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SHIP EFFICIENCY: ENVIRONMENTALISM OR ECONOMICS?

By **Richard Halfhide**

SOURCE: SHUTTERSTOCK

Recently, I read a provocative comment by Roar Adland, shipping professor at the Norwegian School of Economics, in response to a report that LNG is now 63% more expensive on an energy-equivalent basis to VLSFO. Adland argued that not only was LNG a terrible waste of methane as an energy carrier, but that many of the other emerging alternative fuels were nothing more than an expensive greenwashing exercise and shipping would be far better off sticking with HFO – a waste product best utilised for ocean transportation – supplemented by wind assistance and the implementation of carbon capture and storage. In other words, a holistic approach to global emissions reduction would conclude it was currently more prudent to let shipping continue with business as usual.

In the past I've used this column to highlight my personal concerns regarding some of these solutions and it would be redundant to repeat them. Moreover, it's worth noting that IMO is currently preparing its LCA (Life Cycle Assessment) guidelines which should allow for greater objectivity on which fuels are truly green. But though I'm broadly sympathetic to Adland's argument it ignores the proverbial elephant: the maritime industry got what it asked for when it came to its GHG strategy. One argument at the time of the Paris Agreement was that merchant shipping's international character muddied the waters with regard to nationally determined contributions, but could there have been a better way of accommodating shipping's particular fuel needs within the energy supply chain?

At the time of Paris, IMO noted it was the only organisation to have adopted energy-efficiency measures that were legally binding across an entire global industry and apply to all countries. While in providing a standardised metric for newbuildings the Energy Efficiency Design Index (EEDI) represented a laudable achievement at the time, let's keep in mind that these instruments had already been (at least in part) facilitated by the efficiencies that became the norm as the price of fuel began to escalate in 2007, followed shortly after by the Global Financial Crisis. The bar has been raised since with EEDI Phases 2 and 3, but like the innovations and novel designs spawned by the OPEC embargo in the 1970s originally it was money, not altruism, that was the driving force.

This is instructive when it comes to the latest source of regulatory angst: the introduction of the Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII). Such is widespread misunderstanding concerning these instruments it's fair to say that there have even been some erroneous comments within the pages of this magazine.

"Confusion is rife," Edwin Pang, founder of naval architecture consultancy Arcsilea and chair of RINA's IMO Committee, commented when we discussed the matter recently. Pang, who has also played a role in the fine tuning of the pending requirements, is probably as well versed as anyone on their intricacies.

Many operators of the approx. 27,000 vessels that will be affected by the new rules have already started drawing together their SEEMP Part III, or Ship Operational Carbon Intensity Plan; outlining what they plan to do, how it will be measured and what difference it will make to their CII. Given there are in effect just four months to have this documentation approved by the verifying classification society a log jam looks inevitable. Although there's still some uncertainty about exactly what action PSC inspectors might take in the event this paperwork isn't prepared when ship calls after 1 January – detentions being counterintuitive to the intentions of the new rules – IMO is adamant there will be no postponement in its implementation.

EEXI is very similar to EEDI, but is designed to address the energy efficiency of existing ships. It is in certain respects a theoretical exercise, being a calculation derived from quantities and variables validated by other documentation. If from that calculation it transpires that a vessel is non-compliant then some form of physical intervention – be it software-controlled or mechanical engine/shaft power limitation or energy-saving technology – must be installed at the time of its next annual survey and/or dry docking.

It's a point of debate exactly how many vessels would currently be non-compliant. In a press release issued in July, research consultancy VesselsValue said that as much as 75% of the global fleet would fall short of the desired standard, but Pang believes the number will actually be lower and many of those will only require relatively minor adjustments. EEXI is determined by an engine's installed power, but limiting a bulk carrier's 10MW engine to 9MW should still allow it to comfortably operate at most current commercial speeds.

He adds: "With EEDI and EEXI the speed used for the calculation carries certain inherent assumptions. There's some detail about what the specific fuel oil consumption is meant to be, but if people have used a default value, for example 190g/kWh for a main engine, and for most modern two-strokes you're at about 170g/kWh you're already overstating the problem substantially."

In an industry where fine margins are de rigueur, it doesn't take much to disrupt the market. Power limitation will likely oblige some operators to make provision for a lower operating speed in their charter contracts – assuming they remain commercially viable – but others may decide the savvier course is to hedge their bets and hope there is enough money in the coffers to settle any claims which arise in the event of late arrivals. In short, the new rules will likely serve to exacerbate the arbitrage balancing act which is the life of a shipowner.

EEXI and CII are, at least to some extent, predicated by the assumption we live in the best of possible worlds with regard to ship operation. For one thing, CII penalises a vessel if it is compelled to spend time idling while waiting for a berth in the event of port congestion even though CO_2 emissions while waiting are less than when the ship is underway. Similarly, the incorporation of efficiency saving devices which can help improve an EEXI score, e.g. pre-swirl fins or wind assistance, are of negligible benefit during the 30-40% of its time that a ship may be stationary.

There's also a growing body of evidence that demonstrates how natural fluctuations in a ship's performance caused by sea state, as well as operating profile, impact far more heavily on efficiency than CII could ever be expected to. An interesting example can be found in research published last year in the scientific journal Transportation Research Part D: Transport and Environment by Frederik Hammer Berthelsen (DFDS) and Ulrik Dam Nielsen (Technical University of Denmark).

Through analysis of noon report data from groups of sister ships of bulkers and tankers it was discovered that, contrary to accepted wisdom that power is proportional to (at least) speed cubed, when operating at lower speeds the power is actually significantly less than the order of three. 'A speed-power relationship with a constant speed-power exponent will clearly underestimate the needed power when slow steaming. This means that the effect of slow steaming with respect to fuel consumption is overestimated,' the study concludes. This is in direct contradiction to IMO's mantra that: 'to ensure simplicity of analysis, the speed-resistance relationship is held as a cubic and no uncertainty is applied'.

It's important to remember that vessel performance is an emerging science, with very few experts, and the models used for CII and EEXI modelling today are likely to evolve significantly in the coming years as the body of data grows and a more detailed picture of ship-based emissions develops. On the other hand, it's reasonable to ask how much else in emissions policing may be based on fallacious information and oversimplification.

What is evident is that simpler steps, such as hull cleaning at more frequent intervals, may have a more significant bearing on emissions than limiting engine power, simply because of the way vessels operate in the real world. Pang believes the psychological impact of a common language between the shipowner and charterer will in itself lead to improvements, particularly among the laggards. It stands to reason that nobody will want to risk an unprofitable lower-rated vessel when remedial action is available at an affordable price.

Stuck between the comparatively nascent science of vessel performance on side and market on the other, the desire for quick fixes is natural. A retreat back to the carefree days of HFO is clearly off the cards and while long-term thinking might have averted some of the current malaise it's probably better to accept that, in the absence of better solutions, shipowners will just have to make the best of it.

On another note after five and a half years this is my final issue as editor of the *The Naval Architect*. It's farewell not goodbye as I'll be moving into a new role with oversight for an enhanced editorial offering on RINA's revamped website as part of the Institution's ongoing modernisation, however I'll continue to regularly contribute to these pages. Meanwhile, *TNA*'s current deputy editor, Daniel Johnson, will be taking the helm with the October edition. Please make him feel welcome.

It's been an eventful few years; for maritime, the world in general and for me personally, and I must confess I'll be grateful for a short break. Thank you to everyone who's contributed during my tenure and helped make my job a little easier. ■


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NEWS

DECARBONISATION

SINGAPORE AND ROTTERDAM PLAN WORLD'S LONGEST GREEN SHIPPING CORRIDOR

The Maritime and Port Authority of Singapore (MPA) and the Port of Rotterdam have signed a Memorandum of Understanding (MoU) to establish the world's longest green corridor to enable low- and zero-carbon shipping.

As two of the largest bunkering ports in the world, Singapore and Rotterdam provide vital support across the Asian-European shipping lanes. The MoU plans to bring together stakeholders across the supply chain to realise the first sustainable vessels sailing on the route by 2027.

Beyond alternative fuels, the MoU also aims to optimise maritime efficiency, safety, and the transparent flow of goods by creating a digital trade lane where relevant data, electronic documentation and standards are shared.

The port authorities will work with the Global Centre for Maritime Decarbonisation and the Mærsk Mc-Kinney Møller Centre for Zero-Carbon Shipping as action partners, as well as other industry partners across the supply chain, including bp, CMA CGM, Digital Container Shipping Association, Maersk, MSC, Ocean Network Express, PSA International and Shell.

This will enable the green and digital corridor project to raise investment confidence, attract green financing, and kickstart joint bunkering pilots and trials for digitalisation and the use of low and zero carbon fuels along the route, according to MPA and the Port of Rotterdam.

FROM LEFT: ALLARD CASTELEIN, CEO OF THE PORT OF ROTTERDAM AUTHORITY, AHMED ABOUTALEB, MAYOR OF ROTTERDAM, S. ISWARAN, SINGAPORE MINISTER, AND QUAH LEY HOON, CEO OF MPA

"This MoU further strengthens the strong partnership between Singapore and Rotterdam. It reaffirms Singapore's commitment towards facilitating a multi-fuel bunkering transition as part of the Maritime Singapore Decarbonisation Blueprint 2050, and accelerates our digitalisation efforts to optimise maritime efficiency and improve supply chain resilience," says Quah Ley Hoon, chief executive of MPA.

ALTERNATIVE FUELS

CLASSNK UPDATES GUIDELINES FOR ALTERNATIVE FUEL USE

Classification society ClassNK has released 'Guidelines for Ships Using Alternative Fuels Edition 2.0', which now features specific safety requirements for ammonia-fuelled ships to provide guidance for alternative-fuelled ship design. Vessels fuelled by methanol, ethanol and LPG are also covered.

THE NEW GUIDELINES FEATURE SPECIFIC SAFETY REQUIREMENTS FOR AMMONIA-FUELLED SHIPS

ClassNK's guidelines describe in detail the safety requirements necessary for methanol-, ethanol- and ammonia-fuelled vessels, and also outline the risk that these fuels pose to ships, crews and the environment. The requirements for installation, controls and safety devices are also included to reduce overall risk.

Additions to the guidelines include specific requirements, such as isolation distances from areas where there is a risk of ammonia release to areas that should be protected. Furthermore, safety design concepts to design engines and boilers using ammonia fuel have been added to ensure the safety of ammonia-fuelled ships.

"The recently published edition 2.0 reflects the ClassNK's expertise for ammonia, which is toxic to humans and corrosive to materials, gained through R&D in partnership with the industry and its design review experiences based on the guidelines," according to ClassNK.

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CARBON CAPTURE

PARTNERS STUDY FEASIBILITY OF CARBON CAPTURE ON EXISTING SHIPS

THE STUDY WILL FOCUS ON TWO TYPES OF BULK CARRIERS IN OPERATION IN THE WAH KWONG FLEET, WITH SUBSEQUENT RESEARCH WORK CONDUCTED FOR OIL TANKERS. SOURCE: WAH KWONG

Bureau Veritas (BV), Wah Kwong, one of Hong Kong's largest shipowners, and Qiyao Environmental Technology, a subsidiary of Shanghai Marine Diesel Engine Research Institute, have signed a cooperation agreement to study the feasibility of installing carbon capture and storage (CCS) units on existing ships to meet 2030 CII targets.

The study will focus on two types of bulk carriers in operation in the Wah Kwong fleet. Based on the specific design parameters of the vessels, Qiyao Environmental Technology has developed a customised design of CCS units for the Wah Kwong fleet and submitted relevant drawings.

BV reviewed the plans according to existing regulations and rules to ensure the safety of the vessels and equipment, and that the carbon emission reduction targets are effectively achieved during the operation of the vessels. Subsequent research work will be conducted for oil tankers.

The CCS concept developed by Qiyao Environmental Technology has completed laboratory testing, achieving a total carbon capture rate of over 85% so far and the system is in the process of continuous optimisation, according to BV.

The CCS unit can be designed for different ship types and sizes. The design approval of the CCS unit is under review.

The CCS system mainly consists of an absorption unit, a separation unit, a compression unit, a refrigeration unit and a storage unit. The main principle is that the organic amine compound solution reacts with the carbon dioxide in the absorption unit, separating it from the rest of the exhaust gas. The dissolved CO_2 compound solution is desorbed at high temperature in the separation tower, before the extracted CO_2 is compressed, purified and cooled into liquid CO_2 and stored in a low temperature storage tank.

SHIPBUILDING

HYUNDAI HEAVY AND SAUDI YARD SIGN VLCC AGREEMENT

Saudi Arabian shipyard International Maritime Industries (IMI) has expanded its partnership with South Korea's Hyundai Heavy Industries (HHI) through a technical service agreement to further enhance its shipbuilding capabilities.

Under the agreement, HHI will provide technical assistance and consulting services in very large crude oil carrier (VLCC) engineering to IMI.

HHI has been supporting the development of IMI's shipbuilding capabilities and engineering services since its launch in 2017. IMI is a joint venture between Saudi Aramco, Bahri, Lamprell, and HHI.

Dr Abdullah Al Ahmari, CEO at IMI, says: "We are pleased to further expand our partnership with HHI, one of our four founding JV partners and a key enabler of our progress to date. This agreement reflects HHI's ongoing commitment to supporting our efforts to build a world-class shipyard capable of locally manufacturing VLCCs and other vessels, that will help drive the development of Saudi Arabia's maritime industry."

At nearly 12 million square metres, IMI is the largest shipyard in the Middle East and North Africa region.

HHI WILL PROVIDE TECHNICAL ASSISTANCE AND CONSULTING SERVICES IN VLCC ENGINEERING. SOURCE HHI

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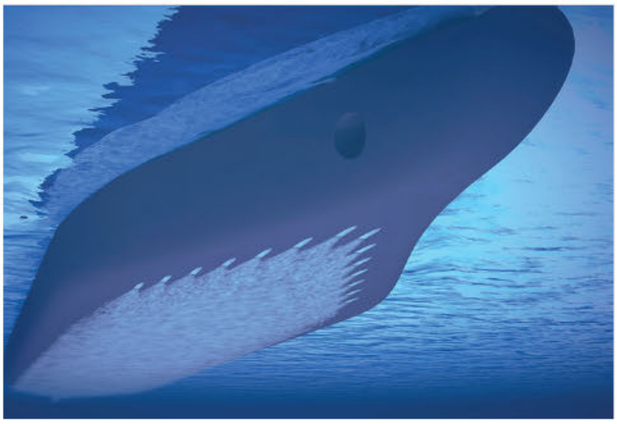
AIR LUBRICATION

SILVERSTREAM PARTNERS WITH MITSUI TO ADVANCE AIR LUBRICATION TECHNOLOGY IN JAPAN



SILVERSTREAM'S AIR LUBRICATION SYSTEMS CAN IMPROVE FUEL EFFICIENCY BY REDUCING THE FRICTIONAL RESISTANCE BETWEEN THE WATER AND A VESSEL'S HULL SURFACE. SOURCE SILVERSTREAM TECHNOLOGIES

UK-based clean technology company Silverstream Technologies has signed a Memorandum of Understanding (MoU) with trading company Mitsui & Co. Europe Plc and its subsidiary Orient Marine Company that will see the companies encourage the adoption of Silverstream's air lubrication technology across the Japanese market.

According to Silverstream, the collaboration will also aim to strengthen its relationships with local Japanese owners, shipyards and design institutions, as well as advance the company's commercial strategy in the region by securing customer leads and driving opportunity generation.

Noah Silberschmidt, founder and CEO, Silverstream Technologies, says: "We are very happy to announce our strategic partnership with Mitsui & Co. Europe Plc and Orient Marine at what is proving to be a critical moment for Japan's shipping industry. In an important maritime market like Japan, being able to count on a local industry-leading player who endorses our technology and shares our vision of a more sustainable and efficient industry is extremely valuable.

"We see the Japanese-owned fleet and newbuild segments as an important market for our technology in the near future, and we are optimistic that our new partners at Mitsui & Co. Europe Plc and Orient Marine will help to deepen our ties to the country and its key maritime players."

Naoki Shinohara, executive vice president operating officer, Orient Marine, adds: "Through the collaboration with Silverstream, we aim to contribute to the decarbonisation of the shipping industries."

In recognition of the necessity to decarbonise and future-proof its domestic shipping sector, Japan has set a target of net-zero greenhouse gas (GHG) emissions by 2050.

FERRIES

STENA LINE INTRODUCES SECOND LARGE E-FLEXER TO FLEET

Stena Line has introduced *Stena Ebba*, the second of two large E-Flexer vessels. The vessel will join its sister ship, *Stena Estelle*, to offer services between Karlskrona, Sweden, and Gdynia, Poland, in December.

Stena Estelle began operations on the route in August.

The largest E-Flexer vessels to date, the 240m-long units are 36m longer than the three existing E-Flexers operated by the Swedish shipping line company. The ships will be able to take 15% more cargo and accommodate 30% more passengers. They will have capacity for 3,600 lane-metres of vehicles and rolling cargo, space for 1,200 passengers, and 50% more cabins.

Like all E-Flexers, *Stena Ebba* and *Stena Estelle* have optimised design of hulls, propellers and rudders for maximum efficiency, while being adaptable to an alternative fuel setup in the future, according to Stena Line.

"The southern Baltic Sea is a key region for Stena Line and our route Karlskrona-Gdynia is a backbone for our ambition to grow and expand further," says Niclas Mårtensson, CEO of Stena Line. "*Stena Ebba*, together with the sister vessel *Stena Estelle*, will set new standards of flexibility, service orientation and customer satisfaction. They are the largest vessels in our successful E-Flexer fleet, and we are proud and excited to soon having *Stena Estelle* and *Stena Ebba* connecting some of the most dynamic markets in Europe."

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NEWS ANALYSIS

RECESSION, RISKS AND RULE PROBLEMS

By **Malcolm Latarche**, Correspondent

Realisation is dawning that the global economy looks to be heading for a recession brought about by energy costs, inflation and a decided lack of consumer confidence in the west. All promise a knock on effect for shipping with container lines looking to fare quite badly.

The port congestion caused by the Covid pandemic was expected to have eased later this year, but it seems that may not now be the case. In early August, AP Moller-Maersk was warning of a drop in demand for cargoes because of weakening consumer confidence and revealed bookings for containers were 7.4% down in the second quarter when compared to the same period in 2021.

Maersk warned that the slowdown was especially pronounced in Europe, where stockpiles have been building up at ports and in warehouses as consumers stop spending. That situation is very likely to be exacerbated after dockers at Felixstowe declared a week-long strike over pay due to begin in late August.

The bumper freight rates for box ships have been falling over the course of the year and if the world goes into a prolonged recession, operators may be regretting orders for newbuildings made at the height of the market. Some delays or cancellations may actually come as a benefit for shipbuilders who are now facing rising costs for steel after having secured several orders over the last year. In early August, all South Korea's leading builders reported widening gaps in operating costs against revenues, souring somewhat the country's success in regaining the top spot in the world shipbuilding league.

The bulker sector by contrast is having a fairly good period. Coal use around the globe has increased throughout the year with every prospect that 2022 will be one of the best years ever. The sector is also likely to benefit from an agreement brokered by the UN and Turkey to allow grain exports from Ukraine to recommence. Since the deal was agreed in late July, several vessels have loaded and departed from Ukrainian ports. The initiative will allow stored grain to be exported but to what extent the war in Ukraine will allow the 2022 harvest and 2023 planting to take place is an unknown.

Events in Ukraine no longer make daily headlines, but the conflict is far from over and sanctions on Russia remain in place. Early August saw another geopolitical risk rise up the list of problems the world is facing when US politician Nancy Pelosi made a visit to Taiwan. China has always seen Taiwan in the same way that Russia sees Crimea and the Donbass – historic parts of their respective countries that need reminders to the rest of the world to keep away.

CONTAINER BOOKINGS HAVE SHOWN A MARKED SLOWDOWN AS CONSUMERS START TO FEEL THE CRUNCH. SOURCE: SHUTTERSTOCK

The result of Pelosi's visit was an immediate round of military manoeuvres and a declaration by China that co-operation with the US on several matters, including climate change, will be suspended. The latter adds to the impact of the energy crisis and could see changes in the decarbonisation debate.

From the point of view of the shipping industry, decarbonisation did look to be deeply entrenched in regulatory changes with the EEXI and CII coming into effect in just a matter of months. It has to be said that both measures are not universally popular with ship operators, and many believe they have been rushed through without sufficient thought. A recent report by analysts VesselsValue suggested that 75% of existing ships would have difficulties complying with the EEXI regulations. Some might be able to comply by way of hull modifications such as ESDs. Most of the rest would need to adopt some form of power limitation meaning they will be obliged to operate at lower speeds and the remainder would likely become uneconomic and forced out of use.

The second measure aimed at decarbonising the fleet is the CII. Initially it was thought that vessels that could not achieve the required A-C rating would be forced out of the market by charterer pressure. The CII was also seen as flawed by many as it would not take into account the impact of enforced delays through congestion or shortage of appropriate cargoes, lay ups or any of the other reasons that would stop a ship from being 100% efficient.

Even so there were some states and others in the industry that wanted to see compliance with CII enforced by more rigorous measures. These ideals were thwarted in July at the IMO Sub-Committee on Implementation of IMO Instruments which failed to agree on whether poor CII performance should be a detainable deficiency under PSC rules. ■

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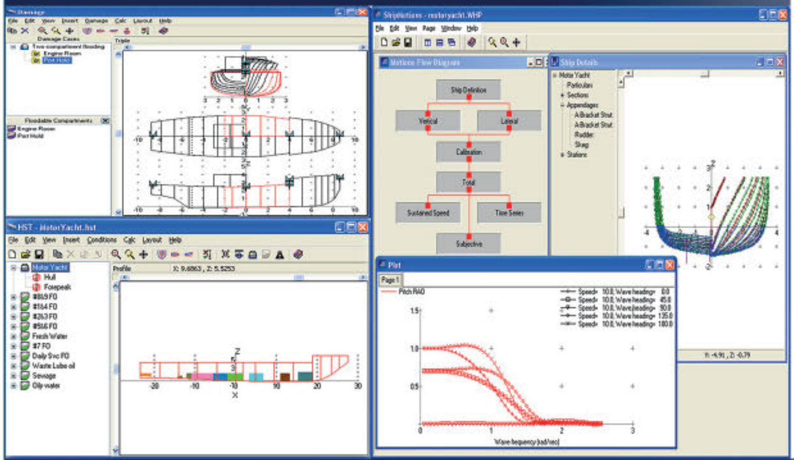

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NEWS EQUIPMENT

ENGINES

WINGD AND CHORD X PARTNER TO BRING CII INSIGHTS TO ENGINE USERS

WinGD has signed an agreement with emissions data specialist Chord X to develop digital solutions focused on sustainability in shipping. Among several areas of development, the partnership aims to bring ship operators "component-level insights" into Carbon Intensity Indicator (CII) ratings.

The companies plan to link WinGD's engine diagnostics platform, WiDE, with Chord X's vessel emissions analytics setup, ecoMAX. Connecting the two systems will enable ship operators to see how future voyages could affect CII ratings, as well as projecting ratings for future years as the CII framework steadily tightens, they say.

The new system will offer other emissions-related benefits, according to the companies. For example, if operators are required to comply with emissions trading schemes or carbon pricing regulations, even a small improvement in emissions performance could lead to significant cost savings.

Tin Wei Hong, head of Business & Partnering at Singapore-based Chord X, says: "Partnering with WinGD will allow us to provide the very best machine-GHG integration, which WinGD and Chord X will design for the next generation of marine main engines. Together, we will unlock the full potential of data-driven marine main engine operation and enable our customers to take the best path for success in the new digital shipping landscape."

WinGD's Rodolf Holtbecker, director of Operations, says: "This collaboration comes at the exact time when our industry needs greater visibility of the effectiveness of GHG-reducing technologies. By combining WinGD's advanced engine technology innovation and Chord X's focus on the emissions profile of vessel operations, users can directly connect the emission calculations with enhanced machinery analysis."

WINGD DIRECTOR OF OPERATIONS RUDOLF HOLTBECKER

COATINGS

NIPPON RELEASES PSPC-COMPLIANT UNIVERSAL PRIMER FOR NEWBUILDS

Nippon Paint Marine has added a new anti-corrosive universal primer for its E-Marine range of paints. E-Marine 2000 is the company's first general-purpose epoxy primer manufactured in China for the Chinese newbuilding market.

Available in grey, red or cream, E-Marine 2000 is an abrasion-resistant, high-volume, epoxy coating with an 80% solid content. The universal primer is reportedly suitable for application to all areas of a newbuild ship, including the underwater hull, boot tops, topsides, decks and cargo holds.

E-Marine 2000 was specially formulated after two years of development to meet the market demand for MSC.215(82)-compliant preparatory primer, which governs the performance standards for protective coatings (PSPC) for ships' ballast tanks. The IMO resolution, adopted in 2006, governs the performance standards for protective coatings (PSPC) for ships' ballast tanks.

Ballast water tanks require a nominal dry film thickness of 320µm, which can be achieved in two coats of primer. However, it can be applied in one coat for a range of film thicknesses on other parts of a ship, with a minimum and maximum dry film thickness of 80µm and 1,800µm, respectively.

"A general purpose, universal primer is a key priority for shipyards as a primer that can be applied to all parts of ship – including ballast water tanks – offers significant commercial technical advantages," says Gerald Mao, senior director, Nippon Paint Marine (Shanghai). "As this anti-corrosion paint has been certified for use as a ballast tank coating, more than 70% of a newbuild's undercoat requirement can be met with just one system."

More than 640,000litres of E-Marine 2000 and E-Marine 2000 LT have been ordered from Chinese shipyards for 26 newbuilds scheduled for delivery in 2023 and 2024, according to Nippon.

WIND POWER

BV AWARDS AIP TO SUCTION WING WIND PROPULSION DEVICE FOR CARGO SHIPS

Bureau Veritas (BV) has granted Approval in Principle (AiP) to France's CRAIN Technologies (Centre de Recherche pour l'Architecture et l'Industrie Nautiques) for its suction wing SW270, an auxiliary wind propulsion device for cargo ships.

The concept, developed in partnership with REEL (Rationnel Economique Esthétique Léger) and based on the principle of boundary layer suction, has a high lift coefficient and a lift-to-drag ratio that provides good performance in upwind conditions and for ships sailing at relatively high speeds, according to BV.

SUCTION WING CONCEPT FOR A VLCC. SOURCE BV

Grids located on both sides of the wing section create a suction force that draws air around the wing section from the outside to the inside of the wing. Mounted on a structural foundation, the wing rotates around a vertical axis and adjusts to wind direction for optimal performance.

While CRAIN Technologies and REEL plan to develop suction wings over a range of sizes for different vessel types, the device that was considered for this AiP was a wing with a span of 27m.

Laurent Leblanc, BV Marine & Offshore's senior vice president, Technical & Operations, says: "The suction wing concept appears to be a very promising option to help reduce greenhouse gas emissions from cargo ship operations. We are pleased to deliver this AiP to CRAIN, and we are proud to help build trust for innovative wind propulsion solutions, which are a key component of shipping's decarbonisation transition. We look forward to seeing the system in operation."

ENGINES

MAN LIFECYCLE UPGRADE PREPARES ENGINES FOR CLIMATE-NEUTRAL OPERATION

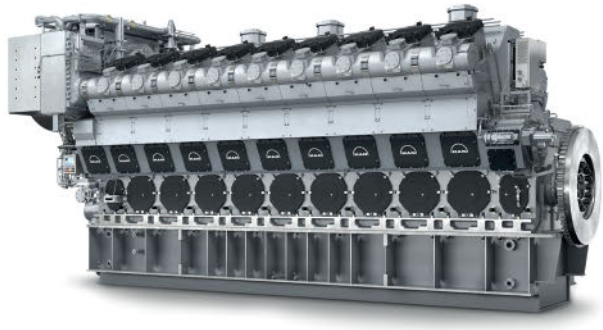
MAN PrimeServ, MAN Energy Solutions' aftersales brand, has announced that it can now retrofit older MAN 48/60 marine engines to MAN 51/60 types as part of the company's new lifecycle upgrade.

The upgrade enables older engines to be prepared for future climate-neutral operation. Furthermore, future conversions to dual-fuel operation can be undertaken because 80% of all necessary adjustments and changes are made during the lifecycle upgrade. Newly converted engines can also be upgraded to run on synthetic fuels.

Calculations carried out by MAN Energy Solutions based on an exemplary business case have shown that by upgrading a 9L48/60 engine to a 9L51/60 type, users could save approximately 500tons of fuel and 25tons of lubricating oil each year – based on an operating time of 6,000 hours under full load.

"With this lifecycle upgrade, we offer customers the opportunity to not only completely overhaul their old engines but also upgrade them to the latest engine technology at the same time," says Stefan Eefting, senior vice president and head of MAN PrimeServ Germany. "The upgrade simultaneously prepares the engines for future operation with climate-neutral fuels without having to change the fuel type they use at this stage. This is because the 51/60 engine type enables further conversion to alternative fuels, making it a futureproof investment."

"Due to the fuel and lube-oil savings from the upgrade and the elimination of ageing effects, we expect our customers to see a return on their investment within one-and-a-half to four years," adds Marcel Lodder, sales manager at MAN PrimeServ.



CONVERSION OF A MAN 48/60 ENGINE TO A STATE-OF-THE-ART MAN 51/60 UNIT REDUCES FUEL CONSUMPTION AND EMISSIONS

INSTITUTION NEWS

RINA APPOINTS NEW PRESIDENT

By **Richard Halfhide**

Although it has a history dating back more than 160 years and a commitment to promoting the best in ship design and maritime engineering, it would be reasonable to suggest that the Royal Institution of Naval Architects (RINA) has struggled with what might be politely described as a gender imbalance. It wasn't until 1923 that the first woman, Eily Keary, was appointed as an Associate Member but she would wait a further half century before becoming the first female full Member in 1973, despite a distinguished career with the National Physical Laboratory.

In 2019, RINA launched the Eily Keary Award to recognise the contribution by an individual, organisation or part of an organisation to increasing equality, diversity and inclusion in their sector of the maritime industry. Finally, and not before time, the Institution has appointed its first woman president: Catriona Savage, who is currently the Technical Assurance and Capability Director at maritime engineering group BMT.

Savage is long accustomed to making her way in a male-dominated profession, although notes that in her own formative years at the University of Southampton (where she studied for a BEng in Ship Science, followed by an MSc in Maritime Engineering), there was actually a higher than usual ratio of female students.

She comments: "There were about 30 or 35 other people on the Southampton course at the time and five of us were women, but I don't know if they've ever hit those numbers again. But when I think of our lectures, which we shared with other engineering courses in the first year, there were hardly any. When I first joined BMT we had a large number of women, but typically with most projects I've worked on there's been none to one woman. This has been a recognisable issue for a long time, although I think naval architecture is an area of engineering that quite often attracts women and so perhaps we should be further ahead than others.

"There's an opportunity to become a really vibrant community, we just need to bite the bullet and do more with our interactions with other parts of the maritime sector, providing thought leadership"

"Nowadays companies are all putting much more effort into STEM. We have to accept that it takes time for that to take effect, but still we would wish that we were seeing better progress than we're currently .... We [RINA] aren't going to start up our own STEM initiative but what we can do is partner and give voice to those which already exist."

Much of Savage's career has been spent at BMT, albeit in an array of different roles. Having originally joined its Bath, UK, office as a graduate naval architect in 1996, her work there encompasses a variety of projects including a shipyard placement at Babcock, collaborations with BMT's Australian and Canadian divisions and involvement in the design of Queen Elizabeth class aircraft carriers. As Technical Director for BMT's UK defence business, she had oversight for all technical delivery; including combat

SAVAGE HAS TAKEN OVER THE RINA PRESIDENCY FROM MAURIZIO D'AMICO (LEFT) AFTER THE COMPLETION OF HIS TWO-YEAR TERM. SOURCE: BMT systems, naval engineering, naval architecture and software.

In 2017, she applied successfully for the Professor of Naval Architecture position with the MoD, a role which also entailed becoming the Chair of Naval Architecture at University College London and leading its submarine design course. "It wasn't necessarily a step up, more something different. It was a four-year position and I really loved working with the students, as well as doing quite a few things overseas," she explains.

When her tenure came to a close, she felt the calling to return to industry once more and rejoined BMT in her present group-level position; a wide-ranging role which includes responsibility for the company's environment and civil infrastructure divisions, which have a heavy presence in Australia and the Americas.

Commenting on the areas of maritime technology and research which she finds the most interesting, Savage selects digitalisation, decarbonisation, and autonomy; noting they are all areas which pose not only technical but regulatory challenges.

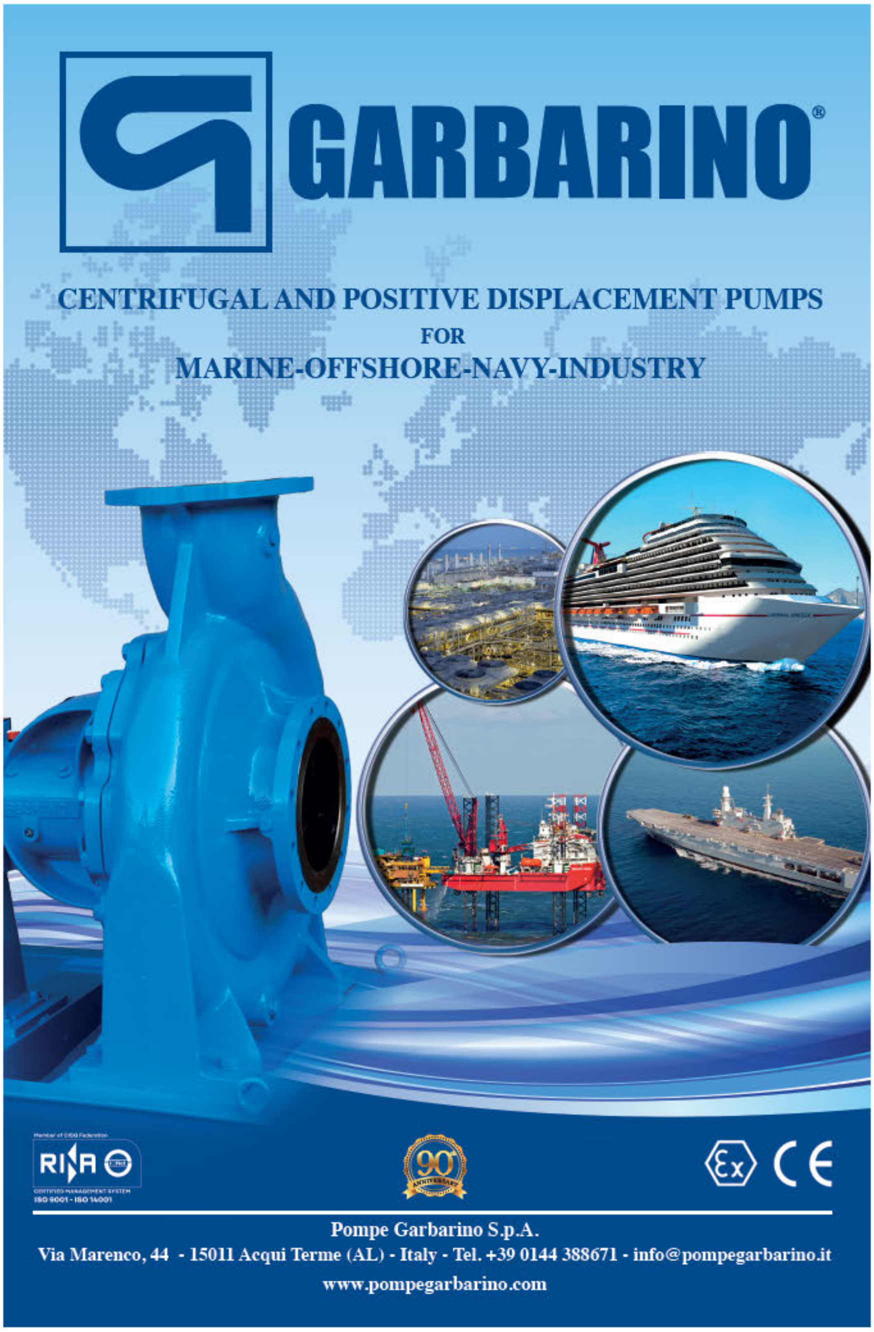
"With most of those I don't think it's going to be the technology that holds us back as much as the willingness, due to either cost or the regulations associated with achieving it. Autonomy in particular is a good example of that, in that the regulatory environment can be very different depending on where you are in the world. The thing about RINA is that it's very easy for us to talk from a UK-centric perspective but even when we talk about things like diversity, globally the constraints and challenges are very different."

Savage's personal relationship with RINA can be traced back to her student days when she successfully applied for a scholarship after it was recommended to her. Indeed, she believes the Institution currently has an ideal opportunity to become the sort of progressive organisation that can appeal to the next generation of maritime professionals.

"The advantage that RINA has is it's accessible to a wide range of people, although they might not know it. It's able to offer quite a lot of depth in its area of focus so it can really do quite a lot on making sure that its members have access to quality information. There is absolutely a critical place for papers and conferences and I can't see a situation where that kind of academic endeavour doesn't continue.

"But I also think we haven't yet grasped the breadth of different styles of communication, whether that's through more panel discussions, seminar-style events, webinars or TED-style talks. There's an opportunity to become a really vibrant community, we just need to bite the bullet and do more with our interactions with other parts of the maritime sector, providing thought leadership.

"I'd like to be in a situation where people come to us and ask RINA's position on subjects, and I don't think there's enough of that," she concludes. ■



CLARKSON RESEARCH SERVICES: HISTORIC AND SCHEDULED DELIVERY

Data extract from World Fleet Register available at **www.clarksons.net/wfr**

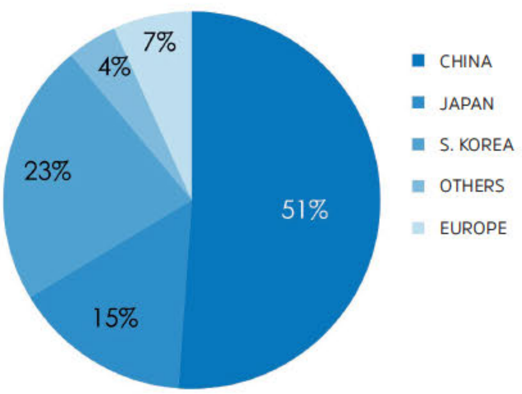
VESSEL TYPE	2011		2012		2013		2014		2015		2016	
	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half
VLCC >= 200,000	35	27	27	22	21	9	14	10	9	11	23	24
Suezmax 120-200,000	26	18	30	15	23	4	4	4	7	3	8	19
Aframax 80-120,000	28	31	30	15	14	6	4	13	22	10	31	22
Panamax Tankers 60-80,000	19	10	9	6	7	5	3	1	2	1	7	11
Products 30-60,000	45	28	27	30	49	29	49	49	60	57	60	42
Products 10-30,000	8	6	13	6	10	4	1	8	4	0	3	2
Chem & Spec. 10-60,000	53	39	39	8	7	13	12	11	36	29	42	38
Tankers < 10,000	56	58	76	41	38	39	32	25	19	23	23	16
Capesize > 100,000	129	122	149	65	63	40	56	38	46	42	64	39
Panamax 80-100,000	81	97	140	94	101	68	62	35	57	41	71	40
Panamax 65-80,000	36	44	53	39	34	42	42	20	19	4	1	2
Handymax 40-65,000	199	198	228	146	147	119	95	97	136	118	123	90
Handysize 10-40,000	191	181	227	117	116	83	101	71	110	86	86	51
Combos > 10,000	3	0	0	0	0	0	0	0	0	0	0	0
LNG Carriers	5	10	1	2	4	13	14	19	16	16	15	18
LPG Carriers	16	14	13	8	22	16	14	14	25	40	49	33
Containers > 8,000 teu	48	30	51	28	51	33	59	42	58	62	37	26
Containers 3-8,000 teu	31	21	39	19	46	29	26	25	18	6	2	0
Containers < 3,000 teu	34	35	38	40	29	19	22	28	28	35	41	28
Offshore	25	20	27	10	11	19	30	30	25	13	24	19
Cruise Vessels	4	2	6	1	6	0	3	2	5	1	8	2
Passenger	11	10	11	8	6	6	12	8	13	8	6	16
Other	183	182	191	97	100	84	72	60	69	47	50	61
TOTAL	**1,266**	**1,183**	**1,425**	**817**	**905**	**680**	**727**	**610**	**784**	**653**	**774**	**599**

DATA INCLUDES ALL VESSELS WITH LOA ESTIMATED AT >100M

THE ORDERBOOK BY YEAR OF DELIVERY ON THIS PAGE IS BASED ON REPORTED ORDERS AND SCHEDULED DELIVERY DATES AND DO NOT NECESSARILY REPRESENT THE EXPECTED PATTERN OF FUTURE DELIVERIES

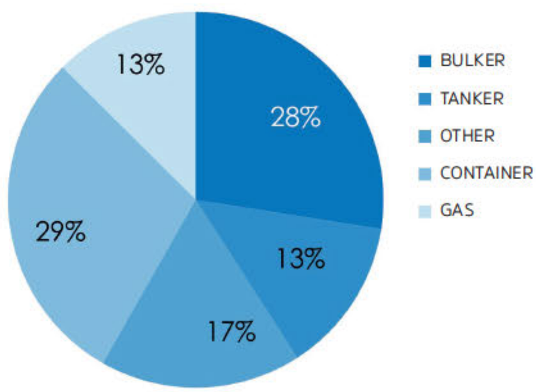
ALL DATA TAKEN AS OF **1ST AUGUST 2022**

ORDERBOOK BY BUILDER REGION (NUMBER OF VESSELS)

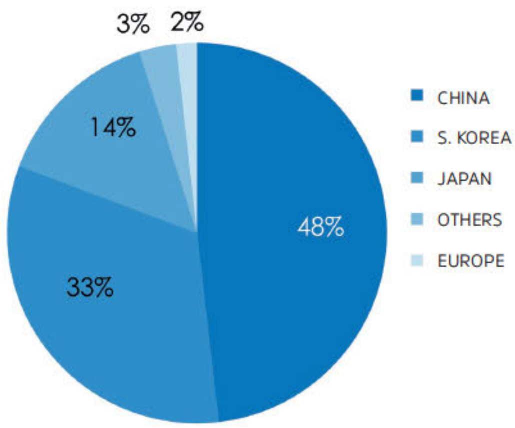


	2017		2018		2019		2020		2021		2022	Scheduled Orderbook		
	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd Half	1st Half	2nd half	1st Half	2022	2023	2024
	29	21	21	18	39	29	22	15	23	12	26	0	20	0
	35	22	25	7	23	3	11	19	20	3	33	8	9	2
	36	28	26	24	41	12	12	6	28	25	22	23	45	17
	10	11	7	6	6	7	6	4	1	1	5	5	2	0
	39	25	27	22	50	46	43	29	39	37	38	26	34	12
	6	6	10	8	5	10	4	6	7	11	8	8	4	1
	38	31	45	41	34	28	32	25	25	23	27	36	33	15
	25	37	45	43	27	28	27	27	23	33	34	36	33	16
	55	20	30	21	31	49	64	48	52	36	32	23	59	30
	75	27	39	25	69	64	96	47	65	37	54	52	118	56
	6	1	2	2	1	4	3	0	0	1	8	14	14	7
	121	51	57	33	55	77	92	56	60	56	60	58	115	100
	73	35	51	45	56	40	44	43	78	56	73	47	102	53
	0	0	0	0	1	2	0	2	3	0	0	0	0	0
	20	12	32	23	22	20	16	21	35	30	17	24	44	84
	45	17	26	9	16	13	19	14	19	14	22	27	78	24
	34	36	47	23	27	23	13	22	28	26	25	24	102	122
	2	5	7	3	6	1	1	5	5	1	0	9	78	125
	35	42	50	38	45	56	42	56	54	48	61	84	171	107
	18	23	24	14	8	9	5	5	10	12	12	23	38	12
	7	3	8	4	12	10	6	8	8	13	8	16	23	14
	20	11	11	18	16	16	11	11	15	16	13	26	17	11
	50	54	49	48	58	54	39	64	81	87	88	114	106	85
	779	518	639	475	648	601	608	533	679	578	666	683	1,245	893

ORDERBOOK BY SECTOR (NUMBER OF VESSELS)



ORDERBOOK (DWT) BY BUILDER REGION



CRUISE SHIPS

COULD ULSTEIN'S NUCLEAR SUPERHERO BE SHIPPING'S SAVIOUR?

By **Richard Halfhide**

ULSTEIN'S CONCEPT DESIGNS FOR THE MSR-POWERED THOR ALONGSIDE BATTERY-POWERED EXPEDITION SHIP SIF. SOURCE: ULSTEIN

As a shipbuilder and designer with more than a century of history, Ulstein has a proven resilience when it comes to adapting to maritime's ever-changing political and economic landscape. Although the group is centred around its Ulsteinvik yard in Western Norway, which today specialises in offshore and expedition cruise ships, it's nowadays perhaps most closely associated with its trailblazing X-BOW® inverted bow concept which today can be found on more than 100 vessels around the world. With European yards fighting what may well be a losing battle with their Asian rivals, there's also a realisation that the company's continued success may well lie in developing innovative intellectual properties that can be licensed to other builders.

Earlier this year, the company made fresh ripples with the announcement of the Ulstein Thor, a concept design for a 149m 3R (Replenishment, Research and Rescue) vessel that would be powered by a thorium molten salt reactor (MSR). The Ulstein Thor would essentially serve as a mobile nuclear power station with which other battery-powered vessels could rendezvous to recharge. While mooted as a potential solution to allow zero-emission expedition ships to operate in the Norwegian fjords and other remote or environmentally sensitive areas, Ulstein is keen to emphasise that really this is just the tip of the iceberg when it comes to Thor's potential applications.

Thorium is an element found in relative abundance in Norway and Ulstein began considering the possibilities for such vessels as long ago as 2008, before concluding the political environment might be unsympathetic to such historically controversial technologies. However, the growing urgency to develop low- and zero-carbon energy solutions, combined with the renewed interest in MSRs as an inherently more stable alternative to traditional (pressurised water reactor) technology as a viable option for shipping, spearheaded by the likes of UK-based Core Power (see *TNA*, January 2022) prompted a rethink.

Torill Muren, lead naval architect, Ulstein Design & Solutions, explains: "One of the reasons we took it up again is our work with expedition ships going to remote areas and the particular lack of infrastructure when it comes to power. Of course, the world energy crisis is one of the reasons why this makes sense as well as the war in Ukraine."

Ulstein's chief designer, Øyvind Gjerde Kamsvåg, adds: "The project started in January when we were challenged to develop a new way to attract new clients. We were supposed to go to the Seatrade trade show in April and it was a natural development of looking into how to establish zero-emission exploration cruising."

Simultaneously with Thor, Ulstein also revealed a concept design named after the mythological Norse hero's partner, Sif, in this instance a battery-driven cruise ship capable of accommodating 80 passengers and 80 crew. Both the designs include Ulstein's trademark X-BOW®. The company reckons that a single Thor vessel could be responsible for the recharging of as many as four ships cruising within a particular area. Dynamic positioning or anchors would be used during these charging operations, with a drone vehicle used to transfer the charging plug between the ships. With the rapid advances being made in battery technology it's estimated that the passenger vessel could be fully charged in as little as six hours.

"It might not be built that way in the future but it's a starting point to enable discussions," says Kamsvåg. "That's an important point of these concepts: how to move forward with zero emissions. It's not just about making a ship with an MSR, because anybody could do that, but also developing an infrastructure around the logistics. The enabling part of the project is as important as the MSR itself."

ULSTEIN'S CHIEF DESIGNER ØYVIND G. KAMSVÅG AND TORILL MUREN, LEAD NAVAL ARCHITECT, ULSTEIN DESIGN & SOLUTIONS

Naturally, the question arises of why not install the MSR directly on the vessel itself. Notwithstanding that passengers might be reluctant to travel for extended periods onboard a nuclear vessel (despite the inherent stability of MSR technology) the energy generated is well in excess of that required for vessels of this size and would lead to significant wastage. Another factor is likely to be the expertise required to operate the reactor core.

Although the unveiling of Thor and Sif were fully intended to be headline-grabbers, Ulstein is looking well beyond the expedition ship sector for potential applications of MSR technology as a viable option, particularly for vessels where other alternatives such as hydrogen and ammonia would present infrastructure problems. Container vessels, tankers and naval ships have all been discussed as possible options, particularly those engaged in deep-sea transportation. It might also be considered as a means of supplementing offshore wind power, which by nature can be prone to outages.

"The main reason we did this was we wanted to start this discussion and try to influence both class societies, politicians and the general public. That's the most important to us," says Muren.

Ulstein envisages its role as integrating MSRs into ship designs, leaving the nuclear technology to some of the merging experts in this field. Discussions have already taken place with Core Power and Copenhagen-based Seaborg Technologies, as well as the Institute for Energy Technology (IFE), which operates Norway's two nuclear reactors.

Meanwhile, Kamsvåg says there's been positive feedback from two major classification societies who are keen to lend their expertise to any future projects, not to mention some speculative interest from flag states. Clearly it's still early days but with momentum growing behind MSR, perhaps it won't be too long before Ulstein-designed nuclear vessels take to the seas. ■

SUSTAINABILITY DRIVES INNOVATION IN BOLIDT'S CRUISE SHIP DECK SYSTEMS

By **Daniel Johnson**

Viking Cruises' new ship *Viking Neptune* will set sail on the Mediterranean in November, before embarking on the 2023-2024 Viking World Cruise. With its diverse itineraries taking in everything from subarctic Scandinavia to the tropical waters of Southeast Asia and Latin America, the 227m newbuild will be faced a wide range of temperatures and climates. Therefore it required an outdoor decking solution that could withstand near-freezing conditions as well as long exposure to direct sunlight, heat and humidity.

Building on a relationship dating back to Viking's foundation in 1997, the owner called on the expertise of Dutch resin applications specialist Bolidt, whose decking systems feature on all of its river, ocean and expedition cruise vessels.

For *Viking Neptune*, Viking chose the Bolideck Future Teak, which represents a lightweight and more sustainable alternative to genuine teak. With Bolideck Select also featuring onboard the ship, Bolidt installed approximately 7,500m^2 of decking in total, covering all outdoor areas.

"We have worked with Viking for a long time, so we know exactly what is expected of us when supplying decking for one of its vessels," Jacco van Overbeek, director maritime, Bolidt, tells *The Naval Architect*. "Viking places great emphasis on sustainable operations and favours simple, elegant design. Bolideck Future Teak has the look and feel of real teak but is more resilient and far less harmful to the environment, making it the ideal solution."

The decking solution's hardwearing and UV-resistant qualities make it a good match for a wide range of weather conditions, van Overbeek adds.

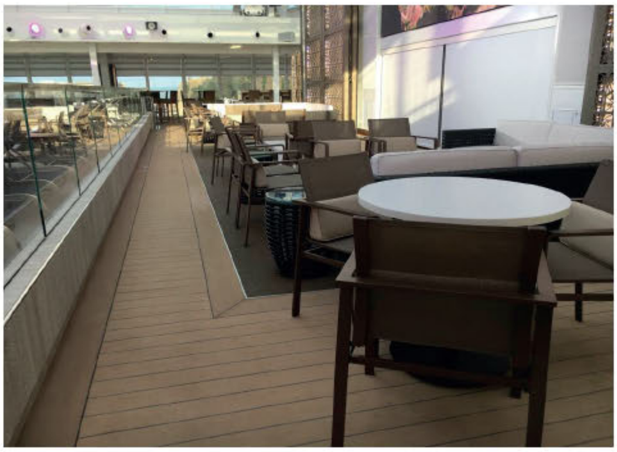
Bolidt's longstanding relationship with Viking covers both newbuilds and retrofits and has seen the companies collaborate at shipyards in Italy, Germany, Norway, Portugal, Egypt and the US. With additional projects scheduled in China, Bolidt will have finalised six Viking newbuild projects by the year end.

Innovation Centre

Bolidt's scope of supply for *Viking Neptune* also included a built-in deck-heating system designed at the company's Innovation Centre near Rotterdam to prevent ice formation in the extreme cold. "Innovation is part of Bolidt's DNA," says van Overbeek. "If you don't think about the future, you will not have one."

"The future is very much about sustainability, which is a continuing focus for Bolidt," he adds.

Sustainability is not a new concept for the company. Bolideck Future Teak was developed over 15 years ago, amidst environmental concerns that teak forests were being decimated and that wood was not always legally sourced.



THE LIDO DECK ONBOARD *VIKING NEPTUNE*, FEATURING BOLIDT'S SUSTAINABLE BOLIDECK FUTURE TEAK

"We are now developing lightweight systems more and more," says van Overbeek. "A large cruise ship can save around 60,000kg just with weight reductions to the base layer, contributing to significant fuel savings."

Bolidt's specialists at the Innovation Centre are also busy working on the development of bio-based hardeners to replace their chemical counterparts. Not only will they have a better ecological footprint than comparable fossil products, van Overbeek believes that bio-based hardeners will soon become a prerequisite. "The chemical-based hardener has a very tiny hazard risk to it. It's minuscule, but in future it will give reasons for shipyards to say, we can't use you anymore. It's a problem every resin company has.

"There's also a possibility that chemical-based hardeners will be banned from the market in a few years' time, and it's something that we need to be aware of and something that we need to work on."

As part of its innovation programme, the company is working with TU (Technical University) Delft to further research into solar power, which van Overbeek sees as a significant evolving concept in decking systems.

"We are working together to find a way for the decks to generate electricity from the sun," he explains. "What we're looking at is a liquid material that can harvest solar energy. We require a bit more time before we get there, but it's something that, once we have it, every cruise line will want. And if we can use that energy to power our deck-heating system, well that would be perfect." ■

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HOW TO PARTICIPATE?

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Nominations are open until the 31st January 2023.
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CRUISE SHIP CONCEPT DESIGN HAS LITTLE STUDIED SOCIAL DIMENSION

By **Kari Reinikainen**, Correspondent

The social relations between the various parties involved in shipbuilding in general are a topic that probably has received little attention in academia. However, Leena Jokinen's doctoral thesis, 'Ideation for Cruise Ships – Collaborative Interorganisational Foresight in Cruise Ship Concept Ideation', which was recently approved at the University of Turku in Finland, looks at these questions and the work has also produced results with potential practical implications.

Jokinen's work focuses on two points: firstly, how to capture the dynamics of futures-focused thinking and acting in everyday work contexts, and secondly how futures studies (FS) methodology can be developed for analysing how social relations shape the future. By drawing on corporate foresight (CF) research, which develops knowledge about futures and alternatives to support organisational decision making, the thesis explores the social aspects of future cruise ship concept ideation and sustainability enhancement.

"The results confirmed that while ship building is an evolving process, futures-focused ideation and collaboration play a pivotal role in the concept ideation phase of planning. However, ideation and the incorporation of new visions tend to happen in relatively closed circles of actors that include shipowner intra-organisational teams, design agencies and intra-organisational design teams within the yard. In the subcontractor network, futures-focused ideation is scattered and tends to be organised around shipyard actors, such as managers and department heads," Jokinen notes in the abstract of the work.

"The challenge is in linking social and operational processes to facilitate the formation and flow of futures insights between different systems," she adds.

Bold ideas often overlooked

The fact that relatively few actors are involved in the ideation and incorporation of new ideas has a number of practical implications, Jokinen tells *The Naval Architect*.

One of them is that there is a tendency to develop ideas that have already been put in practice by small steps, while bold and new ideas often tend to be sidelined. In addition, the views and opinions of relatively few individuals can have a significant weight in the outcome of the ship concept. Jokinen, whose work is based on experiences at the shipbuilding cluster in the Turku region where Meyer Turku has its yard, also found that there is no platform that would facilitate the inclusion of ideas and innovations that come from the supplier and contractor network to the overall concept planning workflow.

"A lot of input is being missed out. The shipyard itself has been concerned for quite some time that there is no mechanism that would allow the ideas of actors in the outskirts to be included. In fact, the entire mechanism of work may be inclined to reject radical innovations," she says.

LEENA JOKINEN

This, again, could be expanded to the question, what exactly is the role of the shipyard, the owner and the supplier and contractor network in the concept design and innovation process? "There are those who say that it is the owner who does take care of this and the role of the shipyard is to build the kind of ship the owner wants. Others, by contrast, say that the yard should actively participate in the innovation process. Personally, I would take this view," Jokinen notes.

In practice, a certain cyclicality can be detected in how cruise ship builders have seen their role in this work. "In the early 1980s, Kai Levander sent members of his team to places like Las Vegas to find out certain things," Jokinen says, referring to the then head of R&D at Wärtsilä's shipbuilding division which used to own the Turku yard at that time.

Four key points

She divided her work in four research questions. The first one asked how foresight can contribute to cruise ship concept ideation. This was followed by, what interorganisational relationships can be identified within networks of ship concept designers and planners? The third question queried how futures insights on sustainability enhancement flow in the joint project context and who are the focal insight brokers and sources of sustainability enhancement within the project network. Finally, she asked what futures images of sustainability enhancement are constructed within the joint project context and how can the evolution of futures images in workshop settings be analysed.

Acknowledging that concept design and innovation process deeply entwines the participants – the owner, yard, design agencies, etc. – once the basics and specifications of the new ship have been decided by the owner, the collaborative interorganisational foresight approach "facilitates the analysis of futures thinking within this process and strengthens the evaluation of different partners' impacts."

Moving on to the second question, Jokinen notes: "While international architects and design agencies have driven concept design, Finnish actors have played key roles in engineering planning, project management and construction based on a deep understanding of futures perspectives. From a collaborative foresight perspective, the shipowner, design company and production yard define the basis for insight creation and adoption. In the concept ideation process, futures-focused actions are embedded in operational-level and collaboration practices that do not include outsiders or actors in the wider network."

Referring to a recent study on sharing of future ideas on sustainability between various commercial, government and non-governmental organisation (NGO) actors, the outcome showed that the joint business-academia project in question had a weak role in establishing coherent collaborative foresight actions, but the collaboration within the joint project offered possibilities for sharing future-focused ideas with the participating actors.

Regarding the final question, the study identified four futures images: money rules, the customer is always right, local economy focus, and the most sustainable ships in the world. "To explore the construction of futures images, the study analysed the content of workshop group discussions in terms of content, range of alternatives, timescale, sociality and resonance, highlighting the role of the social network in resolving sustainability challenges," Jokinen says in her thesis.

Sustainability challenge to shipbuilders may change cruise product

A certain dualism appears to dominate our view of future and this has implication on innovation and cruise ship concepts as well, she continues. "On one hand, we tend to be prone to think that many things will remain the same and changes only occur on the fringes of our lives. On the other, we sometimes tend to exaggerate the pace of change," she says.

When it comes to the cruise ship building industry, a lot of work is going on to make the ships greener, e.g. by adopting new, emission-free fuels. It is likely that this work will significantly change the industry in many ways in the years to come. However, on the other hand the cruise product itself has changed remarkably little in the decades since the industry emerged in its modern form in the late 1960s. "It is still about people going on a cruise with their family or friends to have a good time, to visit the places where the ship calls etc.," Jokinen says.

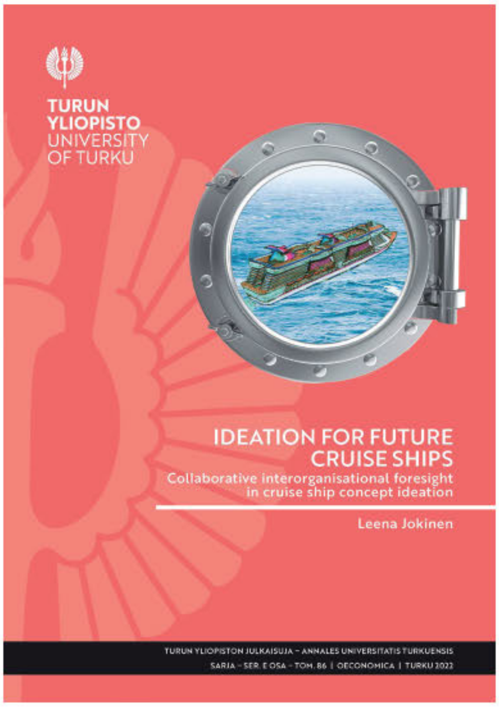
In the years to come, this may change. New generations of people that will go on cruises in the future are likely to be more sustainability focused than their predecessors. "Could this perhaps mean that in ports of call, people will help the locals to make their community better by doing some voluntary work? Or, for example, in the case of expedition cruising, participate in nature conservation," Jokinen asks.

While these questions, which could have a profound impact on cruise ship concepts of the future remain unanswered at the moment, there are practical questions that a shipyard needs to tackle to drive its own sustainability. "For example, panels may have been installed in the ceiling that have been coated by environmentally friendly paint by one contractor. However, it may become necessary to take them down by another one, who will later put them back up and use standard coating that has no sustainability credits at all," Jokinen says. Problems like this cannot be tackled by looking at numerical indicators alone, instead they need communication between the parties so that they all share common standards.

"Understanding foresight culture and futures-focused actions as elements of company operating models can help improve foresight systems and associated managerial practices ... the study reinforces the view that a company's awareness of its network of external collaborators and idea providers and their interconnections can promote rich and diverse multidirectional interaction and insight flow.

"A historical understanding of collaboration in Finnish networks can broaden managerial and expert options for developing processes such as innovation and communication and can help to link concept ideation to other business processes. By understanding vision building, key innovations and their outcomes in changing contexts, this longitudinal perspective will help managers grasp the significance of social context for collaborative foresight," Jokinen says in the conclusions of her thesis.

JOKINEN'S THESIS WAS RECENTLY APPROVED AT THE UNIVERSITY OF TURKU IN FINLAND



AUTONOMOUS SHIPS

JAPAN MOVES FORWARD ON JOURNEY TOWARDS AUTONOMOUS SHIPPING

By **Daniel Johnson**

THE *SOLEIL* FERRY DURING FULLY AUTONOMOUS SHIP NAVIGATION SYSTEMS DEMONSTRATION TEST. SOURCE: THE NIPPON FOUNDATION

Parking decarbonisation to one side, two of the most pressing challenges facing the shipping industry in the decades ahead are attaining a reduction of the accident rate – where human error is said to be involved 70-80% of the time – and the prospect of a lack of qualified personnel. The achievement of fully autonomous navigation is increasingly seen as one viable way to address both these issues, particularly in short-sea and coastal shipping between two given ports.

Japan has some pretty compelling reasons to take these two challenges onboard. The country is home to one of the world's most congested waterways. It also has a declining birth-rate and ageing population, which have resulted in the emergence of labour shortages in a wide variety of fields, and coastal shipping, with its challenging work environment, is no exception; with more than half of its coastal shipping crew members over the age of 50, this is becoming a major concern.

Coastal shipping is key to Japan's logistics system, transporting around 40% of the country's cargo and 80% of its industrial commodities. In addition, the nation has roughly 400 inhabited offshore islands, many of which are visited by ships only twice a day, in the morning and evening. Maintaining these routes has therefore become a critical issue in the daily lives of those inhabitants.

It is no surprise then that Japan has been a prime mover in the journey towards autonomous shipping. In February 2020, The Nippon Foundation launched the Meguri2040 Fully Autonomous Ship programme through support for five consortia encompassing around 50 corporations and organisations to develop fully autonomous navigation system concepts. Investment in the programme to date amounts to ¥8.8 billion (US$65 million), of which ¥7.4 billion (US$55 million) came in the form of a Nippon Foundation grant.

Meguri2040 aims to make autonomous shipping commercially viable by 2025 and has set itself the ambitious goal that 50% of the Japanese fleet will be autonomous vessels by 2040. It also hopes to contribute to the creation of international rules for fully autonomous navigation.

First results

Initial results of the programme were presented earlier this year in a series of demonstration tests featuring a pair of ferries and two coastal container ships.

In January, Mitsubishi Shipbuilding, part of the Mitsubishi Heavy Industries (MHI) group, and Shin Nihonkai Ferry successfully deployed the 223m vehicle-carrying ferry *Soleil* on an autonomous 240km voyage on the Lyonada Sea from Shinmoji, Kitakyushuu City. It was the first time for a vessel over 200m in length to attempt an autonomous voyage at speeds of up to 26knots that involved auto-berthing, according to MHI.

The *Solei*, owned by Shin Nihonkai Ferry, was built for the Meguri2040 'Smart Coastal Ferry' project. The newbuild began navigating with an onboard crew in July 2021, compiling data for the development of a fully autonomous ship navigation system. Mitsubishi Shipbuilding, which has experience in developing navigation support systems to realise automation and crew labour savings, oversaw the integration of the entire system.

The voyage was used to test the Super Bridge-X autonomous navigation system, which performs automatic avoidance manoeuvres and offers an advanced automated port berthing/unberthing function. As Mori Hideo, Mitsubishi Shipbuilding's chief engineer, explains: "Super Bridge-X ensures that the ship travels along the planned route, using automatic identification systems, radar and a target image analysis system to avoid collisions with other vessels."

The target image analysis system includes an array of infrared cameras that are able to detect obstacles even in complete darkness.

A second ferry test was completed in early February, this time by a consortium headed up by the Mitsui group.

The successful demonstration was conducted with the 21-year-old *Sunflower Shiretoko*, a vessel measuring 190m in length and 26.4m in beam, in a voyage that followed the normal commercial route of the ferry, a distance of 750km over roughly 18 hours.

The Mitsui consortium's involvement in the Meguri2040 programme includes conducting sea trials with two different types of ships, a ferry and a container ship, to identify similarities and differences in their navigation and increase the versatility of the technology. A container ship trial was undertaken by the consortium in late January using the 2015-built, 1,870dwt coastal vessel *Mikage*. During the voyage *Mikage* successfully navigated a 270km sea route from Tsuruga, Fukui Prefecture, to Sakaiminato, Tottori Prefecture. In addition to being the first time for an operating container ship to use fully autonomous navigation, the test marked the first use of drones for mooring operations.

According to the consortium, the autonomous berthing and unberthing was one of the most challenging parts of the voyage. For the trial, a system of support sensors developed by Furuno Electric used data from LiDAR, cameras, and a satellite compass to calculate and display distances and angles between the pier and hull. Mooring support technology developed by A.L.I. Technologies used drones to carry the ship's line to the pier.

Congested waters

The series of tests culminated in arguably the most eye-catching of the four demonstrations, an autonomous voyage by a container ship through Tokyo Bay. Approximately 500 ships traverse the waterway every day (compared to roughly 320 through the Straits of Malacca and Singapore and around 40 through the Panama Canal) and it was the first time such a voyage had been attempted on such a congested stretch of water, according to The Nippon Foundation.

The trial, a 790km round-trip between Tokyo Bay and Matsusaka port in the city of Tsu, Mie, was performed by the 2019-built, 204TEU *Suzaku* and included 40 hours of navigation, with full autonomy being activated 99% of the journey's time.

The vessel was chosen for the project by the 'Designing the Future of Full Autonomous Ships' (DFFAS) consortium, comprising 30 Japanese companies and led by NYK group company Japan Marine Science. In addition to representation from the shipping and shipbuilding industries, the project brought together expertise from a diverse range of participants, including meteorological information service providers and marine insurers.

The *Suzaku* made the voyage equipped with a marine collision avoidance system developed by Orca AI. Powered by artificial intelligence and deep-learning technologies, the system was set up on the vessel to act as a 'human watchkeeper' and provide real-time detection, tracking, classification and range estimation on 18 onboard cameras.

Orca AI's algorithms were trained on data collected over a year from *Suzaku* to identify targets in the complex Japanese shorelines. The information from the cameras reflected to the fleet operations centre in Chiba Prefecture, hundreds of kilometres away, via sea-to-ground communication links.

According to Satoru Kuwahara, programme director of the DFFAS consortium, the fleet operation centre marks a significant advance, allowing fully autonomous navigation at sea with tracking from land of functions normally performed by crew, including the monitoring of weather and sea conditions, traffic flow, and the ship's equipment. In emergency situations, the system can switch to remote operation from the fleet operation centre, ensuring the overall system's safety and stability.

"It is an essential element in making autonomous shipping a commercial reality," Kuwahara says.

Avoidance manoeuvres

The trial sailing included operations that would be carried out under normal working conditions, such as offshore manoeuvring, bay and coastal navigation, and berth manoeuvring, using the autonomous navigation system.

"The ship performed 107 avoidance manoeuvres on the on the outbound journey alone. Each change of course enabled the ship to avoid several other vessels, so we can infer that it avoided a total of 400 to 500 ships," according to Kuwahara.

"This year marks a milestone in the testing process," states Nippon Foundation executive director Mitsuyuki Unno. "We are now going to start working seriously on the establishment of a legal framework and accident-response protocols for autonomous vessels. We're 50% of the way to our goal, and as we work to get to 60 or 70%, we also need to consider whether to support the commercialisation efforts of the respective consortiums or to consolidate the strengths of the various members into one."

Unno adds that on the outcomes of this development process, The Nippon Foundation will then approach the International Maritime Organization and other bodies with proposals. ■

INFRARED CAMERAS ONBOARD *SOLEIL* DETECT OBSTACLES AND OTHER VESSELS. SOURCE: THE NIPPON FOUNDATION

NILS HOLGERSSON. SOURCE: MARK STAMPEHL

GERMANY

A NEW 'FERRY' TAIL FOR GERMANY'S TT-LINE

With the delivery of TT-Line's 5,015lm and 800-passenger capacity *Nils Holgersson*, soon to be followed by sister ship *Peter Pan*, China Merchants Jinling Shipyard (Nanjing) has joined the rather exclusive group of Chinese shipyards building complex ro-pax ferries for foreign interests. This is a first for the yard's Yizheng facility which has hitherto been a prolific builder of short-sea ro-ro vessels, having just completed Grimaldi Group's innovative 12-ship GG5G series

By **Philippe Holthof**, Correspondent

China Merchants Jinling Shipyard controls the shipyards in both Weihai and Nanjing. Whilst the former shipyard is building Stena RoRo's highly successful 'one-size-fits-all' E-Flexer ro-pax series, as well as the Superstar class pair for Grimaldi Group subsidiary Finnlines, it is the latter that has broken new ground with the on-time delivery of *Nils Holgersson*. In fact, the 56,138gt ro-pax was delivered a few weeks ahead of schedule, no mean feat for a yard that had never built ro-pax ferries before, not to mention the challenging Covid-19 conditions.

Already back in 2000, the then-emerging Jinling Shipyard – established in the 1950s – took the sceptics by surprise with the on-time and to-cost delivery of its first ro-ro ships, of which the 1,890lm *Finnmaster*, currently DFDS's *Botnia Seaways*, was the lead ship. This quartet proved to be the door opener for more short-sea ro-ro orders, all built at the facility in Nanjing where the vessels were still side-launched into the Yangtze River.

The rather small yard in Nanjing Is expected to be permanently closed in mid-2023 with Jinling Shipyard's (Nanjing) newbuilding activities to be concentrated at the modern Yizhing facility, some 50km downriver on the north bank of the Yangtze River. In more recent years, the Yizheng yard completed Toll's 3,084lm *Tasmanian Achiever II* and *Victorian Reliance II*, followed by DFDS's 6,695lm sextet and Grimaldi Group's hybrid GG5G class: nine 7,800lm ro-ros for Grimaldi Lines service in the Mediterranean and three vessels specifically adapted to Finnlines' requirements with a lower intake of 5,800lm, meeting the typical cargo mix of trailers, forest products, trade cars and containers.

Green Ship

In the hands of Germany's Oetker and Termühlen families since early 2013, TT-Line steers clear of the limelight. The company's first newbuilding project since the 2001 delivery of the SSW Fähr- und Spezialschiffbau-built *Nils Holgersson* (now renamed *Akka*) and *Peter Pan* (converted in 2018 and to be renamed *Tinker Bell*) was shrouded in mystery with the order only officially announced some six months after the contract signing.

When revealing the newbuilding contract in December 2018, TT-Line stated that an option for a sister ship was attached but, once exercised, this was never communicated. It is understood that TT-Line held an option for two more ships of the same class but with newbuilding prices having gone through the roof and Chinese yards eager to concentrate on more profitable and less complex vessel types, such as container ships and PCTCs, the option appears to be void now.

Powered by LNG and with fuel efficiency and consequently emission reduction at the heart of the design, the new generation has been dubbed 'Green Ship'. Denmark's OSK-ShipTech has played a key role in the design; in addition to developing the concept design, it was responsible for both the contract and basic design.

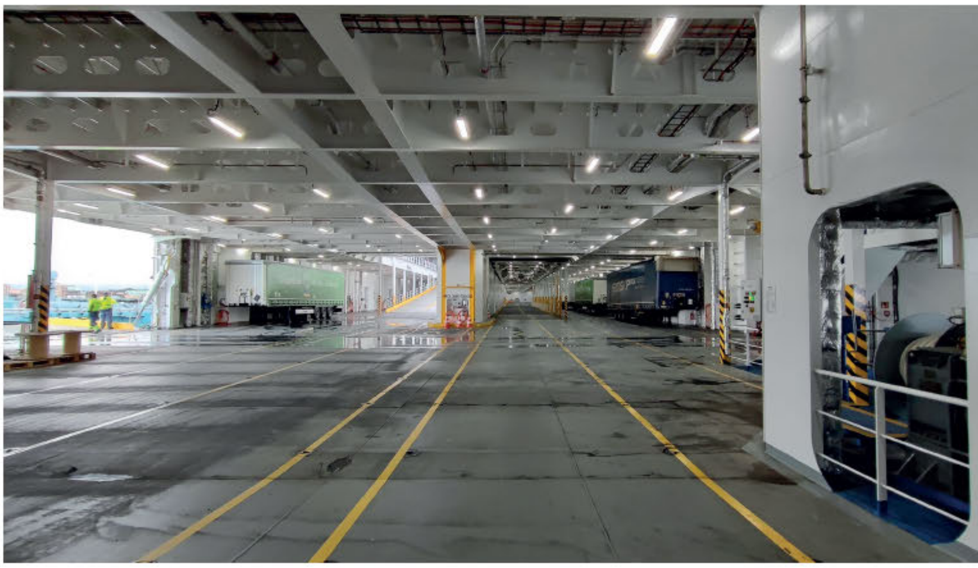
Demanding schedule

TT-Line operates in an extremely competitive marketplace, competing on the Germany-Sweden corridor with Finnlines and Stena Line. Indirect competition comes from Scandlines' shorter Fehmarn Belt link between Puttgarden and Rødby. Competition will only intensify when the fixed Fehmarn Belt link opens towards the end of this decade.

With Bernard Termühlen at the helm, TT-Line has expanded beyond its core Travemünde–Trelleborg and Rostock–Trelleborg routes. A Trelleborg–Swinoujscie service in direct competition with Unity Line was added early in the New Year of 2014, followed by a Trelleborg–Klaipeda route in June 2018. TT-Line adapts supply to demand and therefore, its ferries don't operate on a fixed route and rather rotate. Although the new *Nils Holgersson* and *Peter Pan*, the largest ro-pax ferries in the nine-ship strong fleet, are designed to operate on all four routes, they primarily serve Travemünde–Trelleborg, followed by Trelleborg–Swinoujscie.

Crossing times vary between six and over 11 hours with Rostock and Swinoujscie offering the fastest transit

DECK 3 BOW RAMP AND BOW DOOR ARRANGEMENT. SOURCE: PHILIPPE HOLTHOF



DECK 5 WITH SIDE LOADING RAMP AFT. SOURCE: PHILIPPE HOLTHOF

DECK 7 WEATHER DECK. SOURCE: PHILIPPE HOLTHOF

DECK 12 WRAP AROUND PROMENADE DECK WITH SKYLIGHTS. SOURCE: PHILIPPE HOLTHOF

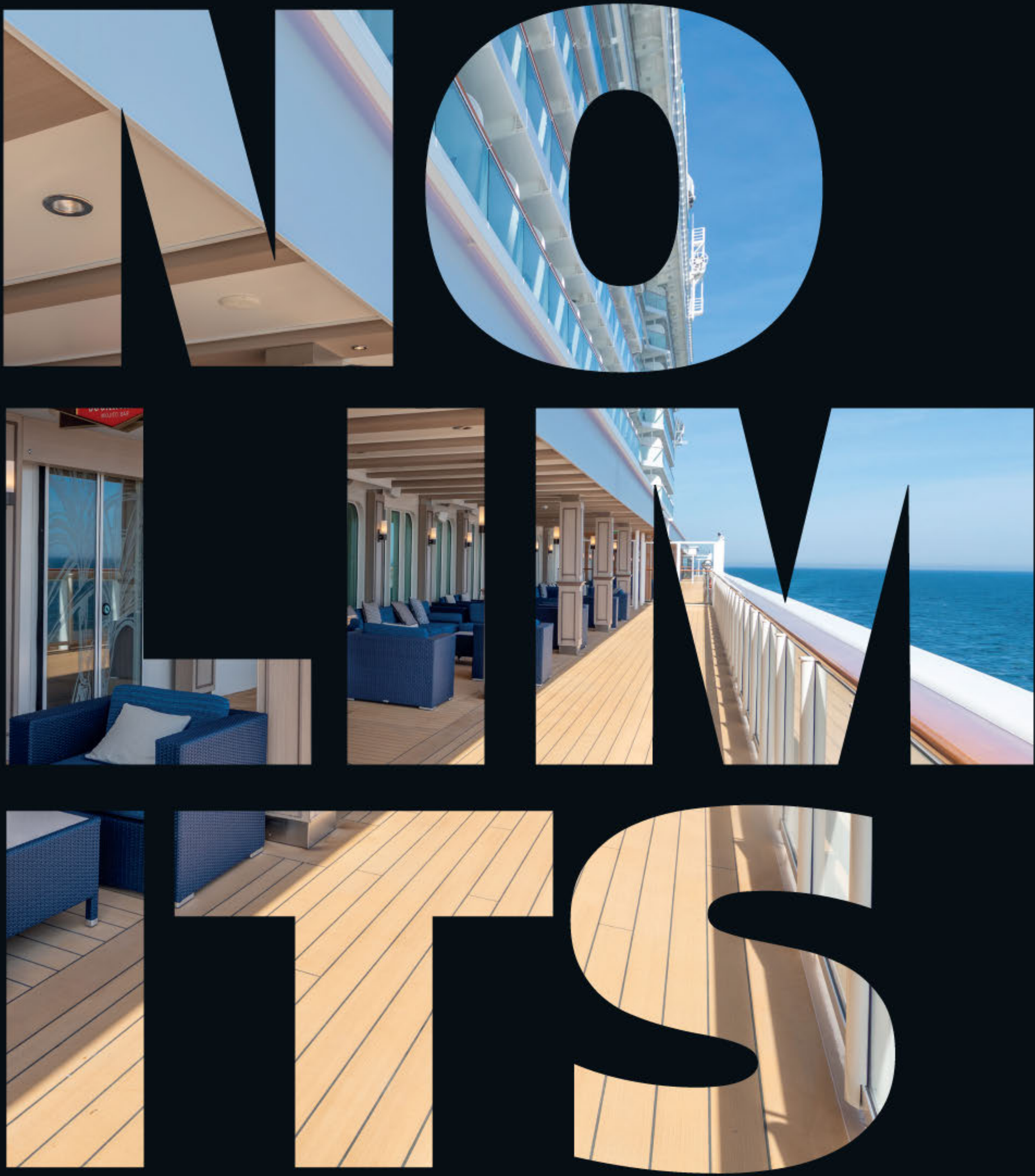
times. To reduce fuel consumption and emissions, TT-Line has also implemented kind of slow-steaming, especially on the Travemünde–Trelleborg overnight service. Consequently, port turnarounds are reduced to the strict minimum with an emphasis on the optimisation of the cargo flow.

Fast turnaround

Already many years ago, TT-Line implemented double-level shore access in Trelleborg, Travemünde and Rostock. *Nils Holgersson* berths bow-in at Trelleborg. Bow access into the 1,495lm main deck, Deck 3, is via a 20m-long (plus 2m outer flap) bow ramp with a 6.2m-wide driveway. It folds out from behind a pair of hydraulically operated clamshell doors. All access equipment, tiltable ramps and ramp covers were supplied by MacGregor, part of Cargotec.

In both Travemünde and Rostock, there is double-level stern access. The twin stern ramps on Deck 3 each have a 12m length with 3m-long outer flaps and a 10m-wide driveway (to fit the linkspan, the flap of the starboard ramp narrows to 5.525m). Stern access into the 1,611lm Deck 5 is via a 12m-long (plus 3m-long outer flap) foldable ramp with a 12m-wide driveway. Double-level linkspans are not available yet in Swinoujscie and all cargo is discharged and loaded via the Deck 3 stern ramps, making use of the ship's internal ramp system. A 56.8m-long (excluding flaps) and 6.8m-wide double-lane tiltable ramp starboard of the central casing connects Deck 5 with Deck 3 below.

To speed up cargo operations in Trelleborg, *Nils Holgersson* boasts twin side access ramps on the portside of Deck 5 – one fore and one aft (on the starboard side, there is one side ramp forward with the shell being futureproofed to install one at the stern). Double-lane tiltable ramps on either side of the casing-cum-funnel connect Deck 5 with Deck 7, the uppermost deck, the aft end of which is a weather deck, allowing for the stowage of certain IMDG goods. To optimise cargo handling operations when alongside in Trelleborg, traffic for decks 5 and 7 is separated. Deck 5-bound trailers drive on board via the 6m-wide forward side-loading



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ramp whilst the aft entrance is used for trailers stowed on Deck 7 which has a 1,630lm capacity.

Thanks to the generous 11m driveway of the aft side ramp, trucks and tugmasters can promptly and easily turn towards the nearby tiltable ramp on the portside of the casing. Access into the 279lm lower hold is via a fixed ramp which has a two-section side-hinged cover for a total length of 50m. In closed position, the cover is flush with the main deck, watertight and hydraulically cleated to deck. *Nils Holgersson* boasts eight 3.1m-wide freight lanes in the widest parts of decks 3 to 7, four on either side of the engine casing.

The LSA recesses on decks 7/8 reduce the number of lanes to six which is also the number of lanes in the cellar hold. All four freight decks have a clear height of 4.7m and with passenger demand only peaking during holiday periods, there was no need to install hoistable car decks. Tourist cars are parked on Deck 5 which is equipped with a total of 32 EV charging points.

LNG propulsion

The new *Nils Holgersson* has a 92% higher freight intake than its 2001-built namesake vessel. In combination with a fuel consumption which is on a par with TT-Line's 1995-built, 2,394lm *Nils Dacke* and *Robin Hood*, this is an achievement in its own right as the emissions footprint per transported truck is halved. Yet, apart from the economies of scale, it's also the latest technologies that contribute to the ship's green status, all the way from an optimised hull form to waste heat and waste cold recovery systems from LNG and sea water. MAN Energy Solutions supplied the LNG FGSS, comprising two 500m^3 LNG Type C tanks which are stowed abreast in the tank hold space abaft the lowermost vehicle deck.

To comply with SRtP rules, a centreline bulkhead divides the engine room compartments into two halves. Aft of the LNG tank hold are the auxiliary engine rooms which each have two Wärtsilä 9L20DF dual-fuel gensets with an output of 1,384kW each. A MAN 8L51/60DF and a MAN 6L51/60DF dual-fuel engine are installed in each of the main engine rooms. This father-and-son arrangement allows for the necessary flexibility with the larger engine having 8,400kW MCR at 514rpm and the smaller one having 6,300kW MCR at 514rpm.

Swinging off the berth in each of the ports it serves, excellent manoeuvrability is key. This is guaranteed by three Brunvoll bow thrusters with an output of 2,500kW each in combination with twin high-efficient, lift-balanced streamlined Becker flap rudders with hub bulb. The rudders can be operated independently or in parallel.

Functional yet attractive public spaces

Until the abolition of intra-EU duty-free sales in mid-1999, TT-Line offered party cruises on its ro-pax ferries. Today, however, TT-Line's ro-paxes are used as a pure means of transport and this is also reflected in the ship's 3,500m^2 of public spaces which are functional and easy to maintain without being Spartan, well on the contrary. The interior architects, Germany's OCEANARCHITECTS, were also in charge of Hapag-Lloyd Cruises' latest expedition class vessels, built by VARD. With the superstructure leaning outward, *Nils Holgersson*'s aesthetics may look somewhat odd, yet the ship has been designed from the inside out, uniquely offering breathtaking views over the bow.

Two large full-width stair halls divide the three accommodation and public spaces decks into three fire zones. The bridge is positioned immediately above the uppermost vehicle deck with officers and contractor inside cabins as well as the messroom being located immediately abaft it. The two fire zones aft of the forward stair hall on decks 9 and 10 contain the 239 passenger cabins for a total of 644 berths. Besides two and four berth inside and outside cabins, there are three-bed deluxe cabins with a double bed and convertible sofa bed at the extreme rear of decks 9 and 10, overlooking the weather deck. Four even larger family cabins on the outer corners aft can accommodate up to five people. All cabins come with energy-saving units, interrupting the power circuit for

TECHNICAL PARTICULARS ***NILS HOLGERSSON***	
Length oa	229.4m
Length,bp	217.7m
Breadth, moulded	31.0m
Depth to main deck	9.5m
Draught, design	6.3m
Gross tonnage	56,138
Net tonnage	30,869
Deadweight	10,922t
Lanemetres (gross)	5,015m
Passengers	800
Passenger cabins/ berths	239/644
Main engines	2 x MAN 8L51/60DF + 2 x MAN 6L51/60DF
Output	2 x 8,400kW MCR at 514rpm + 2 x 6,300kW at 514rpm
Service speed	20.6knots at 22% operation time; 17.6knots at 19% operation time; 14.8knots at 59% operation time
LSAs	2 x 150-person VIKING Norsafe lifeboats + 2 VIKING MES
Class (*)	DNV
Class notation (*)	+1A Passenger ship RO/RO ship, BIS CLEAN, COMF (C-1,V-2), E0, Gas Fuelled, NAUT (AW), LCS (DC), Ice (1B), TMON (Oil lubricated), BWM (T)
Flag	Germany
(*) As built class, transferred to RINa upon delivery	

NILS' LOUNGE. SOURCE: PHILIPPE HOLTHOF

lights and switching the heating in eco mode when there is nobody in the cabin.

There is LED lighting throughout, reducing the power demand for lighting by 80%. In the mid-section, there are a total of 32 outside crew cabins on the portside of decks 9 and 10. Save for the sauna on Deck 9, all public facilities are concentrated on Deck 10 forward as well as Deck 11, the aft part of which gives access to a vast sun deck.

Directly accessed from the forward stair hall on Deck 10 are a commercial drivers' self-service restaurant on the starboard side and the 30-seat Sunrise Pullman Room to the port. An inboard corridor, to the starboard of the pullman lounge, leads to the Smygehuk Bar and Sail-Away Restaurant forward. These bar and restaurant facilities are opened on peak days only, being typically used by groups. For flexibility's sake once again, the restaurant is divided into two separate halves, offering buffet-style meals which are served from the main Deck 10 galley that also serves the Trucker Diner and the Captain Akka's self-service restaurant on Deck 11.

The latter deck is the main passenger deck, being conceived in such a way that the number of staff can be kept to a strict minimum. The reception desk forward doubles as the main bar and checkout for both the shop and 136-seat Captain Akka's Restaurant. The forward restaurant and bar facilities follow an open plan design with the U-shaped main corridor leading past the Sunnerbo Shop to the reception plaza and then continuing to the self-service restaurant. The reception lobby gives direct access to the Uppsala Bar lounge to port and the Lookout Café to the starboard, adjacent of which is the dedicated 57-seat Trucker Lounge, complete with a small smoker's balcony.

Aft of the single stair hall on Deck 11 is the quiet 62-seat Nils' Lounge to the port and conference rooms to the starboard. This area also boasts the 63m² Littly Pixy Playland children's playroom on the one hand and a bar counter on the other. The bar also serves the semi-covered outer deck through a hatch in the rear bulkhead. A clever design element are the circular skylights throughout Deck 11, letting in natural light. The sun deck with fixed picnic tables and large wooden sunbeds gives access to Deck 12, the top deck which comes with a walk-around promenade uniquely stretching to the very front. ■

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GERMAN START-UP AIMS TO MAKE SHIP RECYCLING SAFER AND CLEANER

By **Daniel Johnson**

The vast majority of ships continue to be broken under conditions that pollute and expose workers to immense risk. In 2021, of the 763 ocean-going commercial ships and floating offshore units sold for scrap, 583 of the largest tankers, bulkers, floating platforms, cargo- and passenger ships ended up on the beaches of Bangladesh, India, and Pakistan, according to data from the NGO Shipbreaking Platform.

"All shipowners are aware of the dire situation at the beaching yards and the lack of capacity to safely handle the many toxic materials onboard vessels. Yet, with the help of scrap dealers, most choose to scrap their end-of-life fleet in South Asia as that is where they can make the highest profits," explains Ingvild Jenssen, the platform's executive director and founder.

However, Jenssen adds that clean and safe solutions are available, and in light of new policies aimed at promoting a circular economy, several companies are now exploring the use of abandoned drydocks for the recycling of vessels.

One such company is German start-up Leviathan GmbH. Based in Cuxhaven and founded by naval architects Simeon Hiertz and Karsten Schumacher, Leviathan claims to be the world's first emissions-free clean ship recycling company, a concept that Jenssen calls "a real game-changer".

"The goal is to bring ship recycling into the 21st century with an industrialised and sustainable process," says Schumacher. "Our concept envisages dismantling these ships in large, closed hall docks in the future and then fully recycling the valuable ships steel and other valuable raw materials."

He adds: "We want to dismantle the steel completely without any hot work by using the cold water jet process. Unlike welding, no toxic gases are produced and the risk of a fire breaking out is eliminated. There will also be no workers working on or in the ship. You will only operate outside the hull and many activities will be automated."

Trials on test objects have shown that clean cutting technology can reduce CO_2 emissions during the dismantling process by a factor of 300 and the company is optimistic that the first facility for recycling large ships in northern Germany isn't too far away, according to Hiertz.

"The growing interest of shipowners can be felt. We are in contact with some shipping companies and are holding promising talks," he says, adding that German authorities have recognised that this area of

KARSTEN SCHUMACHER AND SIMEON HIERTZ, MANAGING PARTNERS AND FOUNDERS, LEVIATHAN GMBH. SOURCE: LEVIATHAN GMBH

the maritime economy has been underrepresented in the country and are keen to change this state of affairs.

Hiertz estimates that such a facility, at full capacity, could recycle around 50 Panamax class vessels per year. "This is a drop in the ocean from a global perspective, but we are convinced that this concept is superior and will prevail," he says. If successful, there is potential to roll out more such facilities across Europe.

With scrappers in South Asia benefitting from cheap labour and low social and safety standards, Hiertz sees keeping up with them in terms of price as a challenge. "But we have a very high degree of automation. This helps," he says. "Of course we are also dependant on the world market and the prices we can achieve for recycled steel. In the long term, however, it tends to go up, which also helps us. We're also observing that regulatory and societal pressure on shipping to operate more sustainably is increasing significantly."

Working with Germany Naval Yards in Kiel, Leviathan carried out a pilot project over the summer to demonstrate its process and technologies on a 41m landing boat, the *HC Hagemann 1*. The 67-year-old vessel had been operating as a supply ship.

The operation marked an important milestone, enabling the performance of the ESG-compliant recycling process to be verified, according to Schumacher. Leviathan will now apply for approval following EU regulations. ■

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CONFERENCES

IMDC 2022

By **Prof. David Andrews**, UCL and IMDC chair
Prof. Jon Mikkelsen of UBC, joint chair of IMDC Local Organising Committee

The 14th International Marine Design Conference (IMDC) took place from 27 to 30 June 2022 at the University of British Columbia (UBC), Vancouver. The event was postponed from June 2021 due to Covid-19 and would otherwise have been consistent with the usual tri-annual practice established with the first IMDC sponsored by the RINA in London in 1982.

Last year's postponement continued to affect the run up to the agreed conference dates, as travel and visa uncertainties meant a reduced set of papers were finally submitted and accepted. Worse still, due to visa issues several accepted authors were forced at late notice to present their papers either by a video recording or online, although for the most part the technology didn't hinder discussions. One serendipitous consequence of the reduced number of papers presented at the final conference was that there were only six parallel paper sessions, compared to, typically, three sets of three parallel sessions over three days in recent IMDCs. This meant attendees were less likely to have to juggle which sessions to attend and, for more of the debates, all attendees were able to participate, to the edification of all.

After the conference was opened by Professor Chris McKeeson (of UBC), joint chair of the 2022 IMDC Organising Committee, and by Professor David Andrews (of UCL), International Committee chair, the first of two sponsor presentations was given by Gary Michael, director Functional Engineering at Seaspan Shipyards, a major local shipyard with several Canadian government contracts. The first keynote presentation was by Andrews, provocatively entitled '100 Things (or so) that a Ship Designer needs to Know'. Aside from the ubiquitous list (many from other than the author) the paper also used his major RINA publication on the sophistication in early stage ship design (which narrowly missed exposure at IMDC 2018) to summarise his view of the nature of ship design.

The first of two Novel Design Concepts sessions commenced with UCL's Chris Greenough presenting the 'hydrokentic turbine' concept for energy recovery. This was followed by Juha Tanttari of Elomatic on the 'Elogrid' approach to thruster tunnel design. Both were motivated by propulsive energy reduction, whereas the next paper by Astid Solheim of NTNU, Tondheim, was an unusual example of technology transfer in ship design, namely that of a deep-sea mining study which raised interesting ecological conflicts. The session's final paper, by Connor Arrigan of University of Michigan, was certainly novel concerned with autonomous vessel design but taking a very philosophical stance: that of considering in marine design ontologies (i.e. the nature of being and relevant to AI), provoking an interesting debate.

The second session on novel concepts was on Day 3 and included a second Elomatic paper (by Ted Bergman) on an offshore concept with the simulation of wind turbine installation. Another novel paper in that session was by Nikoleta Charisi of TU Delft on energy saving devices (ESD) for novel vessels, addressing multi-fidelity models for the design of naval vessels with many design drivers including detectability and seakeeping with tumblehome.

A session on propulsion and machinery systems design included addressing fuel flexibility (Benjamin Lagemann from NTNU, Trondheim); hydrogen, ammonia and battery comparisons (a live video presentation by Foivos Mylonopoulos, University of Strathclyde); uncertainty due to energy transition in ship design (Jesper Zaginga, TU Delft) and variation of the Hi-Fin modification to propeller bossing (S Park, from Hyundai HI) - all responses to the energy issue.

The first of five Design Methodology sessions (two of which were concurrent with other sessions) ended Day 1. This should have begun with a video session with Hary Mukti of UCL on the ESD of distributed systems applied to a conventional submarine but was postponed until Day 3 so Etienne Duchateau of Netherlands MoD presented a systems-of-systems approach to simulating the operations of warships, which led to a paper debating fleet modelling by Keon Droste of Damen Naval Group, Netherlands.

Day 2 commenced with the second sponsor's presentation by Juhan Asanti, vice president of independent software consultancy CADMATIC, who spoke on the topic of Digital Twins, claiming it could result in 70% less paper usage during production.

SoA report

A distinct feature of IMDC since the 6th IMDC in 1997 in Newcastle has been the inclusion of at least one State of Art (SoA) Report, recent ones focusing on Design Methodology. Until 2022 a leading co-author has beeen UCL's Prof. Andrews, however this year's authors were Prof. Stein Ove Erikstad and Benjamin Lagemann from the Norwegian University of Science and Technology (NTNU). Their extensive review identified four major tracks: system related, set-based, optimisation and configurational. One particular new feature was to list all the recent PhDs produced in the field of Marine Design (see Table 1) which serves to highlight how academic research (often with strong industry support) into 'ship design' is now comparable with that in the more tradition (naval architectural) sub-disciplines. This growth is as it should be, but is also in part consistent with the vision of IMDC founder Stian Erichsen and his successors that the event should serve to advance knowledge of ship design.

The SoA Report concluded with listing first the current developments in marine design methodology and then those issues which are emerging. Thus current issues were seen to be: design for sustainability (economic, environmental and social); uncertainty and flexibility; design for safety; design for operations and finally a specific case (wind ship propulsion). The emerging developments seen by Erikstad & Lagemann were:

- The Real Thing & Digital Twin – to increase the share of delivered value
- Design Continuity – very design relevant
- AI for Real this time? With Machine Learning, Neural Networks, Digital Twin, Alpha Zero
- Systems Design – extended boundaries and redesign

The report ended with the Andrews & Andrews 'Rich Picture of ESD for Complex Vessels' that regular readers of *TNA* will be familiar with from the January 2021 article, which tried to capture the subtlety of sophisticated ship design practice. A lively debate followed.

This article does not detail the other three days of papers which covered Design for the Invisible Parts of the Ship' (a new topic introduced by UBC and which included the second keynote paper by Professor Dave Michelson, of UBC), Hullform and Integrated Design Environments, Design Education, Maritime Logistics, Sustainable Design, Design for Safety and further sessions on Design Methodology and Novel Design Concepts, but will hopefully whet readers' appetites to peruse the IMDC 2022 website – www.imdc2022.org – for specific papers on these topics.

Discussion sessions

Given that most papers were presented to the full conference, it seemed to foster a set of very lively discussion sessions further exploited during the generous coffee, lunch and tea breaks. These face-to-face sessions more than justified the physical attendance by all present, something that could not have been realised by web-based or hybrid conference sessions imposed by pandemic restrictions. This was particularly felt to be advantageous for the many papers presented by PhD students, either of their recently completed research – in a wide range of ship design issues – or even more worthwhile and courageously, by those students

IMDC 2022 DELEGATES

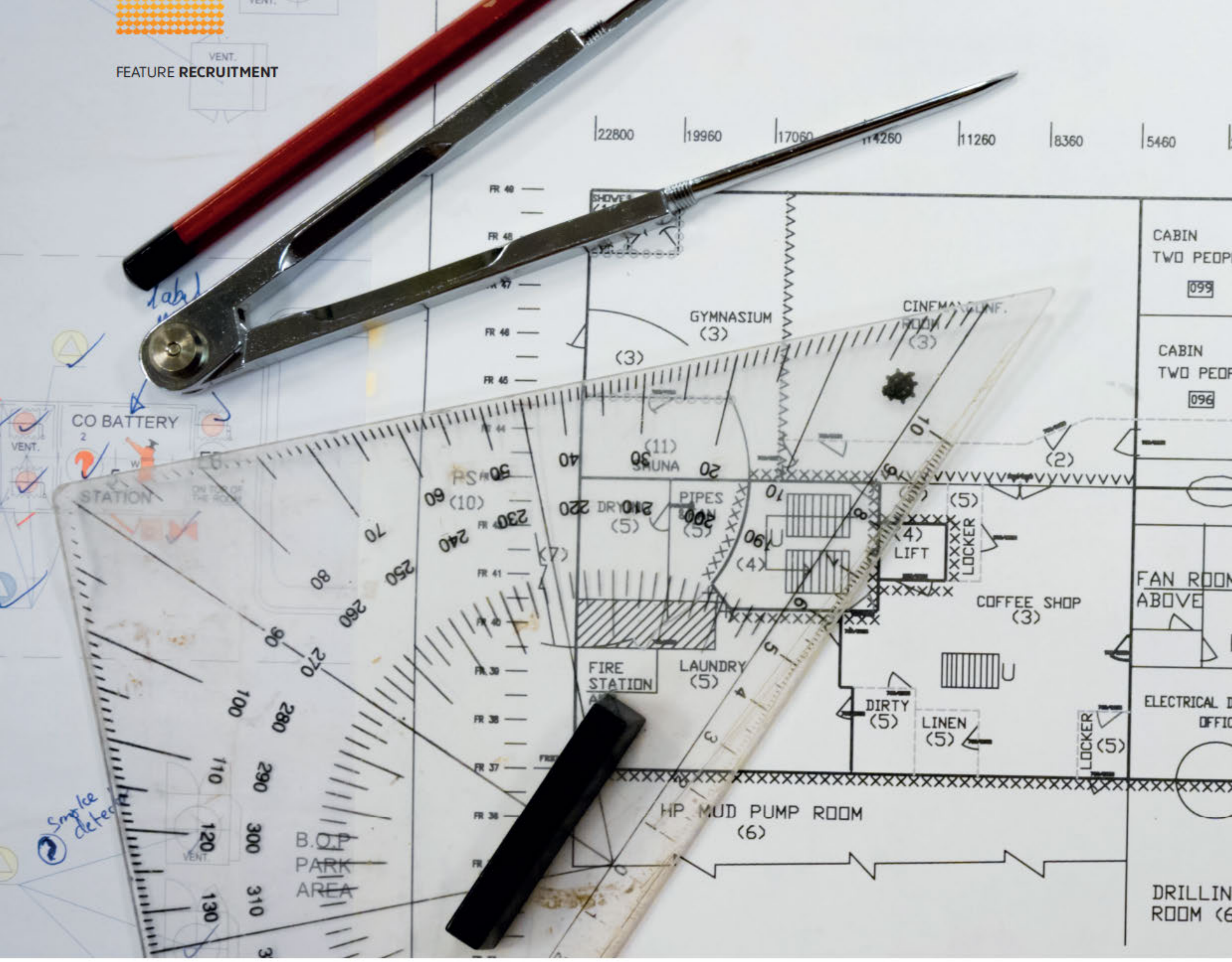
presenting work in progress. This has hopefully encouraged those and future authors to look forward to IMDC 2024 and for the IMDC ship design community to prepare for the next in this friendly and involved association of those committed to an open and fruitful exchange of views on ship design practice and ongoing related research.

As is customary at the conference dinner, the chair of the IMDC International Committee announced the venue for the next (15th) IMDC. This is to be hosted by the maritime group at the Technical University (TU) of Delft in the Netherlands and to be in June 2024. This is only two years after the 14th IMDC but gets the run of IMD Conferences back to the tri-annual intent for the future. Professor Hans Hopman, head of the maritime group at TU Delft, gave a video presentation on the delights of Delft and its region. In addition, David Andrews announced that Prof. Stein Ove Erikstad, head of marine systems at the National Technical University of Norway at Trondheim, would succeed him as the international chair. All being well, Prof. Erikstad and the team at TU Delft will enjoy a less disruptive run up to IMDC 2024. ■

TABLE 1: RECENT PHD SCHOLARSHIPS RELATED TO MARINE SYSTEMS DESIGN

Name	Title	Design strategy	Keywords
Etienne Duchateau 2016	Interactive evolutionary concept exploration in preliminary ship design	Set, Con (Opt)	3D arrangement concept exploration
Francesco Baldi, 2016 (Chalmers)	Modelling, analysis and optimisation of ship energy systems	SysB	onboard energy systems
Ian Matthew Purton, 2016 (UCL)	Concept exploration for a novel submarine concept using innovative computer-based research approaches and tools	Set, Con	submarine design
Ties van Bruinessen, 2016 (TU Delft)	Towards controlled innovation of complex objects. A sociotechnical approach to describing ship design	Sys	innovation management
Peter de Vos, 2018 (TU Delft)	On early-stage design of vital distribution systems on board ships	Opt, Sys, Con	system topology
Dorian Brefort, 2018 (Michigan)	Managing epistemic uncertainty in design models through Type-2 fuzzy logic multidisciplinary optimization	Opt, Set	optimization under uncertainty
Carl Fredrik Rehn, 2018 (NTNU)	Ship design under uncertainty	Set, Sys	design for flexibility
Minjoo Choi, 2018 (NTNU)	Modular adaptable ship design for handling uncertainty in the future operating context	Con, Opt	design for flexibility, modularity
Sigurd Solheim Pettersen, 2018 (NTNU)	Resilience by latent capabilities in marine systems	Sys	latent capabilities
Syavash Esbati, 2018 (UCL)	Design for support in the initial design of naval combatants	Set, Con	3D arrangement, -ilities
Endre Sandvik, 2019 (NTNU)	Sea passage scenario simulation for ship system performance evaluation	SysB	simulation of operations
Nikoletta Trivyza, 2019 (Strathclyde)	Decision support method for ship energy systems synthesis with environmental and economic sustainability objectives	Opt, Con	decarbonization
Alexandros Priftis, 2019 (Strathclyde)	Multi-objective robust early stage ship design optimization under uncertainty	Opt	optimization under uncertainty
Etienne Gernez, 2019 (Oslo)	Human-centered, collaborative, field-driven ship design: implementing field studies for the design of ships in operation		UX design
Nikolaos Kouriampalis, 2019 (UCL)	Applying queueing theory and architecturally-oriented early stage ship design to the concept of a vessel deploying a fleet of uninhabited vehicles	Set, Con	fleet design
Linying Chen, 2019 (TU Delft)	Cooperative multi-vessel systems for waterborne transport	Sys	logistics

Michael Sypaniewski, 2019 (Michigan)	A novel analysis framework for evaluating predisposition of design solutions through the creation of hereditary-amelioration networks derived from the dynamics within an evolutionary optimizer	Opt, Set	design methodology
Lauren Claus, 2019 (Michigan)	Design space covering for uncertainty: exploration of a new methodology for decision making in early stage design	Opt, Set	optimization under uncertainty
Conner Goodrum, 2020 (Michigan)	Conceptually robust knowledge generation in early stage complex design	Set	knowledge-based design
Helong Wang, 2020 (Chalmers)	Development of voyage optimization algorithms for sustainable shipping and their impact to ship design	Opt	simulation
Wo Peng, 2020 (UCL)	Decarbonising coastal shipping using fuel cells and batteries	Sys	decarbonization
Jose Jorge Garcia Agis, 2020 (NTNU)	Effectiveness in decision-making in ship design under uncertainty		design process management
Fang Li, 2020 (Aalto)	Numerical simulation of ship performance in level ice: evaluation, framework and modelling	Sys	simulation
Agnieta Habben Jansen, 2020 (TU Delft)	A Markov-based vulnerability assessment of distributed ship systems in the early design stage	Set	vulnerability of distributed systems
Fabian Tillig, 2020 (Chalmers)	Simulation model of a ship's energy performance and transportation costs	SysB	simulation of operations, decarbonization
John Marius Hegseth, 2021 (NTNU)	Efficient modelling and design optimization of large floating wind turbines	Opt, Con	floating wind turbines
Carmen Kooij, 2021 (TU Delft)	Towards unmanned cargo ships: A task based design process to identify economically viable low and unmanned ship concepts	Sys	autonomous ships
Aleksandr Kondratenko, 2022 (Aalto)	Goal-based optimization in Arctic offshore support vessel design and fleet composition	Opt	arctic
Marjo Keiramo, 2021 (Aalto)	Pathways of the creative journey – the significance of a cruise ship concept design		UX design
Samantha Taylordean, 2021 (Michigan)	A novel framework utilizing Bayesian networks structured as logical syllogisms to determine sufficiency of early stage ship design knowledge queries	Set	design methodology
Mark Allen Parsons, 2021 (Virginia)	Network-based naval ship distributed system design and mission effectiveness using dynamic architecture flow optimization	Opt	distributed system design
Ali Ebrahimi, 2021 (NTNU)	Handling ship design complexity to enhance competitiveness in ship design	Sys	design process management
Hao Yuan, 2021 (Michigan)	Early-stage ship design operational considerations as a thin abstraction enabled by a grid-supported Markov decision process directional decision ensemble framework	Set	simulation of operations
Muhammad Hary Mukti, 2022 (UCL)	A network-based design synthesis of distributed ship services systems for a non nuclear powered submarine in early stage design	Set, Con, Opt	distributed systems design



RECRUITMENT

NAVAL ARCHITECTURE EMPLOYMENT REVIEW 2022

By **Mark Charman**, chairman, Fastream Recruitment Group

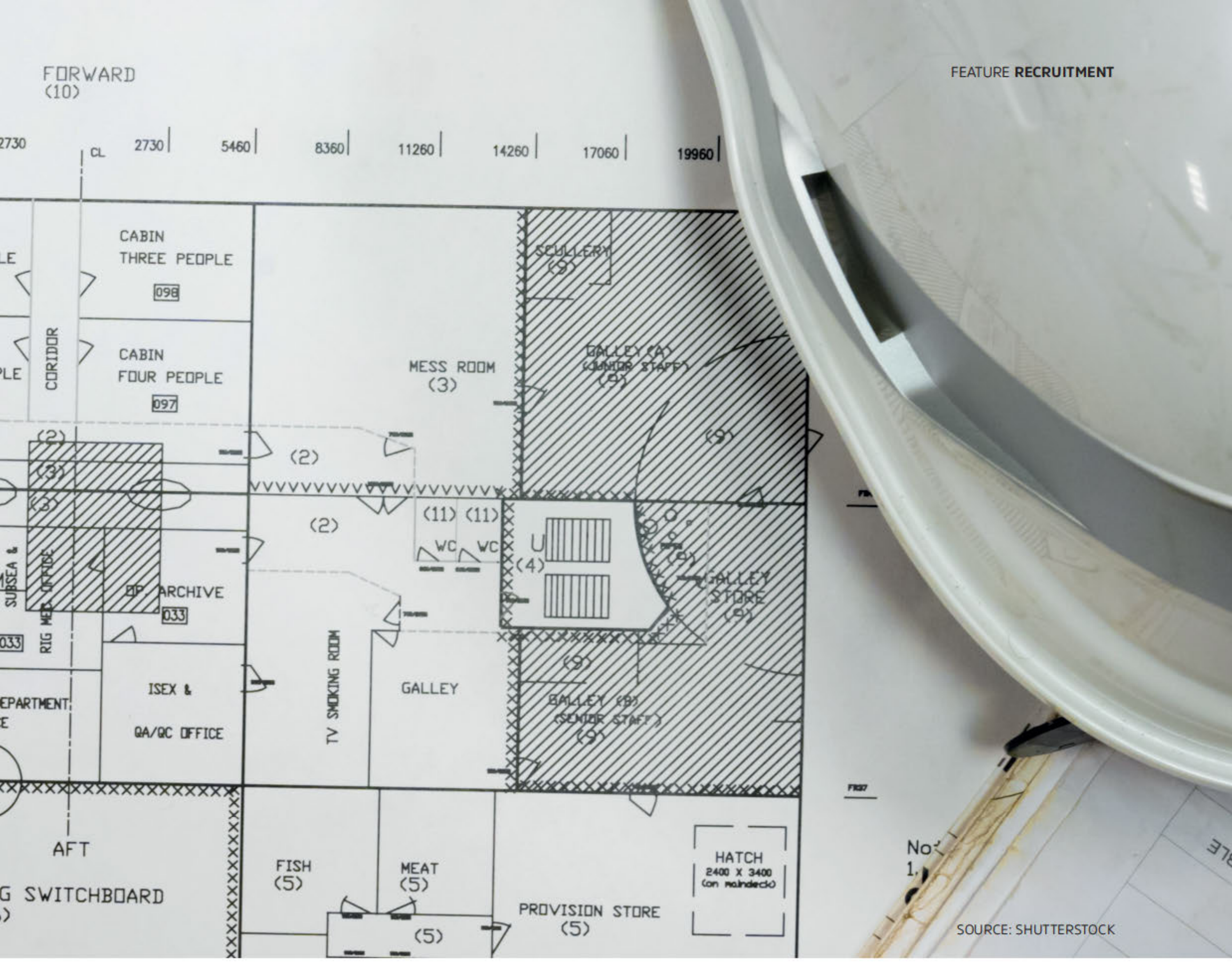
During the summer, Faststream Recruitment conducted an extensive, global survey and connected with thousands of naval architects and marine engineers to gain a unique insight into their views, opinions, and feelings about the future of employment. This report aims to uncover the good and bad of the profession, looking at it from an employee's point of view.

All change with naval architects

The retention and attraction of new talent are a priority for many businesses but our survey revealed that there is still work to do to achieve this goal. Over 70% of naval architects confided that they are planning to look for a new job in the next 12 months. An increase since our 2021 global survey, where just over half were planning to change jobs. Over 80% would also relocate to another country for a new opportunity.

Why are we witnessing such a significant increase in job-seeking this year? The top motivations were better salary and benefits (34%), career progression (30%), and better work-life balance (21%). This is a significant shift since our 2021 survey, where career progression was rated top.

With experienced professionals in high demand, people in this profession know their worth. Retaining employees is a key priority for businesses at present and offering competitive salaries and benefits, flexibility, and progression opportunities will be a huge driving factor in this.



SOURCE: SHUTTERSTOCK

What about the 28% of respondents who are not planning to change jobs (only 1% said they were retiring) in the next 12 months? The top motivations to stay put were work-life balance (35%), followed by company culture and values (18%), along with salary and benefits (16%).

Noteworthy was that 74% of naval architects stated that a loyalty or financial incentive would encourage them to stay in their job for longer. However, 73% of respondents stated that their employer does not offer a loyalty bonus or financial incentive directly linked to their length of service. If loyalty bonuses and financial incentives have the potential to increase retention, we were surprised that so few employers offered them.

MARK CHARMAN

A new shift in prioritisation of employee benefits

In 2022, bonus (61%), private medical (44%), and flexi-time (38%) lead the way as the three most important benefits. Flexi-time was the most important benefit in 2021 and remains integral today. We were interested to see that bonuses have become the priority, particularly as salary and benefits were also the top reason for changing jobs this year.

Although financial reward seems to be a key priority for naval architects, 77% said work-life balance was more important to than salary when we asked them to choose. What does work-life balance mean to them? The top answers were flexible working hours (79%), sufficient holiday entitlement (57%) and working from home (52%).

Are employers offering enough employee benefits? 62% of respondents said no. Over half stated that since the Covid-19 pandemic, their desire for benefits had changed. A naval architect in the Asia-Pacific reemphasised this: "I have never thought of working from home but after Covid, I feel working from home provides us with better life balance."

Will we see reward and benefits increasing, decreasing, or staying the same over the next two years? Fifty seven percent stated they saw it either staying the same or decreasing. Failing to increase reward and benefits could negatively impact businesses as the majority of respondents stated they will change jobs this year for this very reason.

Developing and investing in your people can make you stand out as an employer of choice

Career progression and development remain important to naval architects. Eighty seven percent stated that they were either very important or important to them. However, 47% of respondents said that they did not receive regular progression or development reviews with their employer.

Less than half of the naval architects we surveyed felt their employer invested in them. We asked those who felt their employer was investing in them what the key indicators were. They cited the opportunity to manage projects, training and continuous professional development, receiving constructive feedback and the opportunity to manage people.

Company culture, values and D&I have never been more paramount

Company culture and values have widely become more important across the globe. It is a key attraction factor and helps businesses with retention and growth. Expectedly, 70% of respondents agreed that they would not take a job with a company if they did not align with their values. We have never conducted a survey where company culture and values have been so prevalent in retention and attraction.

Business purpose is also important. 87% of respondents agreed that the purpose of an employer matters to them.

With equality, diversity and inclusion, such an important part of retention and attraction as well as a global issue, we were shocked that when we asked respondents if their employer had an equality, diversity and inclusion statement, 25% of respondents said no and a further quarter did not know.

Are employers doing enough to address equality, diversity, and inclusion? Sixty seven percent of naval architects agreed that they were, but this still highlights a significant gap. Eighty eight percent also said that equality, diversity, and inclusion were either very important or important to them, an increase from 82% last year.

Company culture and people are the foundations of any business. It has never been more crucial for businesses to address their culture and values and provide a safe and inclusive working environment.

Naval architects want more flexibility

With work-life balance a high priority for naval architects, the debate around working styles continues. The pandemic created a shift from traditional office to remote working. Since our last survey, we have seen another change. More respondents this year stated that they were working in a hybrid style, a mix between office working and remote working (45%). Many have gone back to the office full-time (42%), which is almost double the percentage in 2021.

Naval architects working remotely full-time has also decreased tremendously since 2021 from 44% in 2021 to 13% today.

With businesses getting back to normality, an increase in office working is inevitable but how do naval architects want to work? Only 16% want to work in the office full time, whilst 14% want to work remotely and 70% in a hybrid style.

One third of respondents told us that their employer did not offer any type of remote work, whether on a part-time or full-time basis. Do naval architects think all businesses should offer remote working? 62% agreed that they should. 36% would even turn down a job offer if they did not offer it and almost half would do the same if they did not offer flexible working hours.

It is integral that businesses recognise the demands for flexible hours and remote working. Work-life balance has become increasingly important. Hybrid working and flexibility are great solutions to this.

About the author

Mark is the founder and CEO of Faststream Recruitment Group and Faststream Executive Search. With over 25 years working in specialist recruitment, he regularly speaks on the subject of maritime employment and future talent issues that the sector faces globally and has become a thought leader in recruitment within the industry. He is also a Fellow of the Recruitment and Employment Confederation and advises companies on recruitment matters.

About Faststream Recruitment

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CFD & HYDRODYNAMICS

A PROACTIVE APPROACH TO FOULING RISK HELPS TO ENHANCE PERFORMANCE

By **Daniel Johnson**

Hull fouling and its negative impact on hydrodynamic performance is one of the most common reasons for vessel underperformance. Algae, barnacles and other organisms add significant frictional resistance, leading to speed loss. To compensate for this, and to keep up with sailing schedules, vessels are forced to increase power, which also results in an increase in fuel consumption and carbon emissions – according to the IMO's Fourth Greenhouse Gas Study, of the 919 million tonnes of CO_2 emitted annually by shipping, 9%, or 83 million tonnes, is entirely due to biofouling loading of ships.

"It creates obvious financial ramifications, environmental impact, and difficulties in terms of regulatory compliance. In short, a dirty hull is bad news for everyone," according to Stein Kjølberg, global category director, hull performance, at coatings specialist Jotun.

Given that shipowners and operators currently face a battle on two fronts, with the growing pressure to comply with ever more stringent legislation matched by a dramatic increase in fuel prices and a need to control costs and enhance efficiency, a clean hull should be considered a relatively 'low-hanging fruit' when looking to simplify compliance while also achieving bottom-line benefits. However, although coating manufacturers have developed antifouling coatings for almost all eventualities, as yet there isn't one that would be considered ideal for every permutation of factors.

"If you have a coating on the hull that is perfectly specified to your vessel and the vessel trades exactly as you planned when you coat it, it's not an issue. The coating will handle it," says Maria Archimandriti, marketing manager, Western Europe, Jotun. "But in this day and age, it's a fluctuating market. Suddenly a vessel has to stay idle for a few days more than expected or sails in different waters than expected. That's when you need someone to monitor the vessel and predict if it is now at risk, or not."

Jotun's new proactive hull optimisation service has been designed to do just that. Having been tested by a selected number of ship operators, the HullKeeper programme was rolled out to the global market this summer.

"It gives operators full control of their vessels' hulls and gives them the necessary tools to improve efficiency, lower costs and help with their decarbonisation targets," Archimandriti tells *The Naval Architect*.

HullKeeper combines Jotun's analytical and technical services with digital capability and ROV inspections. The programme offers customised monitoring of hull performance and fouling pressure by combining and processing data from different sources, which is used to build an operational profile of the vessel.

FOULING GROWTH ADDS SIGNIFICANT FRICTIONAL RESISTANCE TO VESSELS, RESULTING IN POOR ENERGY EFFICIENCY AND HIGHER CARBON EMISSIONS. SOURCE: GLOFOULING/IMO

"What we are doing here is gathering information on the vessel, where it sails, when it stays idle and what are the oceanographic factors in the water where it sails," explains Archimandriti.

Fouling alert

The service then determines if a vessel has been exposed to a certain fouling risk. This is done by means of Jotun's in-house developed fouling risk algorithm. If the fouling risk is considered as warranting investigation, an underwater inspection using an ROV will be recommended. Based upon the video of the hull condition, which can be transferred almost instantaneously, Jotun specialists can use their expertise and prepare an in-depth report to the operator.

"Because the fouling risk is being constantly monitored, a need for future action should be determined well before the fouling becomes a major problem," says Archimandriti.

Included in HullKeeper is an advisory service that can be used to determine what action is needed and when and where it can be arranged.

"Jotun's extensive experience has proven that maintaining the hull in as clean a condition as possible avoids increased fuel costs and reduces emissions. HullKeeper gives users a competitive edge by identifying potential problems early, before they significantly impact on ship performance and profitability," concludes Archimandriti.

THE ROLE OF THE HULL MODEL FOR A DIGITAL TWIN

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Digital Twins play an increasingly important role in the maritime industry: during design, production and operation of ships and other assets, they offer a large potential to improve the 'product' in terms of (i) better understand the performance of the asset, (ii) study possible ways of improving it and (iii) predict and optimise operational behaviour (e.g. with regard to scheduling maintenance, avoiding failure and improving energy efficiency).

Due to the large number of different onboard components and systems typically found in modern ships, there is generally no unified, all-encompassing Digital Twin (DT) at hand for maritime assets. However, specific DTs are already employed, at least at (sub-) system level. One common bottleneck for a ship's operator is that often important information that would be required to develop more complete DTs are not available to them.

One such element is the mathematical definition of the ship's hull form, its appendages and the propulsion system. This is understandable since a lot of intellectual property rights (IPR) and competitive advantage are associated with these shapes. On the other hand these are typically responsible for 80% or more of the energy consumption during operation – and hence, for green-house gas emissions and operating costs. Consequently, the optimisation of operational performance is often based on incomplete data such as the description of the hull form on the basis of a few global parameters only, e.g. main dimensions, and thus lacks accuracy.

As part of the overall objective to devise a comprehensive system of technologies to improve ship energy management, the German R&D project MariData (https://maridata.org) considers such accuracy aspects. These are demonstrated using one of the project's target vessels, a 183m (Loa) tanker (called CBT) operated by Carl Büttner Shipmanagement (see Fig.1) which was built in 2019 after thorough form optimisation over a given operational profile. The hull features an asymmetric stern, the propulsion system a tip rake propeller and the rudder a Costa bulb.

This vessel has been reengineered at different levels of accuracy using suitable parametric models within CAESES® (Harries *et al.* 2015). The resulting approximated hull forms are analysed using a range of hydrodynamic tools and results are compared with former model test data.

FIG.1: CB ADRIATIC (OIL-CHEMICAL TANKER, IMO 9851696), OPERATED BY CARL BÜTTNER SHIPMANAGEMENT

The hull as part of the Digital Twin

While the project's overall aim is to devise a DT to analyse and optimise the energy consumption of ships during operation in a large range of different conditions, the geometry defining the resistance and propulsive characteristics of the ship is a very important starting point to obtain accurate results. In general, a wide range of representations can be considered. For the present purpose three different levels have been identified and used throughout the study: Level 1 – using the ship type and main dimensions as input for an (existing) automatic parameter model; Level 1.5 – a parametrically remodelled hull in an automatic procedure using additional detailed input data, e.g. the loading manual or dock plans; Level 2 – a hullform remodelled interactively using a parametric model plus dedicated geometry data, e.g. from 2-D drawings. The effort for the generation of such levels varies considerably from a few seconds for level 1 to a couple of hours for Level 2.

Often it is neither obvious what level of geometric accuracy is actually needed for which type of analysis, nor which level of geometric representation yields an acceptable level of certainty of the performance analysis. Although not conclusive, a first example based on the tanker case tries to explain what can be considered a 'suitable' remodelling approach. Fig.2 illustrates what can be achieved in terms of accuracy, e.g. of a power prediction (green bar on the right) depending on the level (and effort) of the geometry modelling.

It is apparent that improved inputs do not necessarily comply with an improved quality of results. Overall there will be a dependency on ship type and operational conditions as will be shown in the following. In the

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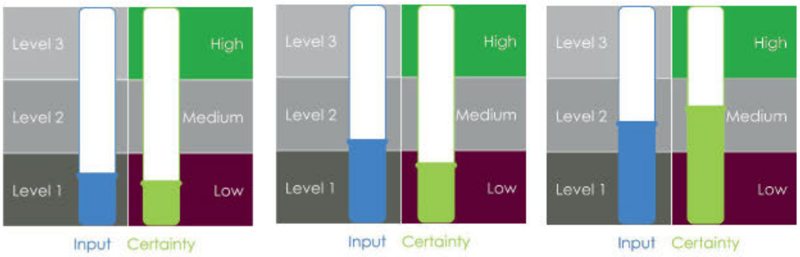


A) LEVEL 1 HULL (B) LEVEL 1.5 HULL (C) 4H-MODEL (LEVEL 2 HULL)

FIG.2: AMBIGUITY OF VARIOUS LEVELS OF INPUT LEADING TO DIFFERENT APPROXIMATION LEVELS OF GEOMETRY AND ACHIEVED CERTAINTY WITH REGARD TO THE ACCURACY OF HYDRODYNAMIC PREDICTIONS

present paper only three levels described above shall be considered. They follow design considerations as introduced by Tillig *et al.* (2017, 2018). Note that a Level 0 representation would not even feature any actual shape and, hence, no remodelling needs to take place. Furthermore, no Level 3 has been studied so far as this would call for operational data to be considered. Finally, it should not be forgotten that there possibly are non-negligible differences between the hull as model-tested and the ship hull as built at full scale.

Within the MariData project the CBT was reengineered at different levels of accuracy on the basis of suitable parametric models within CAESES®. An elaborated description of the approach and findings can be found in Harries *et al.* (2022). Different hull form approximations are hydrodynamically analysed by means of HSVA's database of model tests for similar vessels and high-fidelity CFD simulations. They are systematically compared and benchmarked against full scale predictions based on model tests for the actual geometry as designed.

The benchmark for geometry and hydrodynamics is the model as originally tested at HSVA on behalf of the design office. Here, a very close fit between the digital representation and the large model is attained. According to ITTC Recommended Procedures and Guidelines 7.5-01-01-01 model tolerances should be within ±1mm for beam and draught and max. 0.05% LPP for the length of a model. Based on a thorough inspection procedure for the manufacturing of scale models, HSVA can typically ensure a higher accuracy (i.e., less than 1mm) for its models in all three dimensions. Based on the model scale of 26.6 this yields a rather low value of ± 0.026m for the maximum deviation at full scale. This hull is shown in Fig.3, items 1 and 2.

The Level 1 hull shown in Fig.3.3 is based on publicly available information only (Loa, BMax, T, DWT, design speed and general information, e.g. bulbous bow). Based on this, a CAD model of a suitable hull form can be created within seconds, using a sophisticated and flexible parametric model as provided by CAESES®. It is used to generate a "standard series hull" matching the given input parameters. The parametric model itself was developed by evaluating many representative hull forms. Within the model, the fore-body, the length of the parallel mid-body, the waterline fullness, bilge radius, longitudinal center of buoyancy and longitudinal center of flotation are estimated to represent a common ship

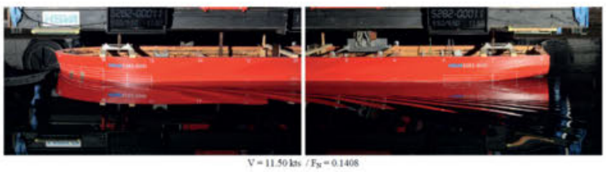


FIG.3.1: MODEL TEST OF CBT AT HSVAA

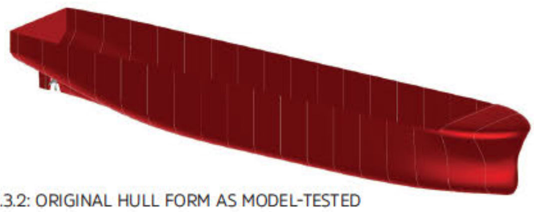


FIG.3.2: ORIGINAL HULL FORM AS MODEL-TESTED

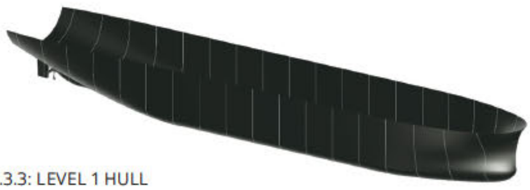


FIG.3.3: LEVEL 1 HULL

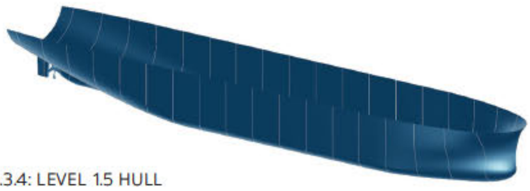


FIG.3.4: LEVEL 1.5 HULL

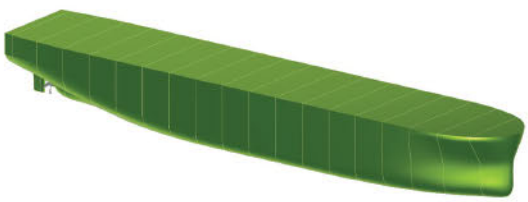


FIG.3.5: 4H-MODEL (LEVEL 2 HULL)

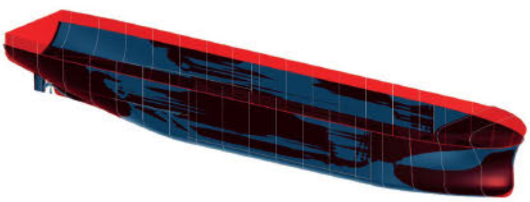


FIG.3.6: ORIGINAL (TRANSPARENT AND RED) VS. LEVEL 1.5 HULL (BLUE)

of such size and to ensure a good quality hull, i.e., a hull with a hydrodynamic performance which will be among a representative average of recently designed ships. Some parameters, for example, the sectional fullness below the waterline in the fore- and aftbody, are free for adjustment using automated optimizations to match the models hydrostatics to the desired values. Infrequent (but desirable) design features such as an asymmetric stern are not taken into account at this level.

The Level 1.5 hull is based on the same parametric model as the level 1 hull with the difference that the displacement volume V and the longitudinal centre of buoyancy XCB are set to those of the original hull so that these hydrostatics parameters are in line at design draught. This has an effect on the shape of the fore- and aft body as can be seen in Fig.3.6. The waterline and sectional fullness of the two hulls are different. However, in the present case, the differences between level 1 and the level 1.5 are small, since the estimated displacement and centre of buoyancy were already pretty close to the original values.

A Level 2 hull can be developed if more detailed geometry information is available such as a general arrangement plan (GA), a loading manual (stability book), a model-test report etc. In most of these documents some drawings and valuable information about the geometry can be found, often as planar curves which can be used to remodel (parts of) the ship hull. In CAESES® a second flexible parametric model allows to adjust the geometry to a handful of sections and important planar curves such as the centre plane curve (CPC), the flat-of-side (FoS) and the flat-of-bottom (FoB).

For the CBT the information was extracted from both the GA and the loading manual which were provided in digital form. Still, details such as the asymmetric stern have been neglected in the model created within the 4-hour time frame specified. Fig.3 clearly indicates the differences in geometry compared with the simpler approximations as well as the proximity to the original shape. This ensures a hull that features similar hydrostatics and hydrodynamics although it must be noted that even this model would still require more work to fully match the original (then approaching Level 3).

The differences between hull forms are clearly visible when comparing the displacement. Fig.4 indicates the relative displacement volume vs. relative draught. The data are normalised by the original hull's values at the design draught of 9.5m. The average deviation between the displacement of the Level 1 hull and the original hull form is +2.7%, the average deviation of the Level 1.5 hull is lower with 0.7% while the difference between the original hull and the 4h-model are negligible as expected.

It must however be noted that the figures mentioned above are valid for the design draught, while deviations for other floating conditions, especially for the lower level approximations, can be much higher. This holds also for other parameters such as the wetted surface of the hull which determines the frictional resistance or the initial stability.

Representations of the propeller and rudder

Propeller and rudder are important elements influencing the hydrodynamic performance. For a fast remodelling of an equivalent propeller (level 1) the webApp – https://www.wageningen-b-series-propeller.com – as introduced by Harries *et al.* (2018), can be used. This requires only a very limited, typical set of input data. Fig.5 shows the propeller generated from FRIENDSHIP SYSTEMS' openly accessible Wageningen webApp. The aft ship is the symmetric version of the level 1 hull.

The actual propeller of the CBT was developed by experts from a large engine manufacturer and thoroughly studied in a model-test campaign. It is a high-efficiency tip-rake propeller adapted to the tanker's wake field. Due to reasons of confidentiality and protection of IPR it cannot be shown here. For the MariData project this propeller has been closely fitted within CAESES on the basis of an independently developed fully-parametric model dedicated to these specialised propeller types. This can be viewed as a representative example in which modelling

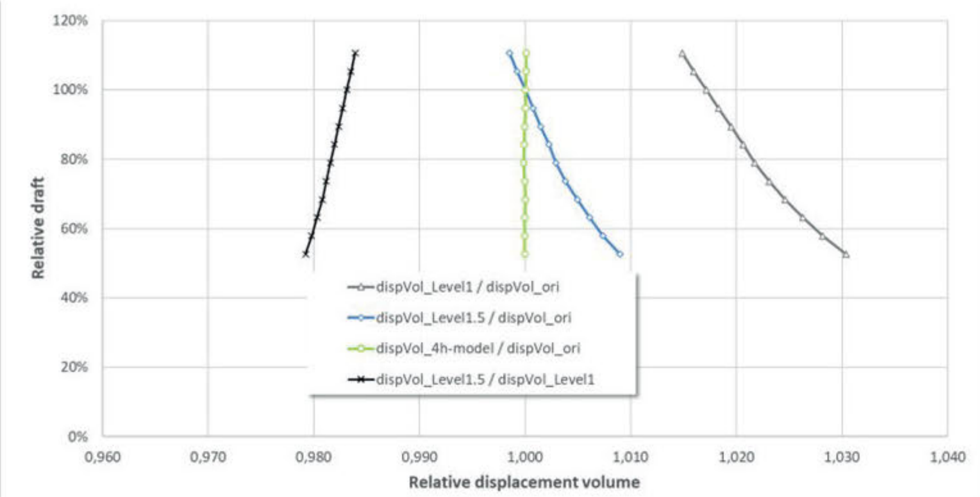


FIG.4: RELATIVE DISPLACEMENT VOLUME (ABSCISSA) VS. RELATIVE DRAFT (ORDINATE), I.E., DRAFT OVER DESIGN DRAFT, BETWEEN APPROXIMATING MODELS OF DIFFERENT LEVELS AND ORIGINAL HULL FORM

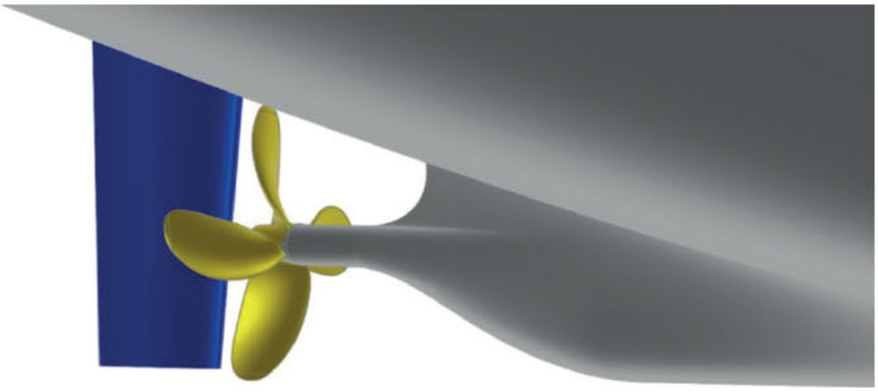


FIG.5: LEVEL 1 REMODELING FOR AFTSHIP, PROPELLER (WAGENINGEN) AND RUDDER (AS NEEDED FOR CFD) (HIGHER LEVELS OF REMODELING CANNOT BE SHOWN HERE DUE TO CONFIDENTIALITY CONSTRAINTS)

skills and very advanced CAD functionality were brought together to achieve a very high quality of representation and accuracy of computational results. The model used in the present comparisons however is much simpler.

The rudder of the ship was also re-generated using a flexible parametric model in CAESES which allows the creation of different topologies, the use of different rudder profiles as well as including a range of energy saving devices such as rudder bulbs.

Hydrodynamic analyses and comparison between model tests and simulations

A comprehensive hydrodynamic analysis was performed using HSVA's in-house CFD code FreSCo+, run for the appended hulls at full scale. Mesh sizes for the different simulations vary between 6.2 and 10.1 million cells. The process followed HSVA's best practice guidelines for resistance and propulsion computations. The free surface is considered, and the ship is free to dynamically sink and trim. Fig.6 compares delivered power PD from full scale predictions based on model tests and RANS simulations at scantling draught with minimum, mean and maximum PD from HSVA's comprehensive database of similar vessels. The CFD simulations (for the original vessel) agree well with model test data underpinning the validity of the FreSCo+ predictions which are used to compare the different approximations of the hull forms. It must be noted that for reasons of IPR protection only normalised data will be presented in the following.

Propulsion performance at full scale

In the following the CFD results for different approximation levels are compared with those for the original hull, Fig.7 and Fig.8. The pressure distributions for the scantling draught as well as for the ballast condition are shown for the original hull, the level 1 hull and level 2 hull (4h-model). Differences in the pressure distribution, especially between original and level 1 approximation are clearly visible, in particular for the ballast condition while original and level 2 appear to be closer.

Wave patterns show a similar behaviour. While original and level 1 do not match closely in terms of size and structure, the differences between original and level 2 are significantly smaller.

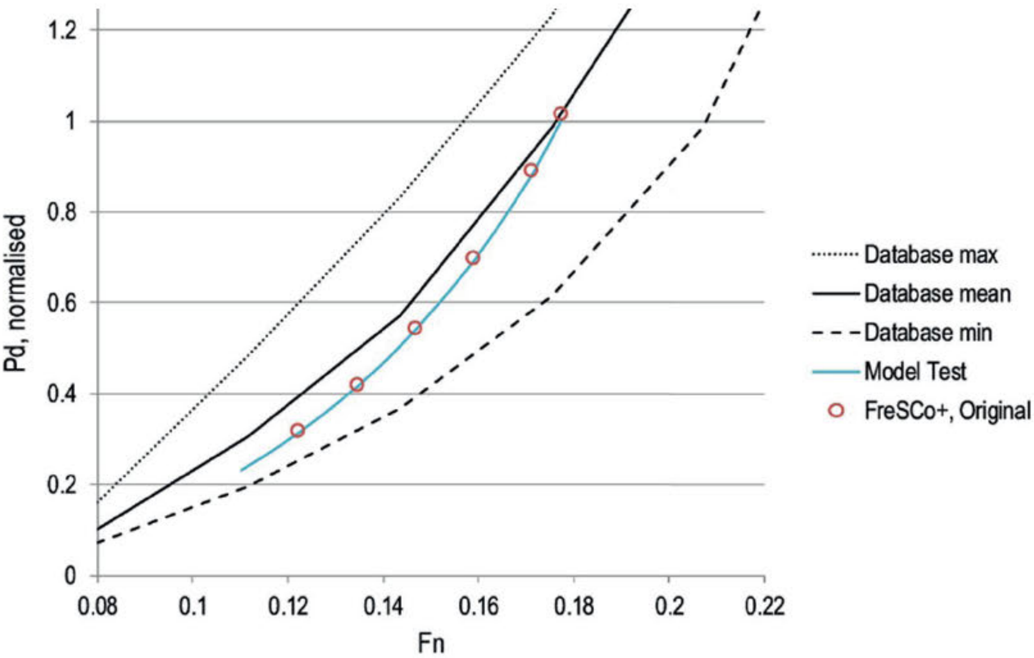
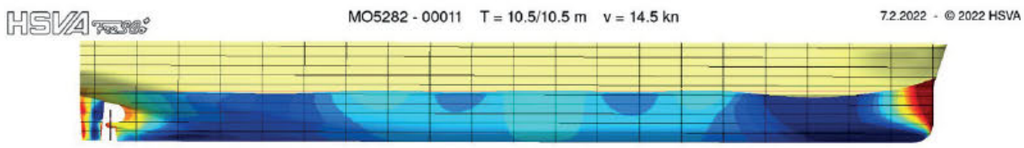
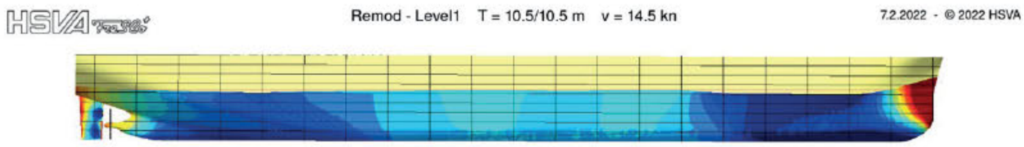


FIG.6: POWER DELIVERED PD FROM FULL SCALE PREDICTIONS BASED ON MODEL TESTS, CFD SIMULATIONS ALONG WITH RANGE FROM HSVA'S COMPREHENSIVE DATABASE

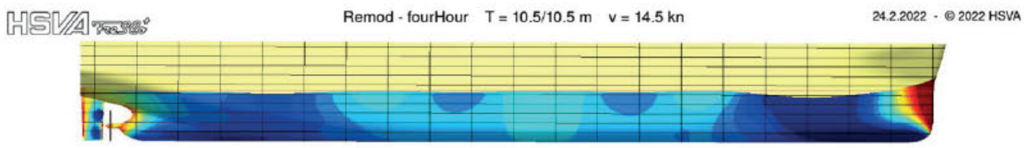
FIG.7.1-3: PRESSURE DISTRIBUTIONS ON DIFFERENT HULLS AT SCANTLING DRAFT AND DESIGN SPEED



(A) ORIGINAL HULL

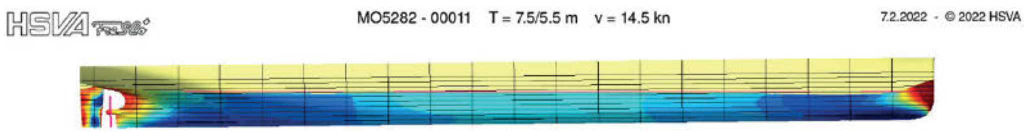


(B) LEVEL 1 HULL

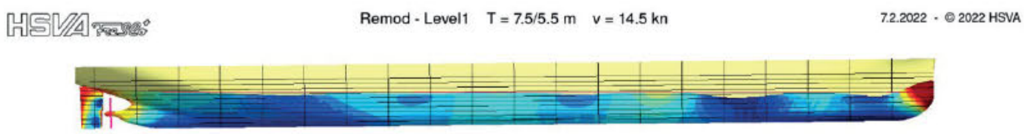


(C) 4H-MODEL

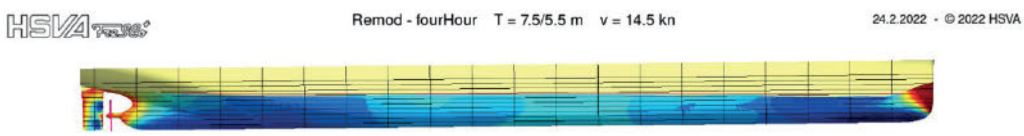
FIG.8.1.-3: PRESSURE DISTRIBUTIONS ON DIFFERENT HULLS AT BALLAST DRAFT AND DESIGN SPEED



(A) ORIGINAL HULL



(B) LEVEL 1 HULL

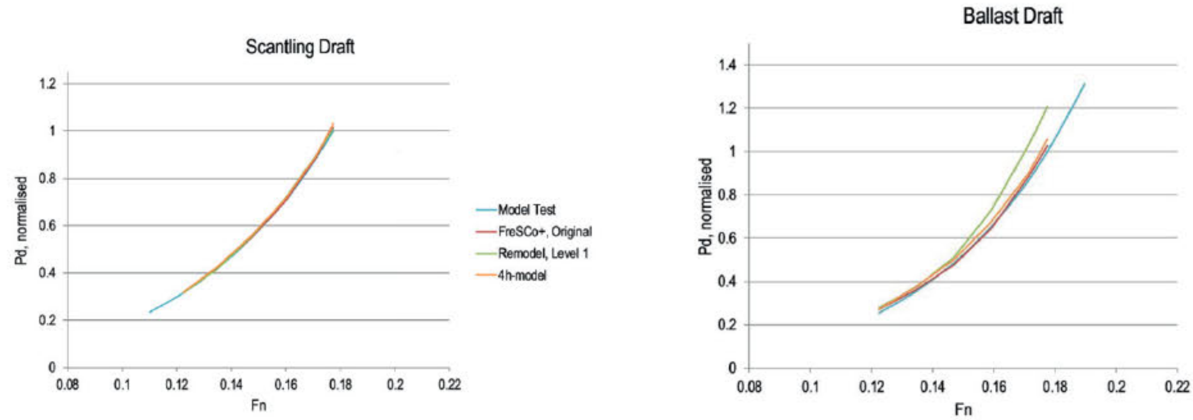


(C) 4H-MODEL

As expected, the three hull forms used differ in hydrodynamic performance. While the differences in PD are in the order of 2 – 3% at design draught, see Fig.9.1, they become quite significant at ballast draught (Fig.9.2). Here deviations reach 15% for the level 1 hull, while the level 2 model shows a maximum deviation of 5% compared to the original hull.

When predicting the performance of a hull it is crucial to also estimate the expected accuracy. According to Tillig *et al.* (2018) the total uncertainty can be subdivided into method and design uncertainties. Using the same analysis method for all cases, the uncertainty in the present case is reduced to the design uncertainty, i.e., the uncertainty associated with the fact that any approximating hull will necessarily be different from the original. A comprehensive analysis using a parametric variation of hulls that maintains all primary inputs provides for a statistical analysis which has been performed for the level 1.5 hull. Due to the large computational effort required, only a resistance analysis has been performed. Results are shown in Fig.10. This indicates that more hulls are produced with higher resistance than hulls featuring lower resistance. The mean value of the resistance of all hulls is about 2% higher than the level 1.5 hull while the best variant sports a 3% lower resistance

Disregarding the worst hulls, the standard deviation would be below 2% in this case. However, differences in propulsive efficiency have been neglected and must be included in a full uncertainty analysis in the next phase. It is expected that the level of uncertainty will increase.



(A) SPEED-POWER CURVES AT SCANTLING DRAFT

(B) SPEED-POWER CURVES AT BALLAST DRAFT

FIG.9: SPEED-POWER CURVES

Conclusions and outlook

Given the overall maritime objective to reduce energy consumption and cut emissions, it is evident that accurate information is required for decision making and optimisation. This holds particularly for hydrodynamic effects which are typically responsible for more than 80% of the energy consumed by a merchant vessel. As hydrodynamics depend mainly on the geometrical features of a hull, the knowledge of the hull form is vital. If this is not known, a number of concepts to estimate or re-model the geometry are available.

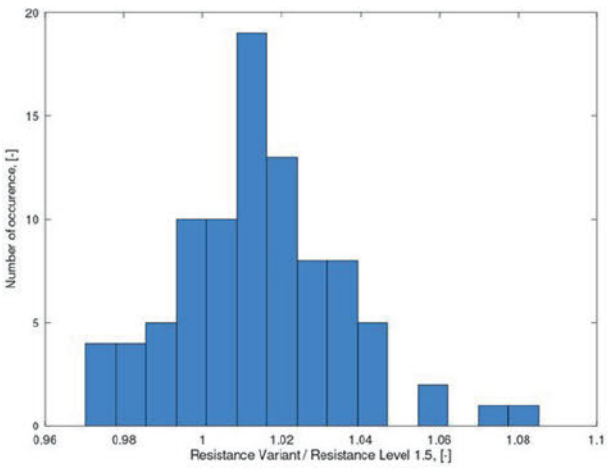


FIG.10: STATISTICAL ANALYSIS OF RESISTANCE FOR VARIATIONS OF THE LEVEL 1.5 HULL

The present paper discusses techniques of remodelling geometry at different levels to provide geometric twins of the ship and provides a first insight into what level of remodelling is required and how to achieve it economically. Results shown indicate that low level models fail to reach an appropriate accuracy while better approximations of the hull geometry vary in quality depending on operational conditions. Although reasonable for design conditions, the quality of results for the ballast draught of the tanker clearly indicates the need for higher level approximations.

In a next step the parametric models used for Level 2 shall be streamlined for faster modelling and the analysis shall be extended to the influence of realistic sea states. Finally, the results shown for the analysis of one specific tanker need further extension to other ship types to make them more general.

Acknowledgements

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A JOURNEY TO UNIQUE PIV FLOW MEASUREMENTS AT SHIP SCALE

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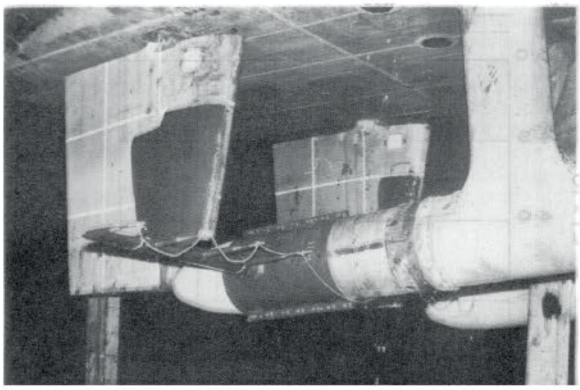
It may sound surprising, but in the 21st century humanity knows a lot about space and the universe, but there is almost no data on water flowing into the propeller of an ordinary ship. All the knowledge available currently is either based on model test experiments (with seriously challenged assumptions) or yet-to-be validated numerical simulations. Up until now, there was no reliable and accurate instrument to measure the flow around a vessel. How are we then supposed to optimise the ship hull and propulsion system if we do not know the details of the flow?

With this question in mind, a group of researchers at Maritime Research Institute Netherlands (MARIN) working on the development of the JoRes Joint Industry Project (Struijk and Ponkratov, 2018) sat together in 2017 and started to think about how to tackle this challenge. If no one has done this before, it does not mean it is impossible!

It's perhaps instructive to highlight previous attempts to measure the flow around a vessel. The first and most obvious way to do this is by using the Pitot tube, invented by Henri Pitot in 1732 to measure the velocity of air or water. Essentially a differential pressure flowmeter, a Pitot tube measures two pressures: the static and the total impact pressure and are nowadays widely used on aeroplanes and in racing cars. They are also used in the maritime industry in towing tanks to measure the flow around a ship model. However, there are practical challenges to using Pitot tubes on a full-sized vessel: the risk of hitting this delicate tool with a floating object, or the risk of fouling by marine growth. Even for research purposes, the most logical scenario would be to develop a retractable Pitot tube, however, the results of these measurements would be velocity points along a line, not the two-dimensional wake field which is necessary for propeller optimisation.

However, there were a few good attempts to measure three components of velocity in the wake. One of the most remarkable cases was the resistance trials of HMS *Penelope*. Its propellers were removed, the special rake



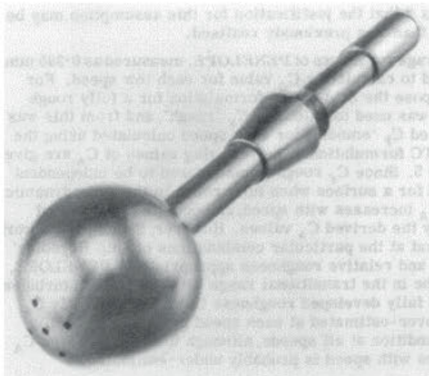


FIG. 1. (LEFT) PITOT RAKE FOR FULL SCALE WAKE SURVEY, HMS *PENELOPE*, CANHAM (1974).

FIG. 2. (RIGHT) FIVE-HOLE SPHERICAL HEADED PITOT, HMS *PENELOPE*, CANHAM (1974).

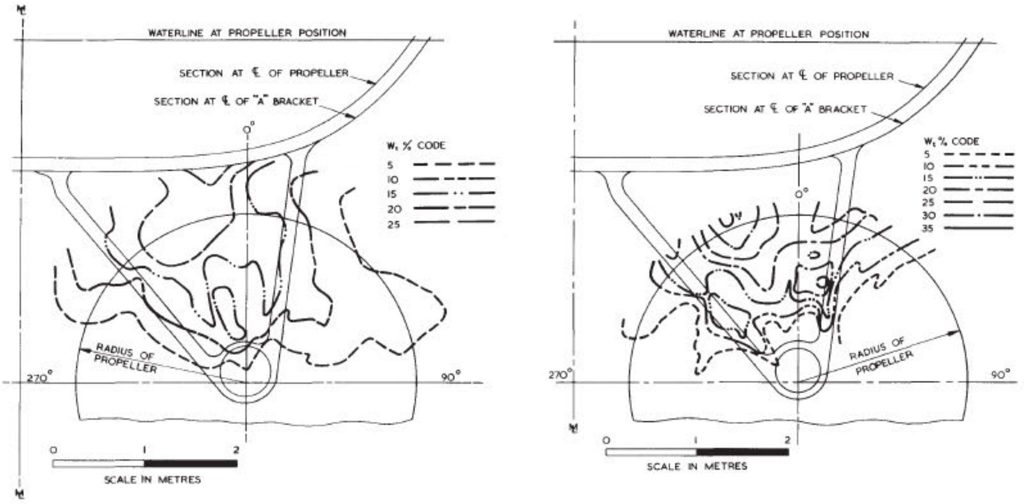


FIG. 3. WAKE PATTERN AT 17KNOTS, HMS *PENELOPE*, CANHAM (1974).
(ON THE LEFT: SHIP SCALE. ON THE RIGHT: MODEL SCALE)

with pitot tubes was installed on the shaft and she was towed by HMS *Scylla* (Canham, 1974).

The pitot rake for the wake survey is shown in Figure 1, viewed from the forward with protective covers fitted over the pitot heads. The arms of the rake carried four five-hole spherical-headed Pitot tubes for measuring tri-axial components of flow velocity and four normal axial type Pitot tubes, disposed of as follows: Pitot tubes at adjacent radii were located on opposite arms of the rake to avoid interference effects. The rake was designed to take measurements in the plane of the starboard propeller and extended beyond the radius of the propeller disc. A photograph of one of the five-hole pitot heads is reproduced in Figure 2. Some results of measured wakes at ship scale and model scale are presented in Figure 3.


FIG. 4. LDV UNIT DURING FLOW MEASUREMENTS ON THE MV *VALOVINE*, PRINS (2015).


FIG. 5. PIV MEASUREMENT SETUP INSIDE THE STEERING GEAR ROOM, MV *AMANDINE*, KLEINWÄCHTER *ET AL.* (2015).

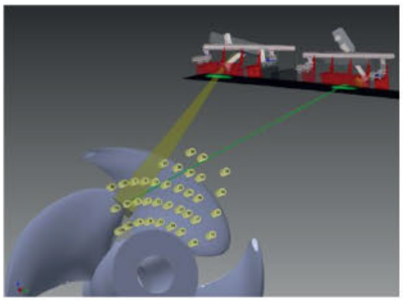


FIG. 6. VISUALISATION OF PIV MEASUREMENTS, MV *AMANDINE*, KLEINWÄCHTER *ET AL.* (2015)

Another option to measure the flow around a ship could be Laser Doppler Velocimetry (LDV), a technique that uses the Doppler shift of laser light to measure the velocity of fluid flows. This works by crossing two beams of coherent laser light. Transmitting optics focus the beams to intersect at their waists, where they interfere and generate a set of interference fringes. As particles (either naturally occurring or artificial) contained in the fluid pass through the fringes, they reflect light that is then collected by receiving optics and focused on a photodetector. The particle and thereby the fluid velocity can be determined from the Doppler shift of the light hitting the photodetector.

LDV is widely used in model tests to measure the wake field but there were comparatively few attempts to use it at ship scale. For example, MARIN attempted to measure the flow on MV *Valovine* within the GRIP EU research project in 2014 (Prins, 2015). Unfortunately, those measurements were not successful. One of the challenges was related to setting up the unit on a vessel; vibrations in the aft end of the ship (due to machinery and propeller cavitation) make intersecting the two beams very challenging. Furthermore, the data rate of LDV that measures in only one point might be limited, requiring long measurement times. Finally, intersecting one set of beams is challenging, resulting in one component of velocity; for the second component, another set of beams would need to be intersected at the same point where the first pair of beams is, increasing the complexity and likelihood of measurement failure even further.

An encouraging project measuring the propeller inflow was done in 2014 by a group of researchers (Kleinwächter et al., 2015) from the University of Rostock and the Potsdam Model Basin (SVA) using Particle Image Velocimetry (PIV). PIV is a technique that uses a strong light source (typically a laser) to illuminate particles contained in a 2D plane of the flow. The reflected light is captured by a camera, after which the particle images are analysed to determine the velocity field in the part of the flow illuminated by the laser.

The RostockUni/SVA group made a series of portholes in the aft end of a ro-ro vessel and operated a PIV system through the portholes (Fig. 5 and Fig. 6). This was likely the first successful PIV measurement at the ship scale. However, there were a few limitations that made this measurement less than ideal. For example, the limited view from the windows did not allow making a large sector scan; the measurements needed to be made in small areas that were first averaged (producing one measurement point) and then combined to form a larger flow field.

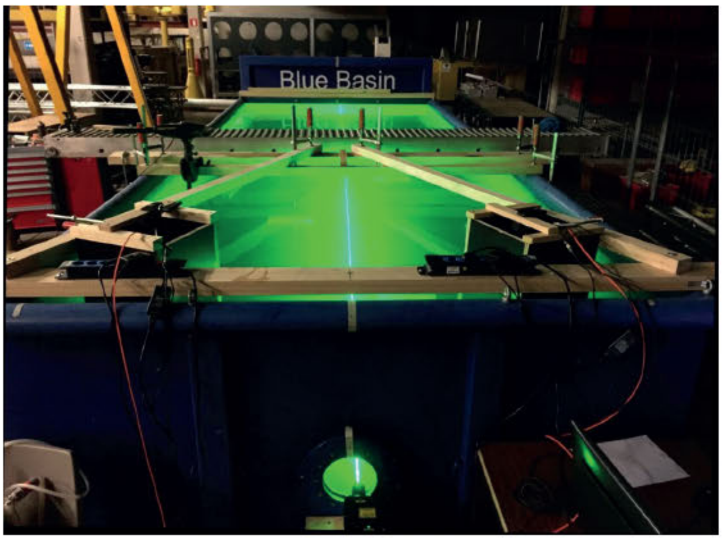


FIG. 7. PIV EXPERIMENTS WITH SEA WATER AT MARIN, 2019

Furthermore, the measurements were not done during a well-controlled sea trial (i.e. with reciprocal runs and careful measurement of all the relevant environmental conditions), making it difficult to use the results in CFD validations. Nevertheless, these measurements showed that PIV at full scale is possible which motivated us to develop our full-scale PIV system. This work was done within JoRes Joint Industry Project aiming to collect ship scale data for CFD validation and create a benchmark for energy-efficient solutions.

Laboratory tests with seawater at MARIN

The most important limitation that a researcher attempting to apply PIV at full-scale (i.e. at sea) is facing is the inability to control the 'seeding' size and concentration. PIV requires particles – seeding – in the flow which reflect laser light and whose velocity is determined as a proxy for the local flow velocity. In laboratory applications, the seeding is added by the experimenter. At sea, one would have to do with whatever is naturally present in the water, which is algae, plankton and inanimate solid particles.

To verify if the natural seeding is of the correct size and in sufficient quantity for performing PIV, MARIN performed two studies. In the first, 2D2C (two-dimensional, two-component) PIV was done at ~1 m scale in North Sea water. The water was either unfiltered or filtered to reduce the number of particles, thereby approaching the particle content of clearer oceanic waters (Atlantic, Mediterranean, Adriatic, etc.).

It was particularly important to measure the attenuation of laser light through water, thereby quantifying its transparency. This and other (visual) methods of judging water quality will be later used to decide if a full-scale PIV measurement is feasible in a certain region of the sea and in a certain season (the transparency changes due to biological activity, which is seasonal).

In the second test, MARIN used filtered seawater again, but increased the complexity of the PIV system to 2D3C (stereo-PIV) and increased the scale of the system to ~3m, thereby reaching the size and type of PIV system that could usefully be applied at full-scale. Since this test was also successful, MARIN was confident that measurements at sea would have a high chance of success, so they proceeded with developing the full-scale device.

Design and development of PIV unit

After establishing the viability of the PIV measurement principle at full scale, the design and development of the PIV unit started. Based on previous experience measuring with complex optical devices, it was decided to make the unit:

1. As robust and as sturdy as possible, since it needs to withstand harsh conditions (vibrations, flow forces, salt water) when installed, as well as during transport and handling. The device should be water-tight and include various levels of protection against leakage both into the device, as well as into the vessel.
2. As universally applicable as possible, meaning not dependent on the specific position of portholes or internal structures of the ship. This means mounting the unit outside on the shell plate, thereby also having an unobstructed view of the flow.
3. Able to measure in a large field of view, such that a sufficiently large part of the flow coming into the propeller is measured. This requires the laser energy and the camera efficiency and resolution to be high. Further, the acquisition frequency of the system needs to be as high as possible to gather large amounts of data in the limited time available in a run.
4. Free from the requirement to calibrate the device after installing it on the ship. Having to perform calibration in a ship environment was identified as a possible source of large uncertainty. The device would therefore only require alignment, calibration and other sensitive activities to be performed in the laboratory, after which the device should be able to work without further intervention in the difficult environment of a sea trial.

With these requirements outlined, it was decided to divide the work between MARIN and LaVision GmbH

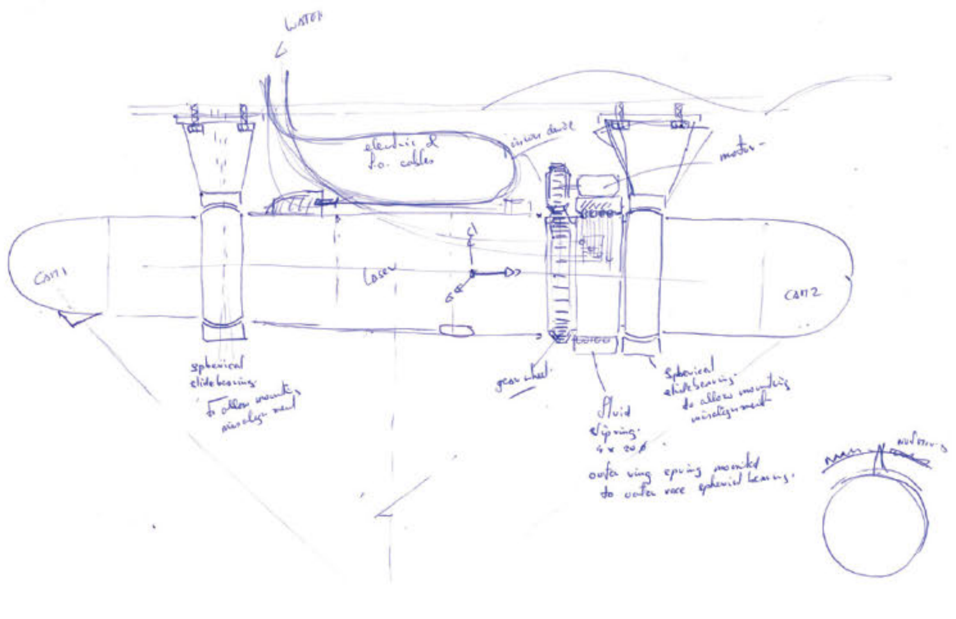


FIG. 8. THE FIRST SKETCH OF THE FLOWPIKE (PIV UNIT), MARIN, 2019

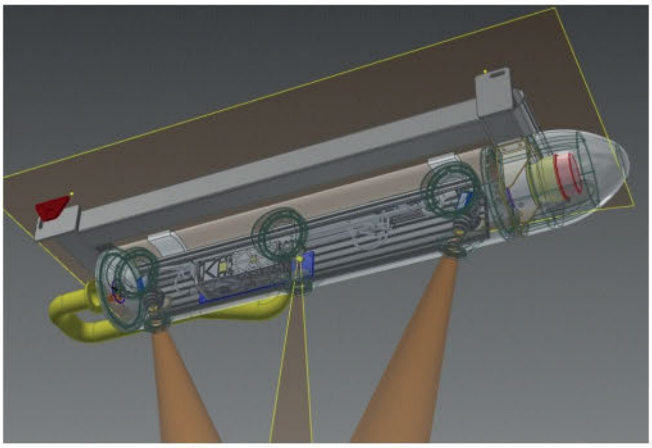


FIG. 9. DESIGN OF THE PIV UNIT, MARIN, 2019

(Göttingen, Germany) in the following way: MARIN will lead the overall development and perform the design and engineering of all the mechanical parts of the system whilst LaVision will perform optical design and deliver the necessary optical and electrical components of the system. After this, MARIN will perform the final system assembly, testing and commissioning.

The optical design included simulating and selecting the individual components necessary to create a large (1m wide, 3-4m long) laser sheet, as well as applying special camera mounts that were resistant to vibration and therefore possible misalignment. Besides this, a custom design was made for all the electrical and optical cables and the air and water hoses necessary for the operation of the cameras, the laser and electrical motors used for lens controls. All these needed to extend from the unit mounted under the ship to the power/control equipment inside the ship, a distance of 10m, passing through several water-tight bulkheads.

The biggest challenges of mechanical design included making a strong yet streamlined body that will be relatively easy to mount and dismount from the vessel, either in a dry dock or at a port in ballast conditions. This included designing a cradle for the device that is used for lifting and a dummy frame used for aligning the hull penetration and unit supports that need to be cut and welded onto the ship hull. Further, to enlarge the measurement area, the unit needed to be able to turn around its axis to a given angle and maintain the angle against the flow forces acting on it. This was achieved by placing a motor, an encoder and a brake in the front part of the device. Naturally, the water-tightness of the static and rotational seals and of the cable feed-throughs on the bulkheads needed to be ensured as well.

After all, the optical and mechanical components of the new PIV unit (FlowPike) were manufactured and delivered to MARIN, and the final assembly and testing took place. Special attention during the assembly process was given to securing all the bolts inside the unit to prevent them from coming loose due to exposure to vibration when installed in the vicinity of a cavitating propeller.

The testing was performed in MARIN workshops as well as in MARIN's Deepwater towing tank. In the dry, the working of all the subsystems were tested (cameras, laser, electrical motor for turning, pressure-tightness of the containment, fit and alignment of cable conduits, etc.). Then, the cameras and the laser were aligned using a specially ordered calibration plate, after which they were tightly secured in place.

Once all this was done in the dry, the unit was closed and placed underwater. There, the system was calibrated using the same large calibration plate previously used for alignment. After successfully calibrating the unit, the final test was to mount the unit onto the tank carriage and perform a day of testing in the basin. During the test, runs with increasing speed were performed. The PIV unit was pointed into the flow, its measurement area is vertical, with the main component of velocity directed through the laser sheet; this is the same configuration as in the intended application on the full-scale vessel. The resulting free-stream velocity can be compared to the speed of the carriage, which was increased from 0.5 m/s to 4 m/s. The PIV unit was able to measure the velocity with several per cent errors.

The final field of view of the unit was approximately 0.6m wide by 1.5m long, with the centre of the area being 2.5m away from the device. The FlowPike is, therefore, able to measure a 10-degree wide sector of the flow, starting at approximately 1.7m away from the device, up to 3.3m away. By rotating the device, a total angle of 160 degrees can be measured. The measurement frequency is 10Hz.

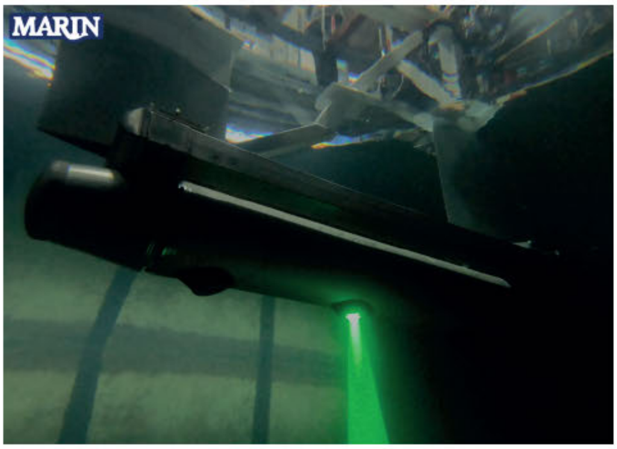


FIG. 10. TESTING THE PIV UNIT IN MARIN'S DEEPWATER TOWING TANK, 2020

With this, the testing of the FlowPike was considered complete and the unit was declared ready for deployment.

Installation of the PIV unit in dry dock

The unit and the welding dummy frame were delivered to the dry dock in early 2022. All necessary approvals by Class were obtained beforehand. As soon as the vessel was dry in the dock, the normal maintenance process of sandblasting the hull was started. It was important to start this process from the aft end to give access to the PIV installation area as early as possible.

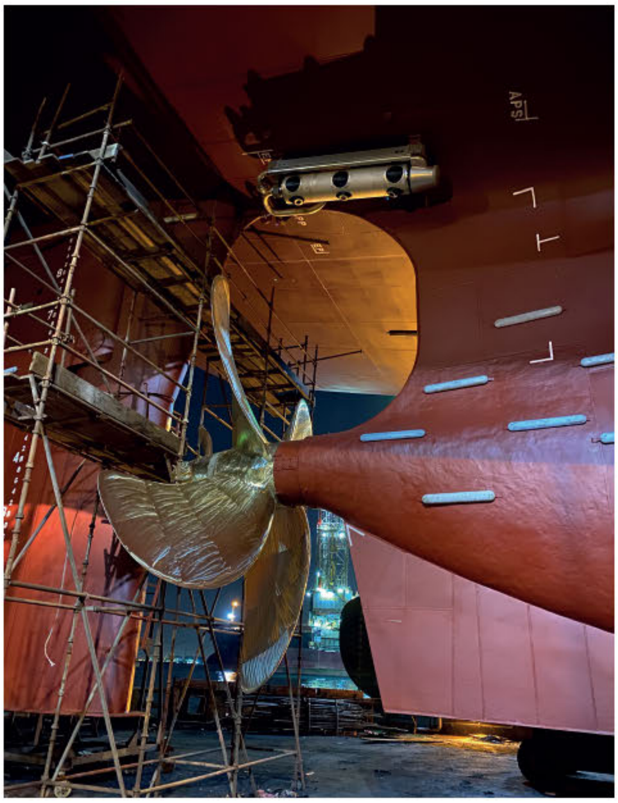


FIG. 11. PIV UNIT INSTALLED ON THE JORES1 TANKER, EARLY 2022

At the beginning of dry-docking, the feedthrough flange was welded in the hull. Four lifting eyes were also welded to the shell plate in the area of the future PIV unit. After that, the dummy frame (which has the same dimensions as the actual PIV unit) was lifted and the dummy feedthrough pipe was attached to the feedthrough flange. This gave the required alignment of the entire frame. While the frame was held by chain blocks, the next step was to weld brackets onto which the PIV unit will be fixed in the correct locations indicated by the dummy frame. Then the frame was bolted to the bracket to check the alignment of the entire structure. The next step was to remove the dummy frame to allow painting the newly installed feedthrough flange, brackets and lifting eyes. The window was closed from the inside to avoid paint coming into the hull. When the area was painted and the paint was dry (on the last day of dry-docking) the PIV unit was lifted by chain blocks and bolted to the brackets. The final operation of that day was a pressure test to ensure the water-tightness of the entire structure.

JoRes1 tanker sea trials and PIV measurements

The main objective of these measurements was to collect ship scale data for further CFD validation within the JoRes Joint Industry Project. For this purpose, a lot of activities took place before the actual trials: the hull and propeller roughness measurements were performed in the dry dock, strain gauges were installed on the propeller shaft to measure propeller torque, the optical sensor was installed next to the shaft to measure propeller shaft speed, anemometers were installed on the antenna mast to get wind characteristics, etc.

It should be also mentioned that the PIV unit was pressurised with nitrogen. If the unit lost its water tightness for some reason, the water would not come inside the unit and the hull. The nitrogen was selected to avoid moisturisation of the PIV equipment and especially the unit windows.

The sea trials were conducted according to the ISO15016:2015 standard. Before the trials, the vessel was stopped at sea to deploy the wave buoy, record vessel draughts and measure water properties. Later on, after the trials, the vessel was stopped again to record vessel draughts and measure water properties. The trials were performed at four shaft speeds (60, 75, 90 and 96rpm). Normally, the ISO standard requires conducting two runs for each RPM setting (minimum of 10min each), however, as it was expected that 10min would not be enough for sufficient PIV measurements, the decision was made to make the duration of each run 40min. Moreover, for 75 and 90rpm settings, four runs were performed, resulting in a total of 12 performed runs.

The main part of the PIV measurements was done at two speeds (75 and 90rpm). Additionally, PIV measurements were done at a third speed (96rpm), where a limited program could be executed. Each run consisted of measuring at different rotation angles of the FlowPike for either 80s or 120s; this amounted to either 800 or 1,200 images per one angle. The device was rotated to cover a total sector of either 70 or 140 degrees (the first of the double runs had a 70-degree sweep, the second a 140-degree sweep), which is a large part of the wake. The centre of each sweep was pointed at the expected position of the wake peak. Repeat measurements were also performed systematically; in fact, most angles were measured twice within one run, which will result in better statistics and will enable to investigate that

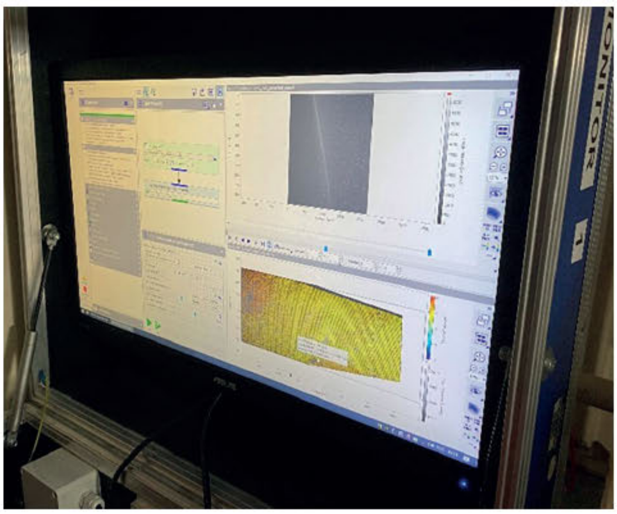


FIG. 12. FIRST PIV RESULTS

FIG. 13. REMOVING THE PIV UNIT WHILE THE VESSEL IS ALONGSIDE, 2022

there are no large scale flow effects that could bias the measurements.

Overall, the quality of the PIV images was very good, comparable to what was achieved with the FlowPike in the model basin previously. The concentration of the seeding particles was somewhat lower than ideal, but this will not have a large influence on the resulting quality. Likewise, the PIV inter-frame time needed to be kept low due to the high flow velocity through the laser sheet, but the resulting particle displacement is considered sufficiently high for a good dynamic range. In total 6.5 terabytes of PIV data were recorded and it will take some time to post-process and analyse it.

Removal of PIV unit after the trials

Performing comprehensive measurements on an ordinary cargo vessel implies some serious limitations as the ship owner normally seeks to have off-hire time as short as possible. Sea trials may be planned well in advance and it is relatively feasible to stick to the schedule provided there is no significant traffic in the trials area. Removal of the unit was a very uncertain operation because no one has done this before. Placing the vessel in dry-dock again to remove the unit would be prohibitively expensive to a research project, so the plan was to remove the unit when she is at the ballast draught (and the unit is above the water) and alongside. An appropriate pontoon was sourced at the yard and stability calculations were performed checking whether it is possible to lower the PIV unit (the total weight is more than 1,000kg) to the pontoon.

After a few loaded tests, it was decided not to put the unit on the pontoon, but use it for chain blocks operators. It was agreed to move the unit towards the stern of the vessel by chain blocks (additional existing lifting eyes in the rudder area were used for that). Another challenge was related to the propeller: as mentioned before, it was important to have ballast draught to keep the unit above the water.

At the same time, this meant that the pontoon and the PIV unit may be too close to the propeller blades. To mitigate the risk of damaging the propeller, the blades were moved by turning gear as far as possible from the unit and the pontoon. The operation was constantly monitored by divers to ensure all was kept clear of the propeller. In the end, the operation was done smoothly and the unit was safely moved towards the transom where it was picked up by the yard's crane. In total it took about 6 hours to complete the operation. The hull feedthrough flange was closed with a plexiglass window and secured with a blind flange on top of it, as intended in design. The class surveyor checked and approved the installation after that.

Conclusions

Naval architects and propeller designers always knew the importance of propeller inflow measurements at ship scale. The initial motivation was to compare the measured wake with model tests and derive recommendations for wake scaling procedures. Nowadays, the main intention is to validate ship scale CFD and better understand and utilise the energy efficiency potential of vessel propulsion. Developing measurement technologies enabled the design and realisation of a new and robust flow measurement tool which is not dependent on vessel geometry and porthole locations.

The successful PIV measurements performed on the tanker within the JoRes project showed that this technology works and can be used on other vessels. The installation, performance and removal activities may be aligned with normal vessel operations (dry-docking, post docking trials) and do not require significant off-hire time which makes it attractive for further comprehensive investigations on other vessels. ■

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This article is based on a paper presented at the 2022 HULLPIC conference.

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