International Code of Safety for Ships Using Gases or Other Low-flashpoint Fuels (IGF Code), the machinery space can be designed as a gas-safe area. Gas detectors within double-walled pipes would be set to sound an alarm at an ammonia concentration of 25ppm and to shut down fuel systems at 300ppm.
- Fuel Preparation and Tank Connection Space: Gas detectors in these areas would trigger an alarm at an ammonia concentration of 25ppm. At 300ppm, they would shut down fuel systems and activate gas treatment systems, thereby controlling gas levels within the space as well as in the ventilation discharging to the open deck.
- During Bunkering: Entry to the area surrounding the bunkering station would be restricted. Gas detectors near the bunkering manifold would sound an alarm at 25ppm, initiate gas treatment systems to control the concentration, and halt bunkering operations at 300ppm.
- Purging of Fuel Pipes: The ammonia treatment systems should ensure that ammonia leakage into the air during fuel pipe purging is capped at 300ppm.

For normal operating conditions, existing gas treatment systems are capable of reducing ammonia gas concentrations to permissible exposure limits. However, emergency scenarios – such as a tank pressure relief valve opening due to fire or collision – could result in substantial leakage. To mitigate this risk, tanks should be safeguarded against impacts and fires. Additionally, robust gas treatment systems and comprehensive emergency response plans should be in place. Specifically including contingency to demarcate toxic zones around all sources of gas release. The gas-safe area should be spatially separated from these toxic zones to prevent the inflow of ammonia gas. The upper limit for defining an ammonia toxic zone should be set at 25ppm.

Regulatory developments

The IMO has accelerated the development of safety provisions for ammonia fuel, targeting completion by 2024 and the adoption of interim guidelines by 2025. These provisions are likely to form the basis for future regulations for ammonia cargo used as fuel under the IGC Code.

CHOI Wooseok emphasises the need for collaborative efforts: "Effective regulations will only emerge from a multi-disciplinary approach involving ammonia chemists, ship operators, builders, and safety experts."

Beyond regulation: human factors and emergency planning

Besides technological and regulatory advances, human factors play a pivotal role in safety. Crew training, proper maintenance, and detailed operational manuals are paramount. In emergencies involving leaks, fires, or collisions, the ship must have a well-co-ordinated emergency response strategy.

Conclusion and future outlook

Ammonia's potential as a marine fuel is significant but not without obstacles. Rigorous safety measures, guided by exhaustive risk assessments and informed by collaborative multi-disciplinary insights, are essential. As CHOI Wooseok concludes: "The era of ammonia-fuelled ships is closer than we might think, but reaching that point safely is a complex journey that requires both innovation and caution."

As regulatory bodies, engineers, and safety experts continue to work together, the development of a comprehensive safety framework for ammonia as a marine fuel is in sight. The roadmap for achieving this lies in detailed risk assessments, safety-centric design modifications, stringent regulation, and proactive emergency planning and crew training.

CAD/CAM/CAE

BY 2040, THE WORLD WILL HAVE CHANGED – SO HOW DO WE DESIGN SHIPS FOR IT?

By **Mikko Forss**, executive vice president for design solutions, NAPA

Ship designers today are building vessels for an economy and tech landscape that might look very different from ours today. Last year, the average age of a container ship was 14 years. Depending on your age, 2009 may or may not just feel like yesterday – but this was a world where Uber and Airbnb had only just launched, we'd only had iPhones for two years, and no-one was going to join a Zoom meeting for the next three years. Just 3,884TW of energy came from renewables in 2009 – it's more than doubled to 8,538TW now. The same ships are sailing through a world that has changed fundamentally.

Those designing ships now need to think on a similar timeframe, accounting for technological unknowns, and a much greener maritime economy. Maersk's methanol-fuelled *Laura Maersk*, recently named, marks – hopefully – the beginning of a new generation of vessels. And while the IMO's latest ruling at MEPC 80 has had a mixed reception, there's reason to believe this regulation could usher in some big changes. A recent evaluation from academics at UMAS has found that, even at the lowest ambition interpretation of the strategy, an average ship's GHG intensity will need to be reduced by 86% by 2040.

Designing for the unknown

Making this a reality starts with the design process – from prototype design and beyond, as new ships make their way from concept to reality – and the creativity and ingenuity of the designers and structural engineers at each stage. This means the next few years are pivotal – and a major opportunity for those who embrace the challenge. The Japan Shipbuilders' Association forecasts that the transition to carbon neutrality will drive a rapid expansion of the shipbuilding market in the next decade, which is expected to surpass historical peaks.

NAPA'S EXECUTIVE VICE PRESIDENT FOR DESIGN SOLUTIONS, MIKKO FORSS

In this context, key considerations for shipyards will be twofold. Firstly, how to streamline the design process to boost their own productivity and protect their businesses' commercial viability. The more moving pieces to manage, the more important it becomes to have efficient processes in place. Naval architects and structural engineers need more streamlined and efficient tools to create their designs and get them approved.

Secondly, in addition to being fast, designers will need to innovate and create next-generation vessels efficiently, by making the right decisions throughout the design process to deliver the best possible outcome for their customers. In practice, this means being able to test different configurations easily, make changes quickly, and manage information in smarter ways.

Design challenges in the future fuel era

This 86% less GHG-intense future relies on designs that can accommodate new fuels. The energy transition increases demand for "future-proof" designs, such as ships that are ready to be converted to methanol or ammonia, or retrofitted with energy saving applications (such as wind propulsion), at a later stage. These designs require allocation of space for additional storage tanks or ensuring that the ship structure will be adapted for wind propulsion, for example.

For the people in charge of creating and building those ships, this growing focus on new fuels and power systems has a direct consequence: it increases the complexity of designs.

While it has always been the case that no two vessels are exactly the same, the number of variables involved in today's designs make them more complex and unique than ever. The single-fuel era is, inevitably, behind us – moving forward, ships will be powered by a broader range of fuels, technologies, and alternative energy sources, all of which have their own specifications and implications for the vessel's structure, stability profile and general arrangement.

For instance, the storage of hydrogen requires at least twice as much space compared to conventional fuel oil, depending on the technology selected. Similarly, using ammonia as fuel will require the installation of additional fuel tanks and safety systems. Furthermore, because of their flammability or toxicity, some fuels will require specific configurations to ensure that tanks are isolated from accommodation or any sources of heat, or to provide additional ventilation systems, for example.

Therefore, switching to a new fuel is far more complex than just changing a ship's engine and tanks – it impacts fundamental aspects such as the vessel's stability, weight, and structural integrity. For naval architects and structural engineers, the challenge will be not only finding ways to integrate new systems onboard, but to do so while ensuring the ship's safety and stability. Being able to navigate this complexity efficiently, while also respecting increasingly challenging time constraints that many shipyards face today, will be essential to flourish in this new era.

The right tools today for tomorrow's ships

Designers might not be able to affect future technology choices, but they can make sure they are using the best tools available today to set ships up for success.

A key place to start is by making a greater use of 3D models in the ship design information management process. One challenge is to enable the vessel's 3D model to be used consistently as a "single source of truth" throughout the design process. A single, consistent model allows better communication and collaboration from the early concept stage through to classification approvals, and then through detail design, and all the way in downstream production design. Beyond that, a digital model has continued utility as the basis of a digital twin throughout the lifecycle of a vessel, providing valuable performance insights and preserving essential details for repair and maintenance operations.

A ship design is an iterative process that typically involves several teams in charge of structures, propulsion, electrical, general arrangements, weight estimations, etc. Using 3D models as the central source of information on a ship design helps break silos, ensures data consistency between disciplines, and enables those teams to communicate more efficiently. Not only does this save significant time and minimises duplicate input, but it also helps avoid costly errors in the downstream process.

Going forward, the increasing need for real-time information exchange and efficient feedback loops will be another key driver towards a single model that facilitates co-ordination between the disciplines and external stakeholders. This reduces the time spent on data input and conversions, allowing teams to focus on what they do best: delivering the best possible designs. As cross-industry collaboration grows in importance the single model will play a vital role in enabling this, while ensuring IP protection – and simultaneously front-loading important decisions and challenges in the design process to achieve optimal, future-proof design.

The next generation of simulation

In addition to using 3D tools for a more efficient process, the next frontier will be to make the most of their potential to support decision-making. 3D models will unlock even greater opportunities going forward, including the possibility to use next-generation simulation tools that can model the future ship's performance in actual sea conditions from the very early design phase. In short, thanks to 3D models, naval architects and structural engineers will be able to compare different alternatives from the outset to deliver the best possible concepts for their clients.

This is more than a theoretical prospect – simulation tools can already deliver a variety of assessments, including virtual voyage simulation, alternative fuel comparison, wind-assisted propulsion simulation, load case simulation, and flooding risk management and accident response.

This is an essential asset for the multi-fuel and multi-technology era ahead. In practice, simulation tools enable teams to assess and test different fuel and technology options, with a comprehensive view of their implications for the ship's configuration, cargo capacity, stability, and even its future performance.

Just like it's impossible to imagine a pre-Zoom existence, or a world where a methanol-fuelled container ship seems radical, we can't predict what kind of world the ships we design today will come of age in. But if yards, designers and structural engineers, along with others such as class societies and owners, make smart design decisions now, we can make sure they are set up for success.

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SHIPBUILDING CAD/CAM INTEROPERABILITY AND DATA UTILISATION

By **Ludmila Seppälä**, business development director, Marine Industry, Cadmatic

Interoperability is a key concept frequently mentioned in discussions concerning data exchange and CAD/CAM data formats within shipbuilding. The necessity for data exchange is abundantly clear in shipbuilding projects, given their intricate and protracted nature, requiring the involvement of numerous specialised software systems at various project stages. Flexibility in interfaces with manufacturing systems is crucial. While the idea of a singular, all-encompassing solution for shipbuilding needs remains an aspirational goal, it is unlikely to be achieved due to the inherent complexity of shipbuilding, which involves specialised naval architecture, calculations, simulations, 3D design, diverse manufacturing equipment, and engineers' preferences, among other factors.

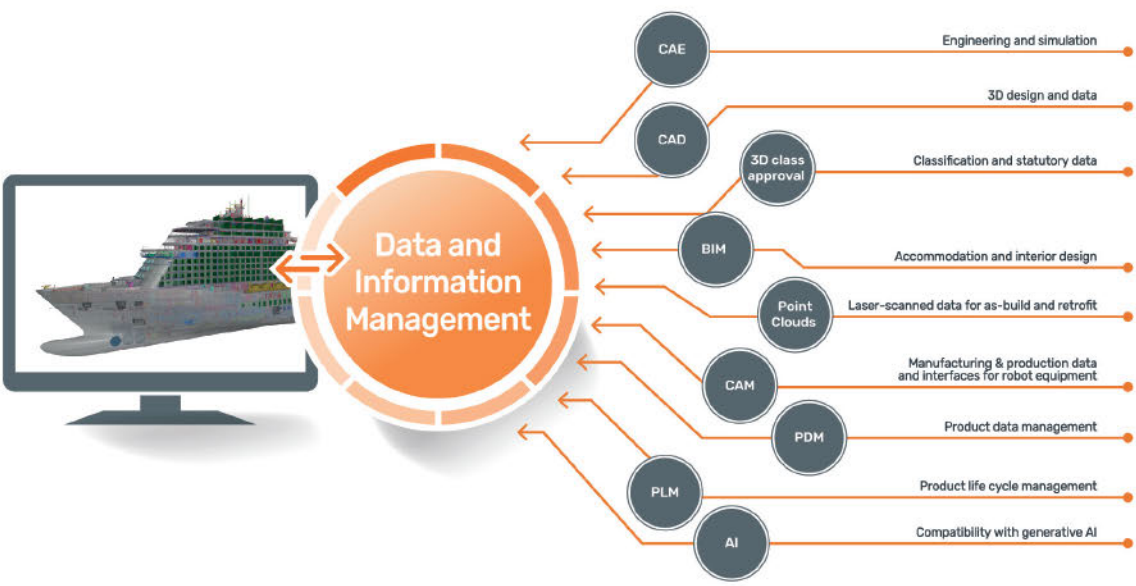
In the typical shipbuilding IT ecosystem, a range of applications must exchange data to support the process and ultimately construct vessels. Consequently, the demand for interfaces and data exchange will remain a top priority for the foreseeable future. This article delves into the underlying processes and highlights various aspects of the ongoing discussion on interoperability within the shipbuilding industry.

The fundamental distinction between interoperability and compatibility lies in the utilisation of data. While compatibility concerns the static aspect of data formats – whether they can be interchanged, imported, exported, or replaced – interoperability goes further by considering the dynamic nature of data use. It examines how data flows can integrate various formats and influence the overall process.

Challenges

Traditionally, CAD/CAM file formats and data structures posed challenges in shipbuilding. These stemmed from vendor-specific data models, often closely guarded by software providers. Each vendor focused on their proprietary solution, making collaboration with external stakeholders like classification societies, subcontractors, equipment manufacturers, and shipowners challenging. This often led to users resorting to 2D documentation exchange or industry-neutral file formats like PDF or DWG. Additionally, there was a need for supporting interfaces and data exchanges with CAM solutions and production MES systems. As digitalisation advanced, it became evident that achieving interoperability required concerted efforts from software solution vendors and promised significant benefits to the industry. The openness of the shipbuilding software solutions supports multi-CAD strategies of companies, provides the flexibility of executing projects involving subcontractors who might use different tools, supports offshoring of production to yards using different CAM solutions, opens the possibility for additive manufacturing and provides potential for facilitation of the digital thread and related new business areas for using the digital assets.

An acknowledged hurdle in shipbuilding is the absence of standardised data structures and taxonomy, which has received less research attention than in industries like mechanical engineering and construction. While attempts to develop neutral formats such as STEP or IGES were made, their compatibility level remained restricted to export/import, failing to preserve topology,



IN THE TYPICAL SHIPBUILDING IT ECOSYSTEM, A RANGE OF APPLICATIONS MUST EXCHANGE DATA TO SUPPORT THE PROCESS

THE CONVERSATION SHOULD FOCUS ON DATA USE AND DIGITAL THREADS WHEN DISCUSSING DATA UTILISATION

interconnections, or support data flows throughout the project life cycle.

Data exchange inevitably carries the risk of data quality degradation. Exporting and importing data often results in losing its "native" characteristics, potentially losing topology information within 3D models, or intentionally simplifying data for specific purposes. The emergence of initiatives like the DNV-led consortium's Open Class 3D Model Exchange (OCX) holds promise. This initiative aims to transition classification approval from traditional 2D drawings to 3D model-based class approval, potentially becoming an industry-wide neutral format for data exchange.

Data security is a significant concern in data exchange, encompassing data storage and transfer and intellectual property (IP) rights. Shipbuilding 3D models and data often contain innovative solutions that companies must safeguard as their IP. As a result, companies are often hesitant to share these with external parties, including classification societies. 2D drawings are seen as a safer option since reproducing them in 3D requires significant effort. Various methods, including model expiration, data filtering, secure access, legal agreements (like NDAs), and contractual obligations, aim to address IP rights for 3D data. However, it will take time for the industry to develop sufficient trust in these technological measures for data protection.

New business opportunities

Transitioning from a digital model to a digital twin is another consideration that necessitates interoperability and unlocks new business opportunities. This entails mapping 3D and metadata to integrated logistics support, operational data, and IoT for smart shipyard processes during manufacturing and throughout a vessel's lifecycle. The shipbuilding industry often fails to utilise digital models from the design and production phases in later stages. This creates a gap in understanding the vessel's as-engineered, as-designed, as-built, and as-is states, complicating lifecycle management and reducing possibilities for data-driven decisions.

The conversation should focus on data use and digital threads when discussing data utilisation. This involves shipbuilding design methodology, organisational design, information flows, and software solutions in use. The latter can significantly alter a company's processes and depends on the interoperability of CAD/CAM solutions beyond data format compatibility. While there is a general belief that all project data should ultimately be collected in a central point to form a master data repository, modern IT systems challenge this assumption. Decentralised data storage and context-based data use have gained prominence, necessitating interoperability at the data format and compatibility levels to facilitate data flow design. It might be that sustainable operations and data utilisation would be more resilient if needed, and a class of interoperability would support a decentralised approach. Examples of such systems can be data visualisation based on multiple sources of data, where instead of collecting data in one database, the online connection facilitates the fetch and use of data for the needed operation.

Artificial intelligence (AI) will impact data interoperability significantly in the future. Ongoing studies and examples demonstrate AI's potential to learn data models and provide mapping for large datasets, offering a potential solution to complex industry problems. The discussion on interoperability will remain pertinent, as data utilisation depends not only on technology and processes but also on human preferences, user experience (UX), and other factors beyond technological advancements. It remains to be seen how AI can perform such tasks while restricted to a limited company's data sets and if it can operate outside the boundaries of vendor-specific data models. ■

HYDROCOMP NAVCAD AND PROPELEMENTS: GUARDRAILS FOR CFD

By **Donald MacPherson**, technical director, HydroComp, Inc

The increased use of CFD for hydrodynamic analysis over the last decade has been remarkable, with tools becoming more commercially attainable and accessible. Designers are now looking to CFD for confirmation, optimisation, and better understanding of the hydrodynamic aspects of their designs. While CFD is now expanding insights to a larger audience, practitioners must also develop the means to judge when CFD computations are being appropriately modelled and conducted.

These judgements of computational fidelity often come from reference validations, both from in-house experience and public data. That said, validation studies are of a specific application that may, or may not, be relevant to the project at hand. To generate suitable references for CFD quality assessment, we call on other tools to provide qualitatively and quantitatively strong validation predictions quicky and efficiently. HydroComp's NavCad and PropElements software are two of the most widely used tools for Vessel-Propulsor-Drive system simulation and propeller detail design.

To understand how NavCad and PropElements fit into the hydrodynamic design workflow with CFD, let's break down a typical design process. Everything is a system problem first. Component design is not worthwhile until the system functions well together. NavCad provides various parametric and distributed volume models for vessel resistance and hull-propulsor factors, propulsor thrust and torque, and drive power delivery. NavCad's effectiveness for early-stage design is evident, narrowing the design space for future CFD confirmation and review – but it can also provide substantial assistance to CFD analysis for initial propeller modelling and to generate benchmark results for confidence in the CFD results.

NavCad oblique-flow propeller models for actuator disks

One of the realities of CFD computations is that they take a long time, and we use certain simplifications where they are appropriate and valid. The use of a virtual proxy propeller model – the actuator disk (AD) – is one such simplification. ADs are typically fed with propeller open-water J-KT-KQ data (and often also with wake fraction) to provide the thrust and torque figures that generate momentum body forces in a propeller disk area. However, when a propeller is placed in "oblique flow" with a shaft angle, the open-water KT-KQ figures are no longer valid. NavCad can consider the effects of non-axial flow, including a corrected KT* for ADs that accounts for a KT oblique flow vector loss and the often overlooked in-plane vertical normal force (shown as KZP). These both can be significant omissions, particularly for planing craft where thrust line and stern lift forces are important contributors to a proper equilibrium force and moment model.

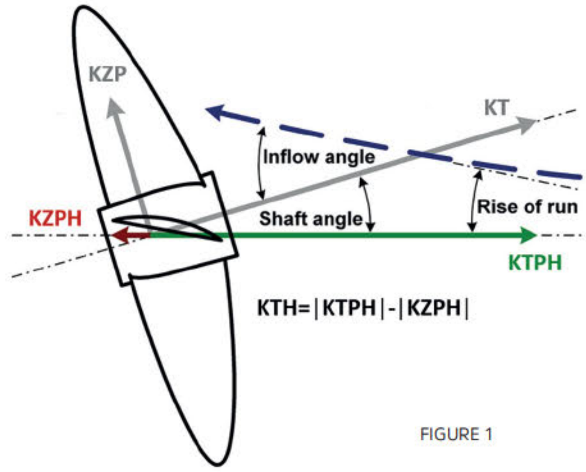


FIGURE 1

Controlling torque-limited computations

Not all computations are for steady-state design conditions. In cases of dynamic operation and loading – such as vessel acceleration or manoeuvring – sometimes we need to understand and control CFD analyses to the limits of drive system operation. NavCad provides a system-level simulation model that can generate drive-specific speed-rpm-power limit data for functions to apply as a control to CFD self-propulsion computations, whether the drive be a diesel engine or electric motor. This can even be extended to dynamic oblique conditions for refinement of results at different dynamic trim angles, for example.

Closely coupling NavCad for interactive dynamic data

Both examples above generate important static data that can be sources for development of "look-up" functions. In some cases, such as controllable-pitch propellers (CPPs), a multi-dimensional static reference can be cumbersome. In these circumstances, the server mode feature of NavCad Premium can be used to dynamically provide performance data back to CFD in real-time. When closely coupled to a CFD code using the server mode feature, NavCad becomes the source for dynamic generation of KT-KQ data, or even specific rpm, thrust, and torque figures.

DONALD MACPHERSON, PRINCIPAL NAVAL ARCHITECT AND TECHNICAL DIRECTOR OF HYDROCOMP, INC.

The benefits of closely coupling NavCad Premium as a calculation server go both ways. In addition to providing dynamic propulsor data to CFD, NavCad can also exploit the vessel resistance data coming from CFD as the reference for system modelling. This establishes NavCad as the executive responsible for the system simulation, with the CFD code accepting updates for the appropriate propeller performance and hull-propulsor coefficients at the indicated time-step condition, then delivering back to NavCad updated resistance (and trim, as indicated) – even incorporating CFD-generated figures for appendage and windage drag.

Full wake-field modelling via closely coupling PropElements with CFD

A full self-propulsion CFD computation with rotating-frame/sliding-mesh propeller models can provide a lot of insight but is typically too computationally rigorous and time-consuming to be effective in design. (Remember, design is largely about iterative analysis, with each generation improving on the former until a conclusive iteration is reached.) While the AD is a suitable proxy stand-in for a propeller in early-stage design or where precision of local forces or velocities are not required, there are many cases where a more realistic model of a propeller is needed – but one without the computational overhead. (Appendage flow alignment, such as twisted rudder design, quickly comes to mind.)

To achieve this, PropElements can be used as a replacement for the AD, reaching nearly the high fidelity of a full 3D propeller computation with the low cost in resources and time comparable to the AD. By dynamically coupling PropElements in server mode, a proper radial and circumferential distribution of body forces can be developed in PropElements and transmitted to CFD. Velocities around the propeller disk (taken either as a pre-propeller or post-propeller wake disk) are transmitted to PropElements for extraction of effective wake velocities (via its internal calculation of induced velocities) and jet compression around the disk area. Body forces on the propeller disk are calculated and returned to CFD for use as momentum sources.

PropElements preparation of geometric models for CFD

Everything we think we understand about a ship's propeller is generated by a model. While models can have different levels of precision, all share two principal sub-models – a geometry model and a computational model, and it is important to get both right.

In the case of propellers, the geometric model is frequently generated from pre-defined curves and profiles. However, arbitrary development of a 3D propeller simply as a proxy for CFD analysis does not take advantage of a propeller geometry that has been designed to meet the performance objectives – not only objectives of high efficiency, but also with considerations of cavitation, hydroacoustics, tip unloading, even blade strength. PropElements provides the "design for performance" platform for the appropriate wake-adapted propeller design first, and then for generation of full 3D geometry for CFD in surface and mesh formats.

Not only can propeller blade geometry be exported in 3D IGES or STL formats, but additional pieces of the CFD geometric space can be generated. Notably, users can develop volumes for the near- and far-field domain, as well as the rotating and fixed volumes. For cases with nozzles, a collection of popular nozzle styles can also be quickly exported as 3D models at the appropriate size to match the propeller and tip gap requirements.

Confident benchmarks for quality assurance

The complexity of geometric and computational models can lead to uncertainty, particularly for those new to the use of CFD for hydrodynamic analysis. Variation in geometric models come from different strategies in meshing and refinement, as well as near- and far-field domain sizing. Very localised shape characteristics can alter decisions in turbulence modelling and time-steps. For example, different characteristics of trailing-edge curvature on a propeller blade can greatly affect decisions on the time steps for advancing the blade. Remember, geometric and computational models must reflect the physics of the shape characteristics. If you are trying to investigate the development of a shed vortex stream, you must advance

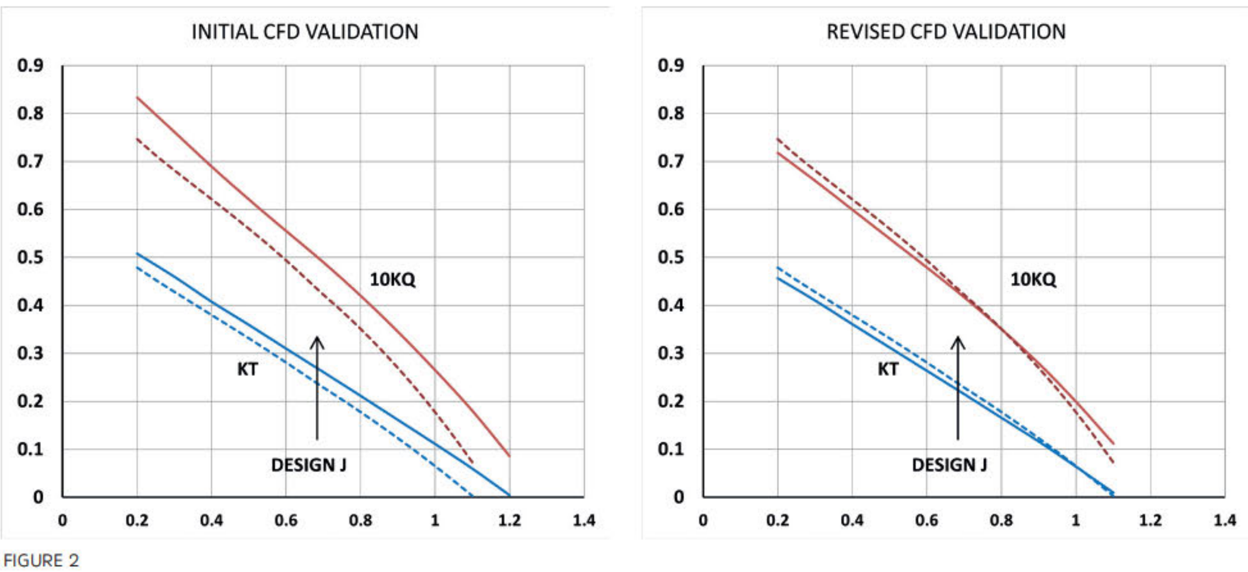


FIGURE 2

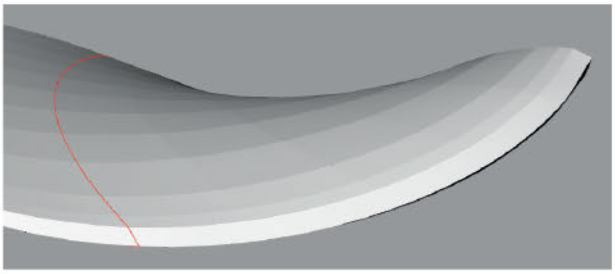


FIGURE 3

the body in very small steps. If your objective is basic force development, then larger steps may be acceptable.

For example, PropElements saved one CFD user from substantial embarrassment by providing a benchmark that clearly indicated something was amiss with the CFD calculation. In the KT-KQ plot in Figure 2, you can see the CFD results (solid) and the PropElements calculation for the same propeller (dashed). (Of course, the first task in this validation study had been to confirm the PropElements calculation with a validation of its own against test data of a propeller with very similar style and parameters.)

As you can see, for the initial CFD study there is substantial difference in KT and especially KQ between the PropElements and CFD open-water calculations. The team discussed the potential cause of the difference, including grid count, edge condition (particularly the trailing edge curvature), and the CFD viscous and turbulence settings. The actual cause of the problem was soon found to be much more fundamental (and obvious, as can be seen in Figure 3). The propeller geometry was pushed to meshing as a faceted surface. The blade sections used sparse offsets, were left as polylines, and not splined into smooth curves before lofting the surface. No visual check was made on the geometry, due to a push to automate the process. The PropElements benchmark caught the issue, the geometry was corrected, and a revised CFD computation was completed – with much greater confidence going forward.

CFD practitioners benefit from pre-defined expectations on the magnitudes of the attributes being investigated. Resistance computations can employ NavCad's bare-hull and added drag predictions and comparison to its "confidence plots" for benchmark validation. PropElements gives you similar benchmarking benefits with details on a whole-propeller level (such as thrust and torque, or KT-KQ plots) and on a distributed level (including induced and total velocities), all of which can be used to validate the CFD computation.

You have invested a lot in CFD. Companion tools like NavCad and PropElements offer useful and important guardrails to help you achieve the best outcomes and return on that investment. ■

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Technical Conference:

Managing CII and Associated Challenges

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As part of its commitment to addressing climate change, IMO has developed a Carbon Intensity Indicator (CII) for international shipping. The CII is intended to measure and drive improvements in the energy efficiency of ships. CII was adopted in 2021 as part of a package of amendments to MARPOL Annex VI, which were a response to the IMO's Initial Strategy on Reduction of GHG Emissions from Ships. IMO's Strategy sets out a vision to improve the carbon intensity per transport work of shipping by 40% in 2030 relative to 2008.

The CII has been designed as a key tool to assess and monitor the carbon intensity of both new and existing ships, with an emphasis on operational efficiency that was not addressed by other IMO short-term GHG measures. CII requirements took effect from 1 January 2023, so in early 2024 the industry is expecting to receive the first feedback of CII measures. A review of the effectiveness of the implementation of short-term CII and EEXI requirements must be completed by 1 January 2026, and it was agreed at MEPC 80 in July 2023 that this process would commence at MEPC 81 in March 2024.

The Royal Institution of Naval Architects is proposing the Technical Conference as an opportunity for maritime influencers to gather and discuss the challenges and opportunities arising from this measure.

https://rina.org.uk/events/events-programme/technical-conference-managing-cii-and-associated-challenges/

SAFETY

VIKING LAUNCHES SPECIAL PROJECT TO TACKLE EV FIRES AT SEA

By **Tom Barlow-Brown**

Fires onboard vessels at sea have become increasingly common in recent times. Many of these are allegedly associated with the carrying of electric vehicles (EVs). The most recent and prominent incident made headlines in July when the *Fremantle Highway*, a 200m ro-ro vehicle carrier, caught fire off the coast of the Netherlands in July.

While the ultimate cause of the fire is still unknown, the vessel's cargo of EVs has been posited as a probable root cause. The fire onboard *Fremantle Highway* led to the death of one crew member and left several others injured. Moreover, the fire is the fourth major incident since 2021 to occur on a car carrying vessel, and the second in July 2023 alone.

A recent report from insurance company Allianz stated that lithium-ion batteries pose a "growing risk" for car carriers, with fires mostly resulting from "substandard manufacturing or damaged battery cells or devices, over-charging and short-circuiting". Allianz also found that fires were the second-highest cause of loss for shipping vessels last year, after sinkings. In 2022 eight vessels were lost and more than 200 outbreaks of fires were recorded.

A call for increased awareness

As a result of these incidents multiple organisations have called for increased awareness of the risks associated with handling EVs as cargo. "These tragic cases have highlighted the urgency of the project regarding safety onboard when you carry electric vehicles. Solutions need to be found, or at least there needs to be some more focus on this matter," Louise Søgaard, product manager at Viking Life-Saving Equipment, tells *The Naval Architect*.

Viking has recently launched an initiative on electric vehicle fires which includes signing distribution agreements for fire extinguishing innovations in marine fire safety. The company will be distributing a strong range of EV fire suppression solutions and technologies to shipowners worldwide, including Bridgehill's car fire blankets. With the increasing demand for EVs the company aims to further develop its position as a leader and go-to expert in maritime fire safety solutions.

The special project was launched in June this year, a month before the *Fremantle Highway* incident, and it incorporates much of the knowledge the company has already gained through fighting conventional fires

FREMANTLE HIGHWAY AFTER BEING TOWED TO THE PORT OF EEMSHAVEN, THE NETHERLANDS. SOURCE: DUTCH MINISTRY OF DEFENCE

TESTING OF A BRIDGEHILL FIRE BLANKET. THE BLANKETS CAN SWIFTLY CONTAIN FLAMES, SMOKE AND TOXIC FUMES DURING AN EV FIRE. SOURCE: VIKING LIFE-SAVING EQUIPMENT

onboard vessels. Viking and its partners hope to take a proactive stance in terms of potential safety issues that both its customers and the wider industry are facing.

Viking has already marketed the HydroPen, a unique and user-friendly system for use in fighting fires onboard container ships. This system has now seen almost industry-wide implementation. According to Viking, the HydroPen has already been used to contain a fire in a container loaded with 150,000pcs lithium-ion batteries. "Electric vehicle fires are in many ways very similar to this case. We have maintained close dialogue with our customers, and we try to identify and act on the challenges they face," says Søgaard.

Recommended risk assessments

The European Maritime Safety Agency *Guidance on the carriage of alternative-fuel vehicles in ro-ro spaces* recommends risk assessments for every vessel moving EVs and carriage of procedures for prevention and mitigation of EV fires. Recommended procedures included the use of "portable equipment (local water cooling etc.)" and "a strategy to contain the fire".

By working in tandem with its suppliers, Viking hopes to produce a solution to both these problems. For instance, Bridgehill's fire blanket offers specific performance characteristics to deal with EV fires and the company has delivered several units to a car carrier owner and to ferries worldwide. The 6m x 8m blankets weigh 26kg and can be deployed by two personnel and reused multiple times. The blankets have a melting point of around 2,500°C. As a result, they can contain an EV fire securely until a more robust response is available or the vehicle is removed, according to Bridgehill. Each car deck should be equipped with its own fire blanket.

"On the equipment side it is of key importance to isolate and stabilise an EV fire until you reach a port. That's exactly what the equipment that we are working with now is for," says Søgaard.

The EU has also funded the Legislative Assessment for Safety Hazards of Fire (LASH) project, which will address 20 critical aspects identified by the European Maritime Safety Agency and the International Maritime Organization. The project has further revealed new information that can assist owners in managing fires onboard vessels – for instance how to deal with a vehicle fire that has not reached the battery – which Viking is also interested in exploring a solution to.

Crew training is vital

Adequate training and preparedness are also vital for crew members who need to tackle fires at sea. This is something Viking is investing in through the company's academy. "Seafarers are rarely trained and experienced firefighters, so training is such a crucial element to consider. I know that our customers have spent quite a lot of effort in trying to train their crew to tackle these scenarios and bring down response times," says Søgaard.

"There is no doubt that we're going to see a lot more electric vehicles being transported by sea, it is a safety challenge to the industry and to the crew and passengers onboard the vessels," she adds. "I really hope to see a lot more focus on the subject and that operators will be able to educate and train their crew to a high level of competency and preparedness, both with the handling of the various products that we supply as a vendor, but also in handling and supressing a fire before it reaches the battery."

The results of the investigation into the fire onboard the *Fremantle Highway* are not yet known, and it will likely take time before they are released. For Viking the findings, combined with the company's own research, will hopefully bring even more knowledge into what the company can provide in terms of safety for ship owners and crew members.

"I'm hoping that this campaign and these products that we put on the market can bring more focus to the issue. Viking's mission is to protect and save human lives at sea and we always remain proactive towards emerging safety challenges," concludes Søgaard.

ADDRESSING THE GROWING THREAT OF CARGO LOSSES AT SEA

With growing container ship capacity and increased numbers of container losses at sea coinciding, classification society ClassNK has published two sets of guidelines to help shipping companies improve cargo safety at sea

The recent increase in container ship capacity – a response to the growing demand for freight container transport – has coincided with a sharp increase in the number of containers lost overboard, including some notable examples of stack collapse. While rising stack heights have surely contributed to this trend, other influential factors include wave height and size, the ship's vertical centre of gravity (CoG), the CoG of the container stack and variability in stowage, and cargo securing equipment.

In one frequently cited incident that saw the loss of containers from a 13,000TEU ship, a maritime authority investigation concluded the most likely cause of lashing equipment failure to be parametric rolling. This is a resonance phenomenon caused by periodic changes in the stability of a ship in a head sea, following sea or quartering sea and can result in heavy rolling in a very short time.

To address the increasing frequency and severity of cargo-loss incidents at sea, ClassNK has released two sets of guidelines for container ships, one offering updated guidance on safe container stowage and lashing and the other focusing on measures to prevent parametric rolling.

Combining load analysis with big data

Guidelines for Container Stowage and Securing Arrangements (Edition 3.1) uses load analysis combined with big data from the automatic identification and oceanographic data captured during the comprehensive revision of ClassNK's ship structural rules to develop recommendations for optimal stowage that consider not only the route but also seasonal effects for calculation of the load correction factor.

Accounting for the growth in container ship size and the evolution of lashing techniques, the guidelines offer an overview of the transportation and securing of cargo at sea, types of container ships, types of freight containers and stowage methods on exposed decks and in cargo holds. The publication goes on to describe typical standard values related to the strength of containers and securing devices before detailing precautions for hull strength related to stowage and securing arrangements and outlining a strength evaluation method for these arrangements.

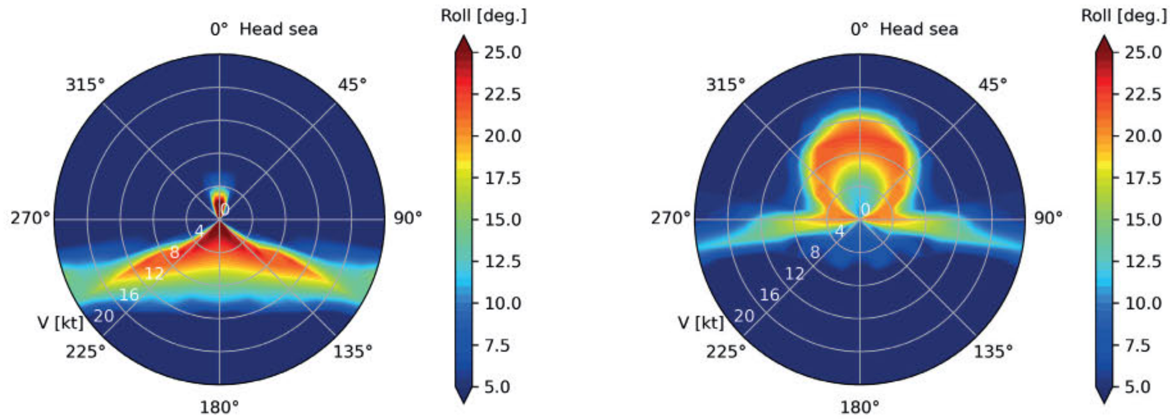
The strength evaluation covers container stowage and securing arrangements on deck and in the hold. It begins with the estimation of loads acting on the container, including ship motions and accelerations – and the correction of these according to sea route and season – as well as the dynamic and wind loads acting on the containers. The strength evaluation also considers stiffness constants for containers, lashing rods and lashing bridges in addition to allowable loads for containers and securing devices. As explained in the guidelines, this can be carried out using a lashing calculation program. In addition, ClassNK plans to release an application for calculating route correction factors and tools for use in strength evaluations of container stowage and securing arrangements.

Preventative measures

Meanwhile, *Guidelines on Preventive Measures against Parametric Rolling (Edition 1.0)* describes the mechanism and features of parametric rolling as well as the requirements for granting notations for ships with effective preventive measures. It also outlines key points for preventing it, including early avoidance of danger zones and immediate course change on detecting any signs of the phenomenon. This requires special attention to the direction and encounter period of swells as well as awareness of vessel-specific characteristics including natural roll period, estimated roll angle – knowledge of which is particularly important for larger vessels – and vulnerability to parametric rolling.

As outlined in the guidelines, a ship's vulnerability to parametric rolling can be evaluated using one of several methods described in the International Maritime

SOURCE: RINSON CHORY/UNSPLASH



EXAMPLE OF POLAR CHARTS OF ESTIMATED PARAMETRIC ROLLING ANGLES

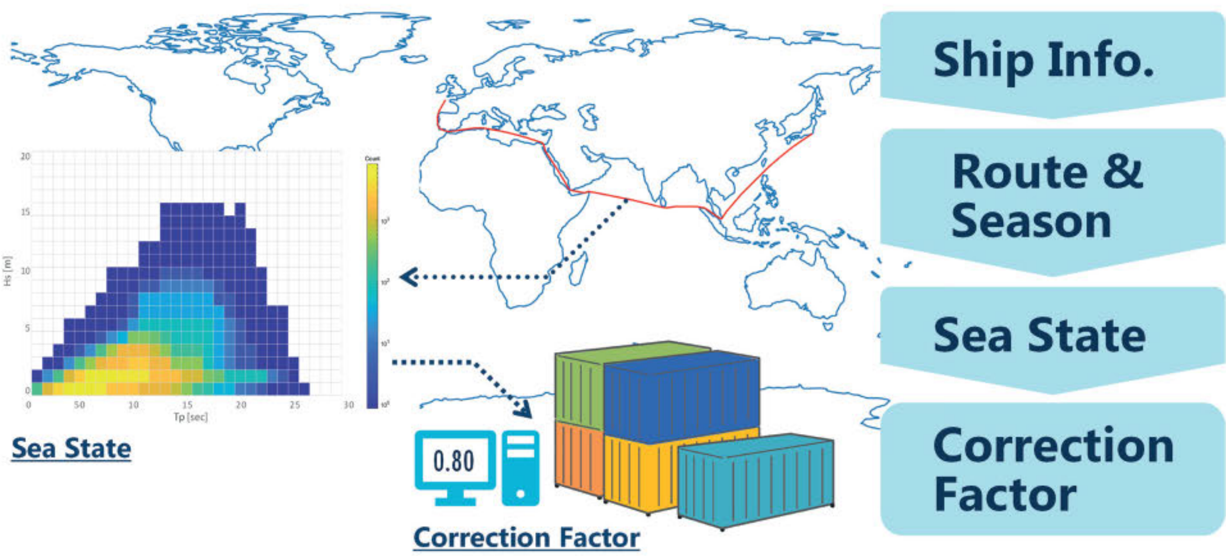
Organization's second-generation intact stability criteria. By carrying out series calculations of the predicted roll angles in various navigation conditions and sea states, it is possible to prepare materials such as polar charts showing the degree of danger of parametric rolling. These charts, in conjunction with operational guidance indicating the action to be taken upon encountering danger of or above a certain degree, can support the avoidance of parametric rolling by enabling the captain to make well-informed decisions.

Monitoring and alert systems may further enhance decision-making. For example, wave radars can accurately observe the direction, period and height of waves and swells and are especially effective at night, when waves cannot be observed visually. While the technology is not yet commonly used as a preventive measure against parametric rolling, its potential is evident. Other conceivable solutions warranting further investigation include natural roll period measurement systems, integrated alert systems combining wave radars and polar charts, real-time simulation and ship-motion data analysis.

Onboard devices

Parametric rolling can already be minimised using onboard devices. Fin stabilisers, which have a significant damping effect, are proven to reduce rolling during navigation, while anti-roll tanks achieve a similar effect utilising the phase difference obtained by moving liquid between the port and starboard tanks when ship rolling occurs. Although generally less effective than fin stabilisers, rudder roll stabilisation systems, which leverage the rolling moment of the rudder force, are a cost-efficient alternative that, unlike fin stabilisers, function well even at low speeds. Enlarged bilge keels can also prevent or reduce parametric rolling thanks to their increased damping force, while a comparable effect can be expected with the installation of appendages similar in shape to the skeg of a yacht. ■

For more information on ClassNK's *Guidelines for Container Stowage and Securing Arrangements (Edition 3.1)* and *Guidelines on Preventive Measures against Parametric Rolling (Edition 1.0)*, including summary movies, visit MyPage > Guidelines of www.classnk.com.

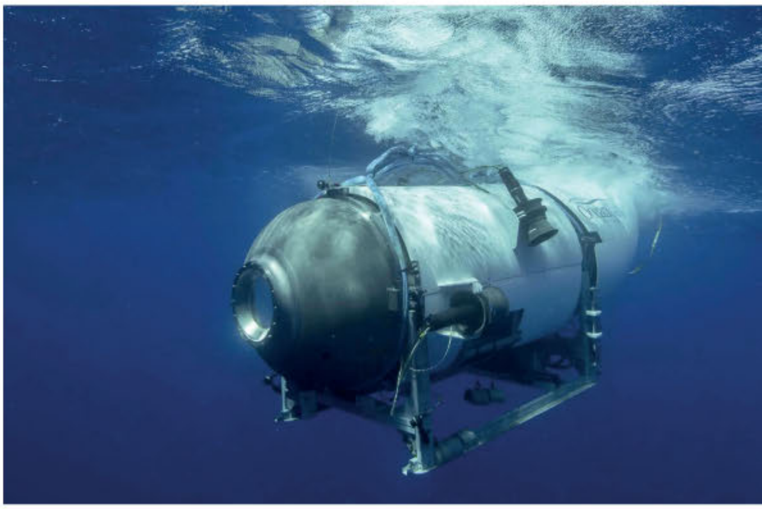


CALCULATION FLOW OF THE CORRECTION FACTOR

CYCLOPS CLASS: THE TRAGIC COST OF ENTRUSTING NON-PROFESSIONALS

By **Dr M J Cianni**, CEng., FRINA, FIEAust

Is deep-sea exploration, like space exploration, worth it? It's dangerous; lives have been lost and probably more will be lost. But if everyone involved knew the risks before they embarked on these journeys, and the toll it takes on us and the ones we love, but sign up just the same – should we judge them? Isn't this this the price we pay to push forward? To explore the deepest depths and wander into the unknown, pushing ourselves to the limits of what is possible. There are sacrifices that must be made of course. Sacrifice is a part of any journey, like the ships that sailed across the oceans in search of new worlds and civilisations. Taking on these great challenges against great odds is part of what makes us human. We choose to explore the depths of the ocean like we choose to explore space, not because it is easy or safe, but because it is hard and takes our learning of who we are, our place in the universe and what the future could hold for us to new heights, such as undersea or space habitats.



TITAN SUBMERSIBLE PRIOR TO ITS FINAL DIVE. SOURCE: OCEANGATE

People will point to the commercialisation of space travel and deep-sea exploration of wrecks as merely tourism or trips for adrenaline seekers; however, there is still a lot to learn from these commercial missions.

For example, you may be forgiven for thinking, given recent news reports surrounding the Cyclops class Titan submersible that carbon fibre for the hull of a submersible, submarine, or for that matter perhaps an underwater habitat in future, is not suitable. However, it has been used and will be continued to be used at depths of 6,000m without failure – a diving depth figure far beyond that of conventional and nuclear-powered submarines which can operate at just 300m to 400m.

This is assuming the carbon fibre is fault free, i.e. not out of date aeronautical carbon fibre, is moulded correctly and to the required thickness including a generous safety margin of at least x2, and the carbon fibre is not damaged in the process of attaching hatches, landing gear, directional propellers, cameras etc. A potential area for concern would be if there is a difference in materials used for the hull and the hatches which would lead to differences in expansion and contraction of the materials due to temperature and pressure, especially considering there will be a seal in between the different materials to make the join watertight. One other area for focus would be the viewing port hole, i.e. the material used and thickness needed to be able to see out from the submersible. If this material or its strength, for a given thickness, is not sufficient with a generous safety margin, then this would be an obvious point of weakness in the overall design.

Professional engineering

Referring to the results of the carbon fibre pressure vessel design tool in Figure 1, we can determine that the minimum wall thickness for a rated depth of 4,000m with a safety factor of 2 is (80.161inches - 60inches)/2 = 10inches, compared to the wall thickness of the Cyclops class Titan submersible which had a wall thickness of just 5inches. This indicates no safety factor was included for the hull design, and it has been reported that the viewing porthole was only rated to 1,300m, i.e. one-third of the required operational depth.

Once the carbon fibre pressure vessel has been designed correctly and manufactured, thermal imaging and ultrasonic scans of every part of the vessel need to be conducted to ensure it has been manufactured correctly, for example that there are no air pockets in the carbon fibre layers. It should then be tested repeatedly until failure, to verify the design parameters are correct and it behaves exactly as expected. The same checks should then be performed at regular intervals and the results compared to the original baseline set of results, to check for any changes that could indicate cycling fatigue.

A lot of attention has also been focused on cycle fatigue, during repeated dives and surfacing. There is the possibility of delamination and progressive failure over time with microscopic water ingress, so that if the vessel passes a pressure test it might not fail on its first dive but is increasingly likely to fail over time.

However, carbon fibre pressure vessels have been built and cycled 200 times at these deep pressures and then brought to implosion but fail at the same depth and in the same way as new pressure vessels, which indicates cycle fatigue is unlikely as a potential failure mode when the carbon fibre pressure vessels have been designed and manufactured correctly. This argument is supported by examples of 30ft-long carbon unmanned underwater vehicles (UUV) with

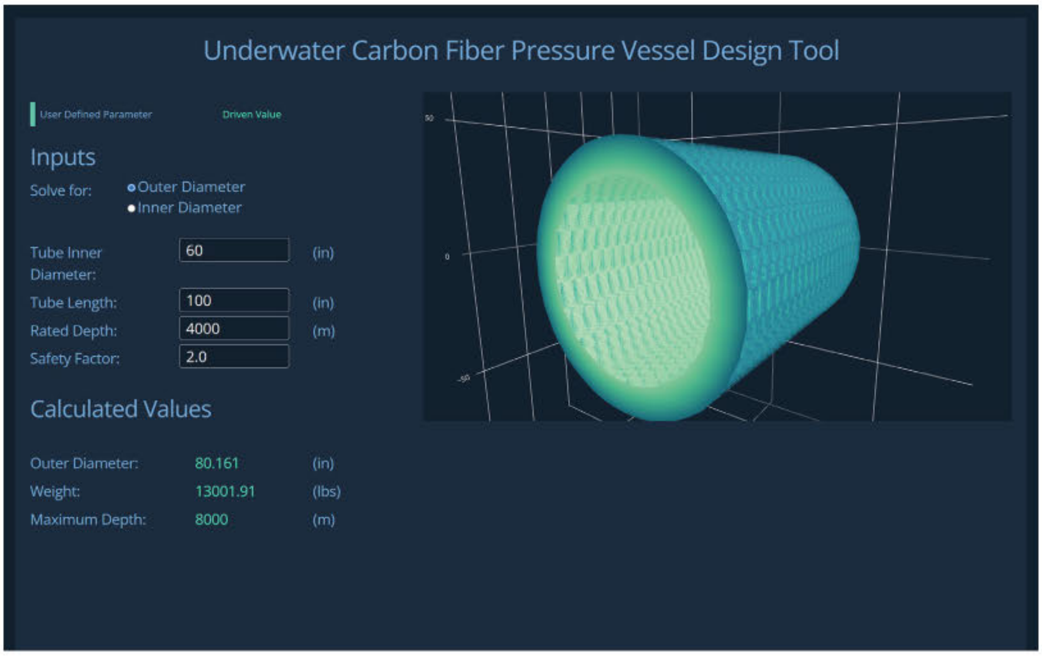


FIGURE 1. UNDERWATER CARBON FIBRE PRESSURE VESSEL DESIGN – SHOWING REQUIRED WALL THICKNESS

over 6,000 operational hours at 6,000m – that's hundreds of cycles without any sign of failure.

We can conclude therefore that the Cyclops class Titan submersible was not designed or manufactured correctly, the regular checks that could have detected a potential failure in the material were also not conducted and are the likely reason that the submersible imploded.

All these deficiencies would have been discovered during any official certification process, which is probably the reason that official certification was not sought and the company was operating in unregulated regions of the world.

Adding insult to injury

The term 'engineer' is widely used for non-professional engineers. However, only professional engineers subscribe to a 'Gold-Standard' of practice that ensures ethical and honest operations. Professionalism acting on the basis of adequate knowledge, exceedingly high quality standards, sustainability and environmental protection and, most of all, public safety are all placed before profit and the ego of non-professional engineers setting out to prove that the 'Gold-Standard' is not required and does not apply to them or their operations – which is plainly wrong and should not be permitted through legislation.

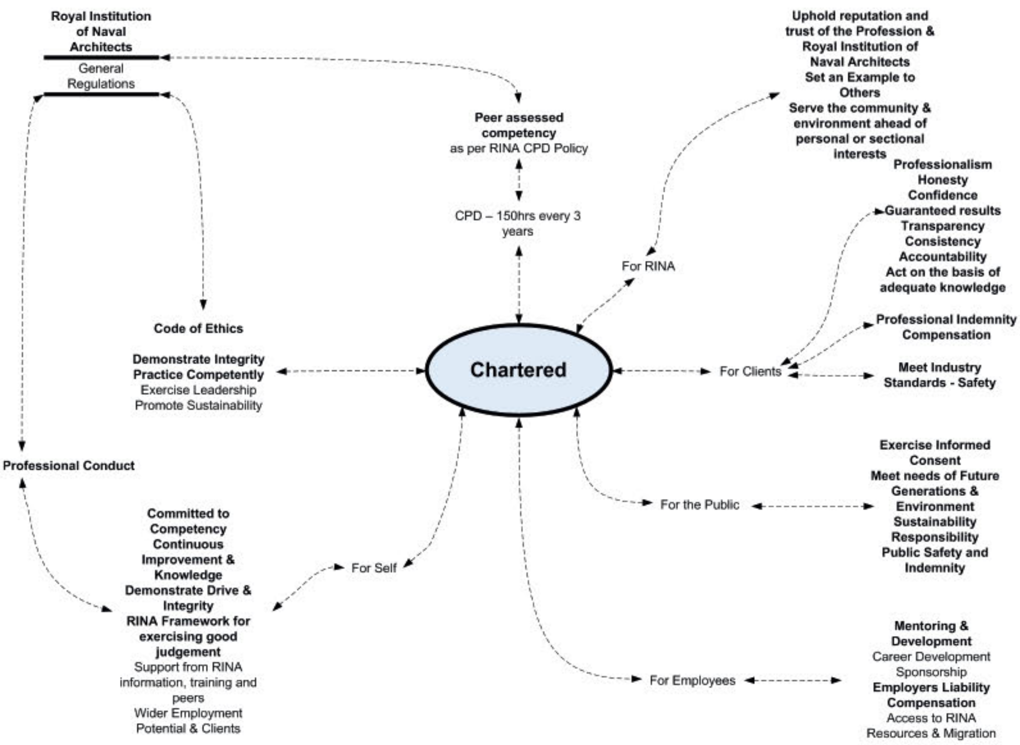


FIGURE 2. THE GOLD-STANDARD – CHARTERED ENGINEER (CENG)

ROPE EVOLUTIONS: WEAVING IN SAFETY TO MEET MARINE REQUIREMENTS

By **Paul Dyer**, technical manager, Marlow Ropes

Ropes have long been used in maritime operations, whether in port or at anchor, at sea or for offshore applications. Safety is an over-riding factor in their choice and application, to protect people and equipment. But what are the common causes of wear and tear, and factors to consider when sourcing ropes and overseeing their ongoing care?

Risk assessment

Reliability is paramount to protect both crew and vessels, with vessel operators responsible for determining safety levels. Risk considerations include:

- Strength and weight – ropes for mooring and anchoring will need to be strong enough to offset the pulling load of the vessel, equipment and crew. It is the responsibility of the user to determine appropriate minimum breakload. With anchor and docking ropes, avoiding breakage is essential for the safety of the ship and crew to ensure ship stability and stop vessels drifting away or colliding with other ships and structures.
- Elongation/stretch – stretch is vital to withstand the ocean swell and currents, without creating sudden movements which could be a hazard to crew or damage equipment and deck fastenings. Tension fatigue from constant stretching can eventually cause premature rope wear, leading to more frequent replacement and higher costs. The degree of elongation also affects breakload, with minimal elongation using less breakload, extending rope life and reducing crew requirements.
- Elasticity/creep – rope will recover on release of loads, once relaxed. Permanent extension occurs over the long term, however, where plaits, strands and yarns bed in. Non-reversible molecular changes or creep also occurs where ropes are subjected to continually high loads, affecting rope performance and strength.
- Durability – consider the wear and tear in use and the susceptibility of the rope to abrasion damage from where it passes over or through equipment. Additionally, some rope materials are better than others at tolerating the harmful effects of sunlight and chemical exposure.
- Weather resistance – marine ropes are exposed to a wide array of ambient temperatures. High temperatures in particular, may induce greater core friction contributing to melting risks.

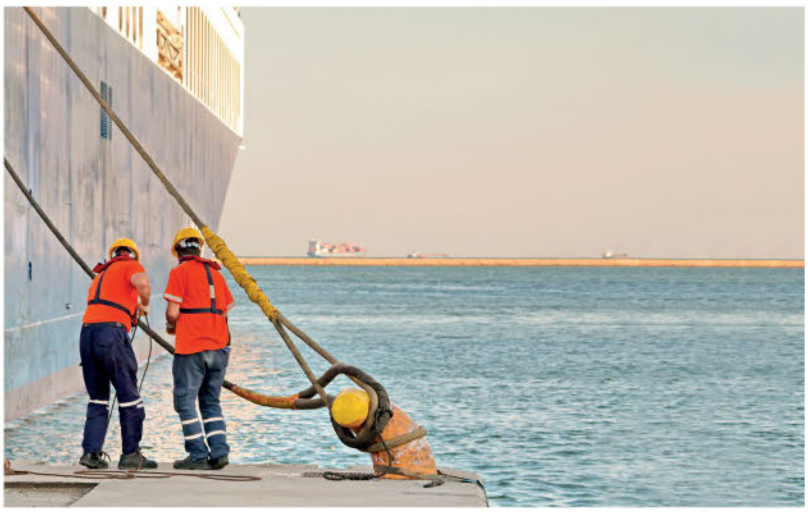
Horses for courses

Marine ropes are now largely synthetic, made from technical fibres such as Dyneema HMPE, polyester and heat-resistant aramid fibres which offer high performance and durability.

Understanding how ropes are affected by external influences and material characteristics is key in matching the rope's intrinsic properties to the specific environment in which vessels are operating and the application, be it escort, ocean towing, mooring, tankers and cargo ships, deepwater heavy lifting or other offshore activities including oil, gas and wind platforms.

Common types for dockside and ocean use include nylon which is a preferred choice for mooring lines for its strength and stretch, with the ability to absorb shock and return to its original length. Polyester also provides a versatile all-round option, valued for its lightweight strength and durability, with good UV and abrasion resistance, while remaining flexible even when wet. However, it is not an option where the ability to float is a requirement.

Other materials include polypropylene, polyethylene and polyamide which are similarly lightweight and robust. Overall, synthetic ropes offer clear advantages over natural rope which can easily be damaged by mould,



MAINTAINING THE HEAVY ROPES USED BY LARGER VESSELS AND OCEAN INSTALLATIONS IS CRITICAL FOR ENSURING COMPLIANCE WITH SAFETY STANDARDS

HIGH-PERFORMANCE WINCH ROPES DURING THE MANUFACTURING PROCESS SHOWING AN EXAMPLE OF TERMINATED ENDS (SPLICED EYES WITH METAL THIMBLE)

mildew and UV light plus tends to shrink when wet, making it difficult to manage.

Extensive research and development and innovative engineering has resulted in new high-performance solutions that have extended the boundaries of rope use. The latest generation ropes offer long life, flexible handling and increased safety in use while reducing operational costs overall.

High modulus fibre ropes now available include aramid fibres and liquid crystal polymer, along with the latest innovation high modulus polyethylene (HMPE), a high-performance material designed for high-load, safety critical applications.

Sustainability is also increasingly important, with the marine sector focused on reducing its carbon footprint. Marlow's bio-based Dyneema (HMPE) rope for example, uses waste from the pulp and timber industry as its primary raw-material, while maintaining the performance of standard Dyneema ropes.

Safety and care

Maintaining the heavy ropes used by larger vessels and ocean installations is critical, given the extreme loads they are subjected to. Regular inspections ensure compliance with safety standards, while keeping ropes in good condition to ensure longevity and reduce lifecycle costs.

Storage – Incorrectly coiling ropes will introduce a twist into them, which can cause operational issues further down the line. Do not allow dirt or abrasive materials to penetrate ropes by dragging them over rough surfaces or dirty ground as they can easily work themselves into the fibres, causing hidden damage. Clean ropes gently with mild soap and rinse before hanging up to dry naturally. Avoid exposure to extreme temperatures and prolonged direct UV exposure which can cause degradation and loss of performance. Exposure to water can also affect elasticity and cause shrinkage.

Inspection – Ropes should be inspected at regular intervals in respect of:

- Abrasion. Excessive abrasion could lead to significant loss of strength. Chafe covers are recommended in certain high-use areas to minimise abrasion.
- Fastenings. It is worth noting that a percentage of the strength in ropes will be lost when a rope is terminated, either in the form of a knot, sewing or splice. Where ropes are spliced, maintaining the care of spliced eyes is important.

End of life replacement – Look for critical signs of degradation which may decide when a rope needs to be retired such as:

- Glazing - glossy areas of rope, which can indicate exposure to excessive heat and melting.
- Discolouration – dirt may be present that may cause internal abrasion or could be an indication of chemical damage and rope weakness.
- Inconsistencies - lumps, flat areas or thin areas could indicate that the rope has been damaged internally.

Ropes are an essential element of marine operation and represent a considerable outlay. Taking the time to choose the right solution to your needs and the time and effort to ensure your ropes are maintained correctly, is important not only to minimise risk but also to protect your original investment. ■

FRESH SOLUTIONS FOR EMERGING APPLICATIONS

As a pioneer in the use of specialist fibre ropes in the marine and offshore industries, Marlow Ropes works extensively with clients, both in advancing rope science and in custom engineering solutions to provide the necessary high-performance characteristics to meet extremely specific and individual demands. For example, working in partnership with Aerones, a specialist in wind turbine blade inspection technology, Marlow has developed a fibre rope solution for the robotics cleaning systems used to maintain, inspect, clean and repair wind turbine blades. D12 Max 99 is manufactured using Marlow's bio-based Dyneema (HMPE) SK99 rope for guaranteed performance, extremely high strength and minimal creep.

NETHERLANDS & BELGIUM

DUTCH LOOK TO A FLOATING FUTURE

By **Daniel Johnson**

OLAF WAALS WITH A SCALE MODEL OF A MEGA FLOATING ISLAND IN MARIN'S OFFSHORE BASIN. SOURCE: MARIN

The UN estimates that two out of every five people in the world live within 100km of the coast, and that 90% of megacities worldwide are vulnerable to rising sea levels due to climate change. With nowhere to expand, rapid population growth in these areas is upping the pressure for space for living, industry, the energy transition and food production.

Large-scale floating structures are an attractive solution to these challenges and the fact that the Dutch are at the forefront in their development should come as little surprise – the Netherlands is one of the most densely populated nations in the world and approximately 60% of the country is already prone to flooding (around a third of which is below sea level).

Olaf Waals, head of Offshore at MARIN, tells *TNA* that the research facility has been working on large 'floating islands' for many years. "Climate change, land scarcity and population growth are all motives. We feel a strong responsibility in solving these social challenges," he says.

Waals is also official secretary of MARIN's Floating Future programme. The project, which recently received €5.3 million in funding from the Dutch Research Council (NWO), was initiated in partnership with think tank the Blue Revolution Foundation with the aim of providing the next step in the Netherlands' transition from "fighting against water to living with water".

"Floating Future is an interactive research project involving a unique mix of industry, research institutes, academia and governmental organisations. We want to understand how the upscaling of floating structures could offer a climate-proof solution for space limitations in the Dutch Delta," explains Waals.

"If we want to scale up this floating infrastructure, we must take steps in terms of technology and in terms of social acceptance of living and working on the water. In Floating Future we investigate just that," he adds.

The programme's work will be divided into three clusters addressing technology, governance and ecology, with researchers collaborating with experienced societal partners to deliver an integrated vision, design and policy guidelines, project proposals and an inventory of the required resources and milestones to implement a floating future for the Dutch Delta.

Pilot cases will be developed for inland, coastal and offshore applications. These will include floating city districts near the centre of Rotterdam, flexible floating space for port developments such as sustainable fuel storage and bunkering, and offshore applications to support the energy transition.

Waals admits the technological challenges are high but believes large-scale islands could be technically feasible within the next couple of decades if the right questions are asked. "Today's large floating structures are maybe 300m long by 80-100m wide, but here we're talking about kilometre-by-kilometre size," he says. "This raises questions like, how do we develop mega structures of that size that are strong and safe in storms and currents? What are the mooring forces to that scale? What materials should be used?

Waals emphasises that societal breakthroughs will be crucial to create governance arrangements for floating islands – no regulatory framework exists yet for building large-scale floating cities, for example – and for societal acceptance of living and working on water. "Would you live in a floating city or work on a floating island?" he asks. "It's a mindset that needs to be studied."

He adds that there are also important ecological questions to be answered: "What is the influence of a big floating community on the water underneath and around? How do we make the system completely circular in terms of water, energy, raw materials and waste?"

"I'm just a naval architect by background so I don't have an answer to those questions," Waals notes. "My role in Floating Future is to bring together experts who do and see if we can start thinking in the right direction. This integrated approach will result in new perspectives on how we can use floating technology."

The implementation of the Floating Future programme and its various work packages will take place over the next five years, with a presentation of the first research results expected sometime in 2024.

"I believe this project will help to shape the future of the Netherlands and many other countries that are close to or below sea level," Waals concludes.

MANOEUVRING IN SHALLOW AND CONFINED WATERS

By **Evert Lataire**, **Guillaume Delefortrie** and **Maxim Candries**, Maritime Technology Division, Ghent University, and **Katrien Eloot** and **Verwilligen Jeroen**, Flanders Hydraulics

At the end of 2022, the Towing Tank for Manoeuvres in Shallow Water was inaugurated with a traditional Mixing of the Waters ceremony. The new towing tank (174 x 20 x 1m^3), shown in Figure 1, was designed specifically to be able to test 8m-long ship models and complements the Towing Tank for Manoeuvres in Confined Water at Flanders Hydraulics, shown in Figure 2, which was built in 1992 and which is limited to 4m-long scale models.

The towing tanks are used extensively by researchers associated with the Knowledge Centre Manoeuvring in Shallow and Confined Water, established in 2008 by Flanders Hydraulics and the Maritime Technology Division at Ghent University. The Belgian coast is located on a continental flat with a low tide water depth that averages 20m. Important container lines, which connect with major European ports such as Rotterdam, Antwerp and Hamburg, need to cross this shallow area. Moreover, the ports of Antwerp and Hamburg are seaports which are both located a fair distance upriver. This forces the vessels to follow a bendy trajectory with high traffic density, so that shallow water effects such as ship-bank and ship-ship interaction occur. The river Scheldt for instance is characterised by sills, which only allow a draught up to 13.1m anytime. Due to tidal action, however, it is possible to sail at a draught up to almost 16.0m towards Antwerp, allowing under keel clearances (UKC, i.e. the percentage ratio of draught that is available between keel and bottom) as low as 10%.

Manoeuvring behaviour

Water depth restrictions have several effects on the manoeuvring behaviour of a ship and they become more pronounced as the depth to draught ratio decreases. Limitations in water depth will change the pressure distribution around a moving vessel considerably and will mostly cause an increase of the hydrodynamic forces. Besides an increase of the ship's resistance, the effects in general include a decrease of her manoeuvrability. This is clearly seen in the results of standard manoeuvres, as illustrated in Figure 3 (Vantorre *et al*., 2017). The dependency of the manoeuvrability in the lower UKC range is very significant because a small decrease in UKC results in a significant increase of the turning circle dimensions. As a result, larger bend radii are required in shallow navigation channels. Figure 3 (left) also reveals a decreased drift angle in a steady turn compared to deep water, resulting in a narrower swept path and a relatively smaller decrease of the ship's forward speed in the bend.

Water depth also has an effect on the course-checking ability of a ship. Figure 3 (right) shows that in (very) shallow water, overshoot angles during zigzag tests are considerably smaller compared to the deepwater case. In spite of this apparently beneficial effect, the zigzag manoeuvre takes much longer as the yaw rates are significantly lower in the case of shallow water. It should be noted, however, that this is not always the case and also depends of the ship hull form (Vantorre *et al*., 2017).

The behaviour of a ship is also affected by the lateral limits of the navigation area, such as banks and quay walls. Bank effects are defined as the forces and moments acting on a ship due to a motion that is (almost) parallel to the bank.

A ship navigating along the axis of a canal with a constant, symmetric cross-section will not experience any lateral force or yaw moment, but only an increase in resistance. On the other hand, if a ship is moving on an eccentric course or if the navigation area is asymmetric, the flow around the ship will cause an asymmetric pressure field, resulting in a lateral force and a yawing moment. In general, the relative water velocity at the side of the nearest bank will be increased compared to the open side. Due to Bernoulli's law, the pressure and the water level will decrease more on the side of the nearest bank than on the open side. In almost every case, the resulting force will therefore push the ship toward the nearest

FIGURE 1. GENERAL VIEW OF THE TOWING TANK FOR MANOEUVRES IN SHALLOW WATER WITH AN 8M-LONG SHIP MODEL NEXT TO THE TANK. SOURCE: EVERT LATAIRE

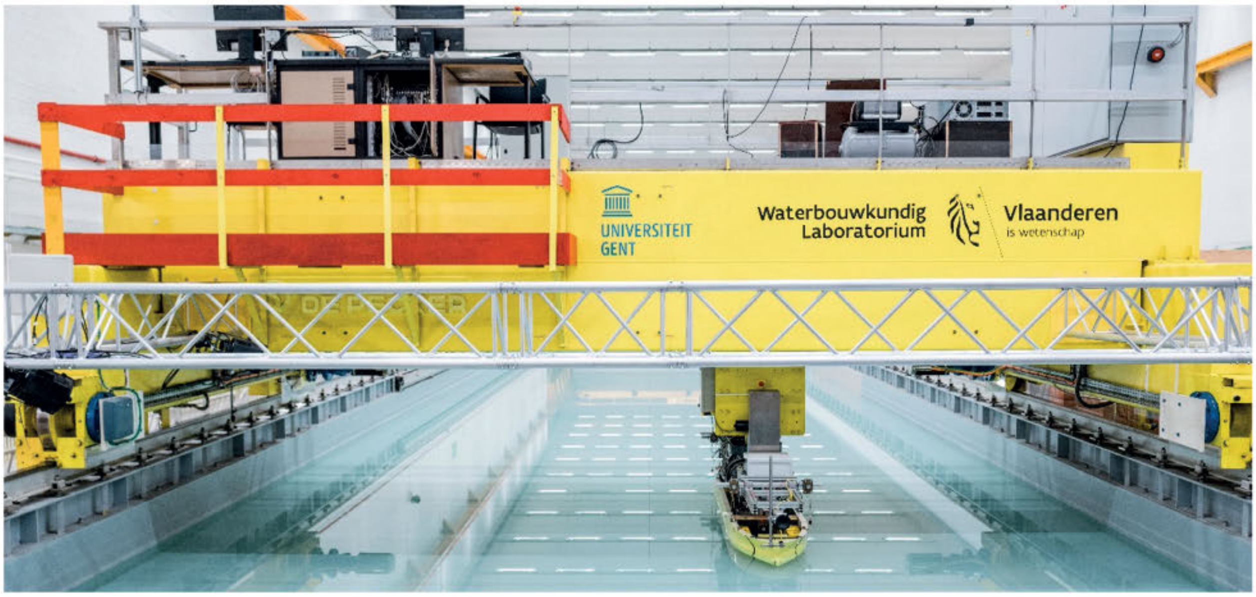


FIGURE 2. VIEW OF THE TOWING TANK FOR MANOEUVRES IN CONFINED WATER

bank. The water level depression is larger near the stern than at the bow. The bow wave may even result in an overpressure near the bow. As a consequence, this lateral force is accompanied by a yawing moment that moves the ship's bow away from the closest bank, also known as a "bow-out moment". The vicinity of a bank also induces an increased ship resistance, as well as a modified squat and trim behaviour (Vantorre *et al.*, 2017). The magnitude of the bank effects depends on a number of parameters, such as the distance between the ship and the bank, the bank geometry, the speed of the vessel and the water depth to draught ratio.

One of the most obvious consequences of these bank effects is that constant rudder action is required when maintaining an eccentric lateral position in a channel. Such a situation will occur frequently in two-way channels, where vessels will meet each other or when a faster ship overtakes a slower ship.

Ship-ship interaction

While meeting or overtaking, ships will interact with each other. These effects also occur in other situations where two (or more) vessels are relatively close to each other. Three other scenarios can be distinguished: interaction when a vessel passes a moored vessel, interaction when two vessels sail at approximately the same speed in parallel and close to each other (i.e. lightering manoeuvres and underway replenishment) and the interaction of tugs with (much larger) ships.

Ship-ship interaction effects result in rapidly changing attraction and repulsion forces between the vessels and in yawing moments on each vessel. The sequence of these forces and moments depends on the scenario. Figure 4 gives a schematic example of the horizontal forces and moments in the case of a meeting manoeuvre (Vantorre *et al.*, 2017).

A good knowledge of the phenomena that occur in ship-ship interaction is important in order to avoid accidents. Overtaking manoeuvres are quite notorious as they take a relatively long time and collisions may occur at different stages in the manoeuvre (Eloot *et al.*, 2009). Accidents also happen frequently when a ship passes too quickly or too closely to a moored vessel, which induces motions of the moored vessel. This may hinder (un)loading operations or cause damage to the mooring system (Van Zwijnsvoorde *et al.*, 2019).

Based on all the experimental data obtained in the towing tanks, complex mathematical models

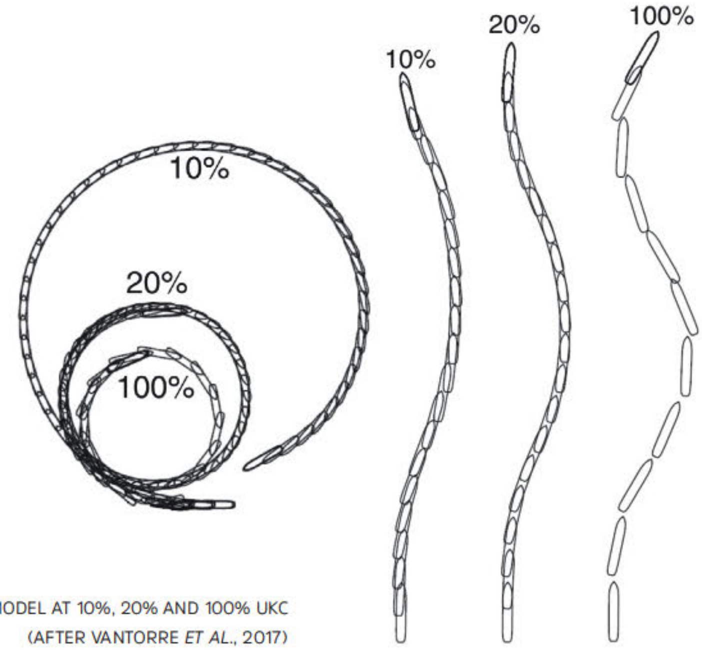


FIGURE 3. TURNING CIRCLES AND 20/20 ZIGZAG TESTS WITH A SHIP MODEL AT 10%, 20% AND 100% UKC (AFTER VANTORRE *ET AL.*, 2017)

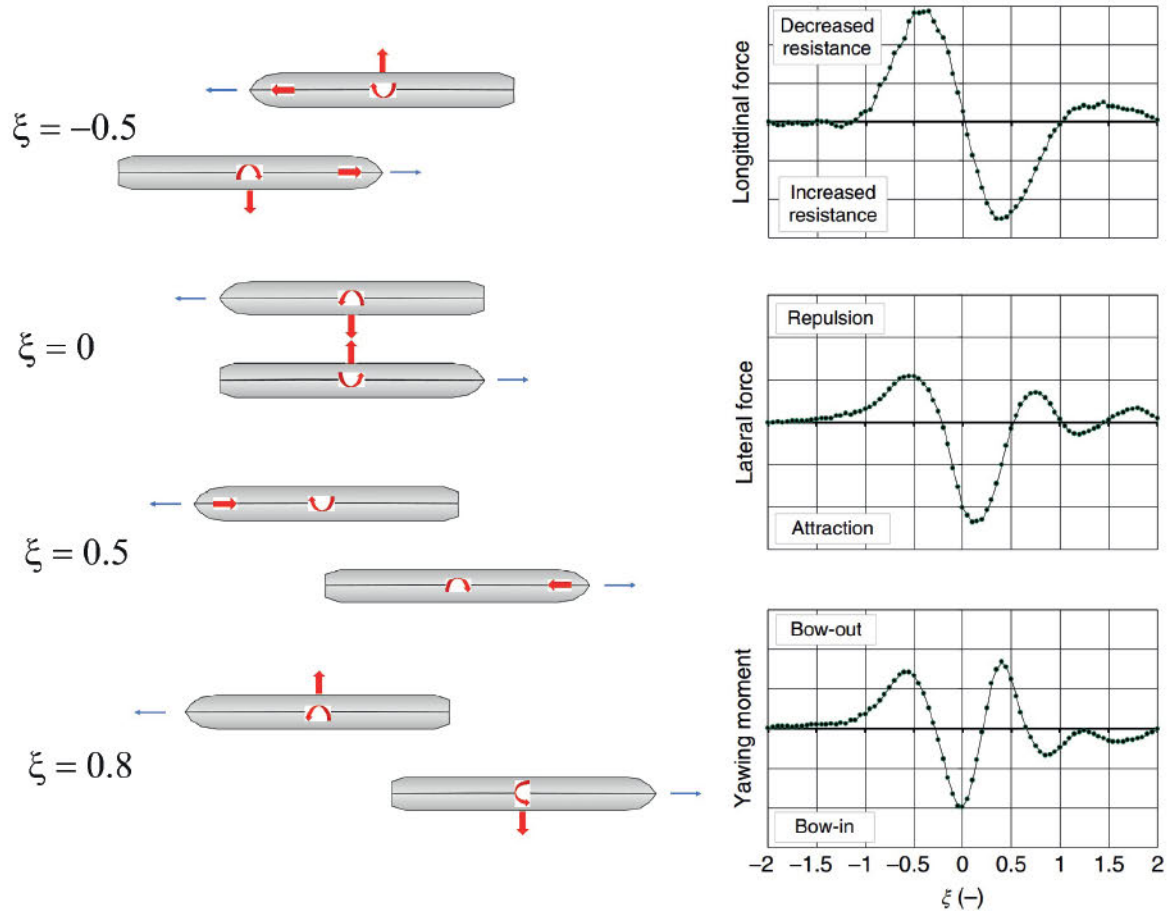


FIGURE 4. GRAPHICAL INDICATION OF THE HORIZONTAL INTERACTION EFFECTS DURING MEETING MANOEUVRES IN FUNCTION OF THE STAGGER DISTANCE ξ, WHICH IS THE NONDIMENSIONAL LONGITUDINAL SEPARATION DISTANCE BETWEEN BOTH MIDSHIP SECTIONS (AFTER VANTORRE *ET AL.*, 2017)

can be developed, which take account of the forces related to shallow water, banks, ship-ship interactions and even other effects such as locks, waves, wind and current and nautical bottom. The mathematical models can then drive ship manoeuvring simulations. Fast time simulations can be carried out on standalone simulators installed on a PC or laptop. They are interesting to perform large batches of simulations, for example to study the influence of certain parameters on different manoeuvres. Flanders Hydraulics also disposes of three full mission bridge simulators for real-time simulations, one of which (shown in Figure 5 on the left) is specifically designed for inland navigation. Real-time simulations are very important to validate the feasibility of manoeuvres by pilots. The use of real-time simulations using the full mission bridge simulators is even imperative in certain cases, for example to test how a container ship of the latest generation can reach the port of Antwerp.

The manoeuvring simulators can also be coupled with each other, as shown in Figure 5 where two pilots are performing a meeting manoeuvre. Coupled simulators have been used extensively to study meeting and overtaking scenarios in inland navigation, for example to see whether larger vessels can still safely ply the existing waterway network.

Autonomous navigation

Quite uniquely, the simulators at Flanders Hydraulics can now also serve as a virtual test bed for autonomous navigation by interfacing (third-party) controllers via an Application Programming Interface called SimAPI. By using SimAPI, an external client application can fully interact with the manoeuvring models of FH, providing control values and receiving the updated dynamic state of the ship. The dynamic state of the ship which is shared through SimAPI, includes the ship's position and velocity in six degrees of freedom, as well as the state of controllable ship components, like the propeller number of revolutions and the rudder angle. In addition, the dynamic state also includes parameters related to the environment such as water depth, current and wind condition. The interface is not bound to the time step of the simulators.

In the framework of a PhD research project, researchers at the Maritime Technology Division at Ghent University have integrated SimAPI in a front-end application, which provides different autonomous control algorithms to steer a ship on a track. The steering decisions of the front-end provide the rudder angle and propeller rate via SimAPI to the simulators. SimAPI then returns the ship motions which are determined by the advanced mathematical model of the ship manoeuvring simulators in conjunction with

FIGURE 5. TWO SKIPPERS PERFORMING A MEETING MANOEUVRE ON COUPLED FULL MISSION BRIDGE SIMULATORS AT FHR. THE PHOTO ON THE RIGHT WAS TAKEN 20 SECONDS AFTER THE PHOTO ON THE LEFT

the environmental conditions. In the example shown in Figure 6, a tanker sails in a waterway under the control of a Model Predictive Control path follower. Another demonstration showing a test of automated collision avoidance compliant with COLREGs can be seen via https://youtu.be/6Wkcq2uELDY.

In order to share information, the Knowledge Centre Manoeuvring in Shallow and Confined Water sends out a newsletter every three months. Open sets of benchmark data are released every three years. These benchmark data are particularly useful to parties wishing to evaluate and validate the accuracy of numerical tools against experimental data. The benchmark data are released in between the MASHCON (Manoeuvring in Shallow and Confined Water) conferences which are organised by the Knowledge Centre. Each conference pays particular attention to one particular topic. The 7th MASHCON conference will pay particular attention to clean power in shallow water and will be held from 22 to 26 May 2025 in Bruges.

More information on the activities of the Knowledge Centre can be found at the website *www.shallowwater.be*.

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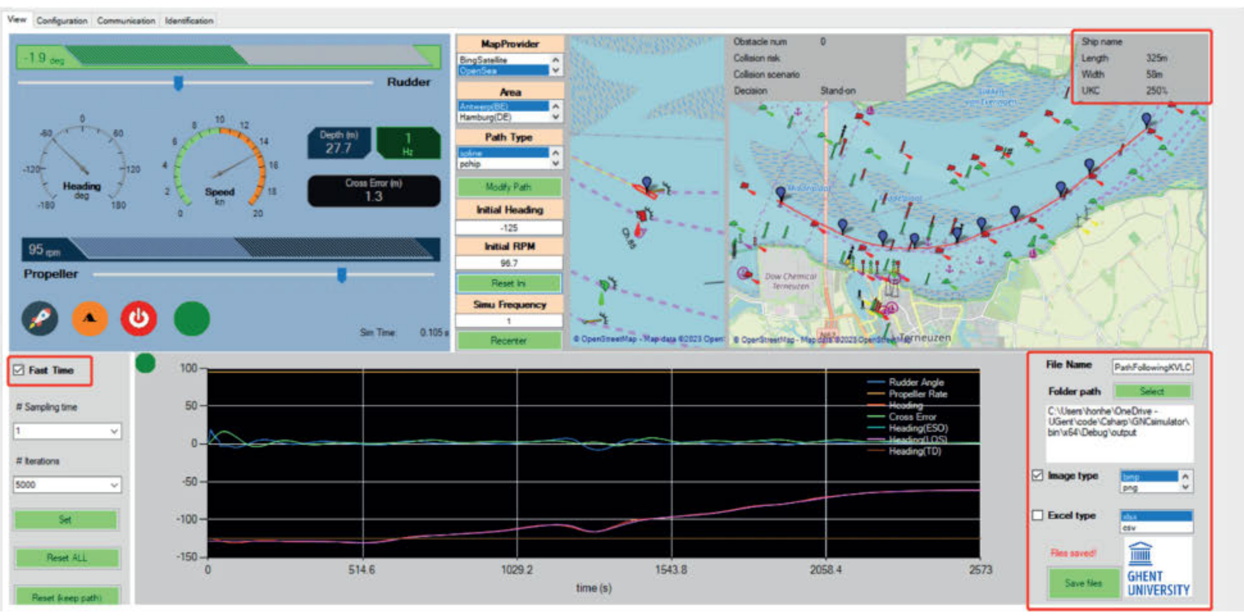

FIGURE 6. AUTONOMOUS NAVIGATION SIMULATION OF A TANKER USING SIMAPI TO LINK TO SHIP MANOEUVRING SIMULATORS

NACHT® GENERATES A NEW DESIGN APPROACH THAT MERGES SHIPPING AND YACHTING

SUPERYACHTS

NACHT®: A NEW FORM OF POST-INDUSTRIAL SUPERYACHT DESIGN

By **Mario Biferali**, PhD naval architect & yacht designer, Genoa University, biferali.m@gmail.com

As technology constantly evolves and offers increasingly daring solutions that solve design problems linked to size, it should not come as a surprise that we are now seeing ever-larger "out of scale" private vessels occupying entire bays and ports which alter the perception of the environment and the landscape. In recent decades an increasing number of large projects have been built, becoming the norm and no longer the exception. Human eyes have become used to admiring these provocative and extravagant projects.

We live in an era where the state of art is consistently changing, and there is no reference in yacht design that is not already obsolete. In a form of architectural cannibalism, each superyacht incorporates and surpasses the previous one both stylistically and dimensionally, absorbing and enclosing all proposed innovative solutions to become, once again, the most revolutionary product on the market. Furthermore, the latest trend is to design voluminous yachts taking shapes and sizes to extremes; it is a form of dimensional competition motivated by constructive innovation, technological progress, formal plasticity and innovative materials.

Superyachts have become so advanced and sophisticated that they have become prototypes of continuous new engineering and stylistic experiments. In a future projected towards the concentration of large dimensions and large engineering projects that arise with the utmost naturalness, nothing seems to be impossible. Thus, it would come naturally to predict the upcoming success of 'bigness': everything will be accomplished and only a few things will surprise in this hypothetical scenario dictated to by dimensional and formal chaos. The return to simplicity could be key to new emotions. If these were the projections of the future of yachting, we could be inspired by the shipping industry as an icon of the winning combination between large dimensions and formal simplicity, thus generating a new yachting design vision and identity.

A new life, a new identity

The project presented here is the result of a new design concept that enhances large dimensions, a driving parameter for many new superyachts, and the purity of forms and looks at the shipping environment as an expression of a new form of post-industrial yacht architecture where ships, instead of being beached along the shores of India, Bangladesh and Pakistan at the end of their lifecycles, will be fully regenerated to have a new life and identity.

The term Nacht® is a blend of the words Naval and Yachting. It embraces the merging of two industries extremely far apart – i.e. shipping and yachting – and generates a new design approach where the form of any merchant ship can be translated into a luxury vessel.

Nacht®, which in Dutch means night, emphasises the darkness that falls on the yacht and, metaphorically, the return to the land of origin where it all began as if to mark the beginning of a new naval-nautical era.

The project Nacht®, the design of which is intellectually registered and protected, follows the design of a container feeder ship 150m long, 22.6m wide and 10,630gt. The sleek profile with clean lines and large cut out hull windows make Nacht® stand out from the crowd.

The hull is designed to show its formal essentiality, bare of any plastic and stylistic element; the only sign of softness and dynamism is revealed on the bulwark, where a slight arched curvature extends from bow to stern, adapting to the rigidity of the hull, streamlining its line and stretching its ends. The height of the bulwark ensures safety in navigation and total privacy, hiding all activities onboard from the eyes of strangers. A glass opening forward the main superstructure disrupts the continuous length of the bulwark to let the passengers enjoy a view of the sea.

The main feature of Nacht® is the extension of the main deck, which is interrupted only by the single tower that divides it into convivial areas at the stern and recreational areas in the front, with the latter zone equipped, if necessary, with sports fields such as basketball and paddle courts. On the forward end of the deck, a certified helideck bridge – with an underneath dedicated lifted heli-hangar - allows the owner and guests to quickly reach the vessel; a dedicated stairway forward of the main deck allows them to reach the main areas below deck and the crew the tender garage. The garage, with its length of 13m and full beam ensures space for guest and crew tenders as well as a wide range of toys.

The focal point of the main deck is the 20m-long swimming pool which, raised on a central podium that creates an infinity pool effect and emphasises the pool's centrality, allows the passengers to admire the view while lying on a large sunbathing area. The swimming pool is divided into a social area aft with shallow depth and benches and hydromassage and an area with a deeper depth dedicated to swimming. A glass bottom allows natural light to radiate and create a play of reflections on the cabins below.

To the owner, the tower

The hull's image of simplicity is contrasted only by the tower, the base of which is the junction of vertical and longitudinal flows for both guests and crew. A covering of extensive glass surfaces ensures that natural light can shine on each level and create a great view outboard.

The tower, with its decisive and impactful design, is the characterising and distinct element of Nacht®, and in the form of a commanding position dominates the

MARIO BIFERALI

MAIN AFT TERRACE

entire vessel. This, with the exception of the bridge deck, is entirely dedicated to the owner: it is a multi-deck apartment with the lower level dedicated to formal and sociable spaces such as offices and lounges for a few close friends, the upper one totally for private use. Above the wheelhouse, the owner has his private and exclusive sun deck to enjoy total privacy and a 360-degree view over the entire length of the ship. To the owner will no longer be dedicated the owner's deck, but the owner's tower.

In addition to the owner's tower and the main deck, Nacht® is internally divided into several levels of lower deck, differentiated respectively into guest-lower deck and pleasure-lower deck. The first, starting from aft, houses the main saloon and the dining area with large full height windows on the hull; it is directly connected to the main aft terrace covered by a brise soleil which creates a play of light and shadow, emphasising the connection between indoor/outdoor areas. The lobby located below the tower divides the aft area from the extended forward one, where a long corridor gives access to the guest compartment, offering maximum flexibility in terms of layout for the client depending on the running of either private or commercial operations. The guest cabins are differentiated into guest cabins, VIP cabins and super VIP cabins: all of them have full-height windows opening onto the sea and feature a private balcony for the VIP cabin and a two-level loft with three vertical floor-to-ceiling glass windows for the super VIP cabin.

Finally, on the lower level, the pleasure-lower deck is dedicated to cultural activities such as cinema, library and study areas, and to recreational activities such as sports fields, a full-beam gym open to the sea with folding terraces, and a large spa/wellness area.

This whole composition unfolds in a harmonious game of simple and linear shapes; this new dimension extends to the sea, it does not seek its physical contact, but only what the sea can offer as a place of dreams, fantasies and desires. The sea remains the background on which the hull glides, the waves lap its essential and minimal form which, with its raw and extreme shell, does not communicate pomp but tends to hide its true richness, the sobriety of luxury.

ECO-SHIP TECHNOLOGY

GREATER THAN THE SUM OF THEIR PARTS: MERGING GREEN TECHNOLOGIES

By **Amy Parkes**, University of Southampton and Arcsilea Ltd, and **Przemyslaw Grudniewski**, Theyr Ltd

"EMERGENCE" IS THE CONCEPT THAT WHEN MULTIPLE INDIVIDUAL ELEMENTS ARE COMBINED, THE EFFECT IS GREATER THAN THE SUM OF THE PARTS

Climate change is the challenge for our generation. Across all our transport sectors we are trying to understand how we can make immediate emissions reductions while generating affordable and effective long-term strategies. For its part, shipping has been pursuing energy efficiency with significant success, however the newly adopted IMO revised GHG strategy at MEPC 80 will require even more ambitious efficiency improvements. In the effort to reduce emissions, a number of companies are producing "green tech" or "smart shipping" approaches such a wind-assisted propulsion, air lubrication, voyage optimisation or weather routing, and vessel optimisation. Among the cheapest and least intrusive solutions are those based on using data to change the operation of a vessel; enabled by increasing levels of data collection and digitalisation in the shipping industry. Leveraging insights from this data allows immediate reductions to emissions and, in the longer term, will make more expensive zero-carbon fuels more palatable.

Two of these technologies are the Just Add Water System (JAWS), which predicts the optimum draught and trim of a vessel for any given speed, and the Theyr Voyage Optimisation Solution (T-VOS), which is a voyage optimisation software. We propose that the combination of these approaches can lead to emergent behaviour, producing larger savings than either one alone. A system which optimises both the voyage and the ship operation should allow better exploitation of the most efficient operating conditions, while not compromising the required voyage characteristics. For example, if different draught and trim are preferable in rough open ocean compared to shallow and calm straits, then the speed for these portions of the voyage can be optimised in combination with the draught and trim to reduce fuel consumption while maintaining the required ETA in port.

To test this hypothesis The University of Southampton, Arcsilea, Shell, Theyr, and The Alan Turing Institute performed simulations to explore the potential for emergence and to show that substantial reductions in emissions are possible with immediate effect. An augmented JAWS is incorporated into T-VOS to allow it to optimise the ships draught and trim as well as other voyage parameters. The results are then tested on real routes performed by the ship, to calculate estimated improvements compared to a shortest path voyage.

JAWS

The Just Add Water System is a data model which uses historic high-frequency vessel performance data to predict the optimum draught and trim of a vessel for any given speed. By selecting the optimum draught and trim on voyage, a vessel can use less fuel to move through the water, in turn reducing the emissions produced. The software was developed by Shell Shipping and Maritime Technology in collaboration with the University of Southampton. The software was built on Shell's large vessel data set acquired from over 2,000 vessels operating on Shell business on any given day. Shell is rolling the software out across its Liquified Natural Gas (LNG) carrier fleet, with fuel and emissions savings of 5% on average achieved to date.

T-VOS

Voyage optimisation systems suggest routes which should require minimal fuel while still meeting voyage requirements such as ETA in port, safety requirements, and ship behaviour in emission control areas. They allow for just-in-time arrival of ships at ports, helping to reduce the large quantity of emissions produced while ships wait to load/unload. Voyage optimisation software has been recognised to cut emissions in the region of 5-10%.

T-VOS Theyr – Voyage Optimisation Solution is the first modular voyage optimisation engine developed by Theyr Ltd in collaboration with the University of Southampton. It results from a decade of fundamental research and development in artificial intelligence. The software combines the latest high-fidelity metocean forecast data (RDAS) with cutting-edge genetic algorithms to create the most efficient routes. Compared to existing solutions on the market, T-VOS provides an additional improvement of at least 5% in fuel and corresponding emissions savings, 7% in transit time savings, and more than 8% in savings for Time Charter Equivalent.

Integrating the technologies

To combine the two technologies, T-VOS must be able to ask JAWS for the optimal draught and trim and the resulting power requirement for any given speed throughout its own optimisation process.

The performance of JAWS hinges on the power prediction method it uses, it needs to accurately estimate power requirements of the ship in all vessel and weather conditions. In this study, a new machine learning methodology based on artificial neural networks which are biased to model the ground truth are used [1]. Artificial neural networks are data-driven modelling methods inspired by biological neural networks that can learn complicated multi-dimensional relationships. In this situation, the ground truth is defined as the underlying physical interactions between the ship and its environment.

Machine learning methods are constrained by underlying assumptions, meaning they are only valid for specific applications [2][3]. The power prediction needed for JAWS is one scenario which violates the assumptions. This means that using traditional machine learning, which is designed to reduce point-based error measures, could lead to a poor model of the ground truth. These constraining assumptions are often not acknowledged by recent applications across engineering, including many attempts to produce ship models.

The new approach used here, which biases the modelled input-output relationships towards the ground truth, reduces the constraints on the data. Therefore, producing more accurate relationships in a broader range of applications, which leads to power prediction that is more reliable than those from other neural networks methods. This improved approach in JAWS is given a ship speed and responds with an optimal draught, optimal trim, and the propulsion power required to maintain those conditions. This is then used inside the T-VOS optimisation, to optimise not only the voyage parameters but also the ships draught and trim.

The heart of T-VOS is the co-evolutionary Multi-Level Selection Genetic Algorithm (cMLSGA), which was specially designed for complex engineering and optimisation problems [4]. Genetic Algorithms are a popular optimisation method inspired by the Darwinian theory of evolution and processes of natural selection. They do not require historical voyage data to operate and are valued for their flexibility and high effectiveness across a wide range of complex problems. cMLSGA utilises multi-level selection as the inspiration to improve the performance of the algorithm, where the survival of individuals is dependent not only on their own abilities but also of the group they belong to, as seen in ant colonies, wolf packs and human societies. Using a multi-objective algorithm means it is possible to simultaneously take full advantage of state-of-the-art data-driven vessel performance models with multiple operational parameters, like JAWS, for more accurate fuel and carbon emission predictions and voyage planning. Therefore, operating parameters, such as draught and trim, can be optimised alongside the vessel's speed before and during the voyage to reduce carbon emissions.

Testing for emergence

To define the potential savings achievable by a combination of JAWS and T-VOS, real data from an LNG carrier is used. Four distinct port-to-port voyages which the vessel performed between 2021 and 2022 are analysed. For each route the following scenarios are explored: if this ship is in ballast or laden condition; the type of power prediction module used inside JAWS; whether draught, trim or both are adjusted; how often they can be adjusted; and how much adjustment can be made.

The routes used are the following:

- Malabo (Equatorial Guinea) to Quintero (Chile) – South Atlantic route from 12-27 Feb 2022.
- Savannah (US) to Milford Haven (UK) – North Atlantic route from 19-26 Sept 2022.
- Nagoya (Japan) to Chincha Alta (Peru) – Pacific route from 11-30 March 2022.
- Singapore to Bonny (Nigeria) – Indian Ocean route from 8-26 March 2021.

The routes are based on the historical track of the vessel and were selected to ensure a diversity of locations and metocean conditions. During optimisation all potential voyage paths were bound by the same arrival and departure times which are specific to each port-to-port route. Which ensures fairness of comparison, where arrival time is based on the voyage time along the shortest path voyage. A shortest path voyage is defined as the shortest navigable route between both locations with constant speed along it. The speed was taken as the modal speed for the given loading condition, and the modal trim and draught settings were selected.

The optimisation for each scenario is performed five times in total to produce statistically significant results.

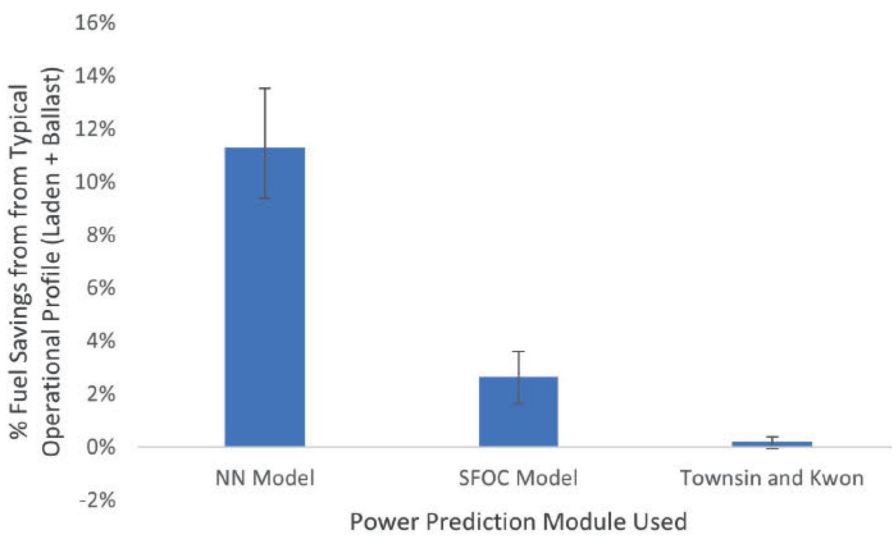

FIGURE 1. FUEL SAVINGS FROM T-VOS+JAWS WHEN DIFFERENT POWER PREDICTION MODULES ARE USED

For optimisation purposes, the vessel can change its course every 135nm and speed every 405nm. With chosen speeds, this leads to course adjustments every eight hours and every 24h for speed, on average. In scenarios with adjustment throughout the voyage, the trim and draught are altered simultaneously to speed. It is assumed that course, speed through water, trim, and draught remain constant between those changes. The resulting comparative savings are calculated against the predicted fuel consumption along the shortest path voyage.

Estimating potential savings

Benchmarking of the power prediction module clearly illustrates that using a higher fidelity model increases the possible fuel saving of the technology, Figure 1. The resulting savings are from an average across all four routes, assuming 50% time in ballast and 50% time laden. For these simulations it is assumed that draught and trim are only adjusted at the beginning of each voyage, to keep in line with current JAWS practice. Error bars indicate the range of expected savings from different routes. The Townsin and Kwon empirical method for increase in power in weather [5], and the extended version of it, called SFOC model, where the SFOC and baseline power curves have been adjusted for the selected vessel based on the real operational data instead of utilising generic curves for the class of the vessel.

The current JAWS system reduces fuel consumption by 5% across all operating conditions [6], whereas savings of over 11% are estimated when using the neural network module. JAWS is not compared directly in Figure 1, as the routes used to verify JAWS savings are more varied than those used in this study. In the following analysis the neural network module is used in JAWS to illustrate the potential savings using a module which is biased towards the ground truth.

As the frequency of draught and trim adjustment increase, the potential savings from the T-VOS and JAWS combination is increased, Figure 2. In laden conditions T-VOS is allowed to change the speed between the ranges of 17-19knots, whereas a range of 15-18knots is allowed for ballast conditions. The results show that for this LNG carrier, notably larger savings can be found while the ship is in ballast, Figure 2. This is believed to be due to the increased allowed speed range in ballast compared to laden but could also be an increased sensitivity to trim in the ballast draught ranges.

Although the predicted savings in the ballast condition are much larger than the laden fuel savings, they do not increase as much with increasing adjustment frequency. Moving from no adjustment (static draught and trim) to varying at most every 18 hours more than doubles the savings while laden, whereas the ballast savings are increased by only 15%. This could indicate that the ballast search space is less dynamic than the laden, and therefore less adjustment is required to find the best savings. It also suggests that a plateau of improvements have been reached, and savings of much more than 20% should not be expected to be found with increasing adjustment frequency.

Illustrating emergence

The savings from using JAWS and T-VOS independently on the same vessel can be compared to the savings from this study to assess the potential for emergent behaviour, Figure 3. The savings for using both technologies separately is 12% on average, as the combination of 5% savings from JAWS and 7.5% from T-VOS and due to the phenomenon of diminishing returns. Using both technologies together with draught and trim adjustments of +/- 0.5m increases the fuel saving by 3.4% and increasing the adjustment size to +/- 1.5m adds a further 3.1% savings. This results in a total expected savings of 18.6%.

This is evidence of potential emergent behaviour between vessel optimisation and voyage optimisation technologies. Savings of 18.6% are made by allowing the two technologies to work together, compared to 12% from them working independently, this is an increase of x1.5. As the size of the green technology industry inside and outside of maritime is expanding, more research is required in the area of emergent

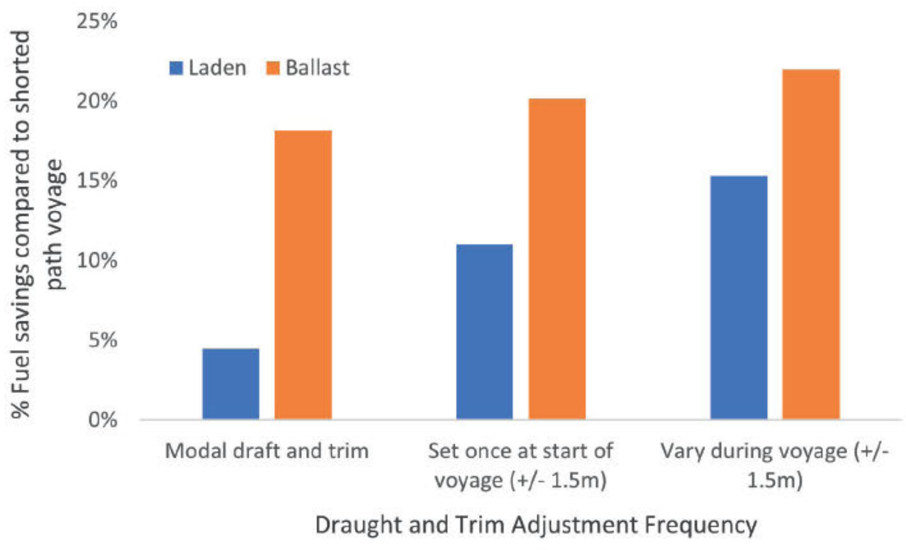

FIGURE 2. FUEL SAVINGS FROM T-VOS+JAWS, FOR DIFFERENT ADJUSTMENT FREQUENCIES TO ILLUSTRATE THE DIFFERENCE BETWEEN BALLAST AND LADEN SAVINGS. VARY DURING VOYAGE REFERS TO ADJUSTING TRIM AT MOST EVERY 18 HOURS

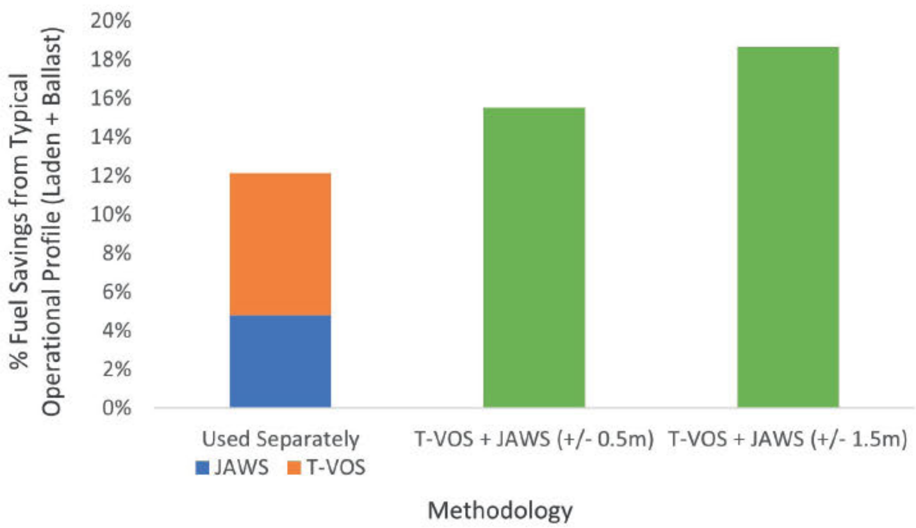

FIGURE 3. COMPARING FUEL SAVINGS FROM USING T-VOS AND JAWS SEPARATELY ON THE SAME VESSEL, TO THE RESULTS OF THE STUDY COMBINING THE TWO GREEN TECH SYSTEMS. ADJUSTMENTS ARE ASSUMED TO BE AT MOST EVERY 18 HOURS

behaviour. Integrating other existing smart shipping technologies such as wind-assisted propulsion with weather routing or voyage optimisation, or air lubrication with vessel optimisation such as JAWS, is a very cost effective/inexpensive and non-intrusive way to help meet the 2030 emissions targets and reduce the cost barrier to expensive net-zero fuels beyond this.

Acknowledgements

The authors would like to acknowledge the following fellow contributors to this research and article: Adam Sobey, University of Southampton, The Alan Turing Institute and Theyr Ltd; James Helliwell, Shell; Dominic Hudson, University of Southampton; and David Young, Theyr Ltd.

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