THE NAVAL ARCHITECT

A publication of THE ROYAL INSTITUTION OF NAVAL ARCHITECTS
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APR 2021

50 YEARS OF THE NAVAL ARCHITECT

LOOKING BACK ON HALF A CENTURY OF SHIP DESIGN

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April 2021

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THE NAVAL ARCHITECT

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Printed in Wales by Stephens & George Magazines.

A 2021 subscription to The Naval Architect costs:

THE NAVAL ARCHITECT SUBSCRIPTION (10 issues per year)

LOCATION	PRINT ONLY	DIGITAL ONLY	PRINT + DIGITAL
UK	£211	£211	£269
Rest of Europe	£222	£211	£279
Rest of World	£237	£211	£295
	Includes P+P	Inclusive of VAT	

The Naval Architect Group (English Edition)
Average Net Crculation 9,763 (total)
1 January to 31 December 2020
ISSN 03060209

YOUNGER THAN YESTERDAY

By **Richard Halfhide**

SOURCE: SHUTTERSTOCK

Half a century ago, then editor Robin Burnett began this same section by noting how the first edition of the *Journal of the RINA* "marks the realisation of a new policy to spread the knowledge of ship technology and to bring the Institution, its branches and individual members into closer contact with one another".

Apparently the decision hadn't been made at the time the column was written to adopt the slightly pithier name of *The Naval Architect*, but it's remarkable how closely the publication has adhered to that original ethos of disseminating maritime knowledge. In my four years at the helm I've lost count of the number of times people have told me that they value *TNA* for its commitment to more technical content while other titles have arguably adopted a more 'commercial' approach.

That as many people haven't commented upon the magazine's somewhat dated appearance during that time is perhaps out of courtesy, or sentimentality towards the 'old school' aesthetics. Suffice to say it's something that we at RINA have been conscious of for some time and took the decision several months ago to coincide *TNA*'s 50th anniversary with an overdue revamp. While one of the determining factors was a desire for the magazine to look fresher and more visually appealing, we've tried (certainly in terms of content) to avoid change for its own sake, but would welcome feedback, whether good or bad. It's also part of a long-term strategy for an Institution that better reflects today's world and is able to offer its members the services and platforms to complement that.

But this issue is about looking back as much as it is to the future. As part of the 50th birthday celebrations, I reached out to all of the magazine's previous editors for their recollections of working on the title for a special retrospective on the last five decades in maritime. In addition, we asked some of the magazine's regular contributors to reflect on developments in their particular subjects of naval architecture expertise.

It's fascinating also to note how some of the subject matter in our regular features for this issue would have been inconceivable 50 years ago. Vessel performance analysis (p50-52) barely even existed a decade ago yet has grown into an increasingly competitive and rapidly maturing service sector for the industry. Equally, our Noise & Vibration section (p62-75) gives considerable focus to underwater radiated noise, which was scarcely even discussed as a problem back in 1971. We may have expanded the remit of the feature beyond such traditional preoccupations as propeller cavitation but it reflects how the maritime world has been obliged to consider its environmental impact. The paradiigm shift is an irrevocable one and likely to shape the shipping world for decades to come.

Incredible as it seems, it's now just over a year since Covid-19 brought huge disruption to all our lives and while I'm glad to say that we've been able to maintain a regular supply of material for these pages it's not been without some element of compromise. As I found myself discussing with one of the interviewees, Zoom meetings and webinars are at best an acceptable compromise but no substitute for spontaneous real-world interaction. The current inaccessibility of the RINA offices was one reason why we couldn't dig into the *TNA* archives as much as we would have liked for this issue, but perhaps there might be some further opportunity later in the year.

In closing, I think this anniversary is a good time to say thank you. Firstly, to the unsung 'backroom' staff at RINA, past and present, who have played such an important role in this magazine's continuing success and good standing. Second, to the thousands of people in the wider maritime community who have given up their time for interviews, articles and other contributions. Finally, thanks to you, the readers, for your ongoing support; *The Naval Architect* was created to reflect your professional interests and we plan to continue doing so for the next 50 years. ■

NEWS

SHIP DESIGN
DELTAMARIN LAUNCHES LNG-POWERED CONTAINER FEEDER DESIGN

SOURCE DELTAMARIN

Finnish ship designer, Deltamarin, has announced a new LNG-powered Kielmax container feeder design for the C.Delta series, known as C.Delta2100. The 179.4m-long, 10m scantling draught design builds upon the existing performance of the Polar Code C.Delta2150 model, focusing on best-in-class cargo capacity, flexibility and fuel economy.

With a 2,100TEU container capacity across four cargo holds and on deck, C.Delta2100 has an increased cargo hold breadth for better fully laden condition stability and an improved utilisation rate of approximately 1,595TEU. Deltamarin comments that this intake can be optimised for a specific cargo profile and through route-specific loading.

Its design flexibility accommodates pallet-wide 40' container stowage and three tiers of high cube (HC) containers in the cargo hold without losing container slots. C.Delta2100 is equipped with lashing bridges for reefer container access and has 450 reefer plugs, enabling efficient, smart stowage and minimising unnecessary container movements.

The ship design complies with EEDI Phase 3. In the interest of fuel economy, C.Delta2100 has a main engine consumption of 30.8tonne/day of Tier III LNG and 0.8tonne/day of pilot oil at a service speed of 18knots. As a result, the vessel has a fuel efficiency of less than 0.015tonnes LNG/TEU/day design draft and a 15.2dwt/14tonne TEU ratio, which Deltamarin stresses is a standard more commonly seen in large container ships.

ALTERNATIVE FUELS
A COMMITMENT TO GREEN AMMONIA FEASIBILITY

A group of industry leaders have signed a Memorandum of Understanding to conduct a feasibility study into a competitive green ammonia[1] supply chain for ship-to-ship bunkering in Singapore.

The study aims to evaluate an end-to-end supply chain for ammonia bunkering. This involves the development of a cost-effective supply chain for green1 ammonia – carbon-free ammonia synthesised from nitrogen and carbon-free hydrogen produced from renewable energy – as well as designing ammonia bunkering vessels and related supply chain infrastructure.

The supply of ammonia and its potential synergy with existing requirements for mild refrigerated storage, vessels and barges designed for liquefied petroleum gas (LPG) will also be examined. Testing will cover whether these requirements can withstand brown3, blue2 and green1 ammonia, where brown3 ammonia is conventional ammonia produced from natural gas and blue2 ammonia is carbon-neutral ammonia produced from natural gas, with the CO_2 produced from the processes captured and prevented from entering the atmosphere.

Each key partner, A.P. Moller – Mærsk, Fleet Management Limited, Keppel O&M, Sumitomo Corporation, Yara International and the Mærsk Mc-Kinney Moller Center, will pursue different roles. For example, Keppel O&M will develop and design a newbuild ammonia bunkering vessel and ammonia-ready LPG bunkering vessel, aiming to coordinate with authorities in Singapore to establish port regulations and operational guidelines.

Whereas Maersk will provide container ship-specific input and develop safe bunkering procedures. The company comments that ammonia has long been considered one of the most promising alternative marine fuels, with green ammonia possessing huge potential as is it derives solely from renewable electricity, water and air.

WIND PROPULSION
BV PUBLISHES NEW WIND PROPULSION GUIDELINES

BV PUBLISHES NEW WIND PROPULSION GUIDELINES SOURCE WALLENIUS

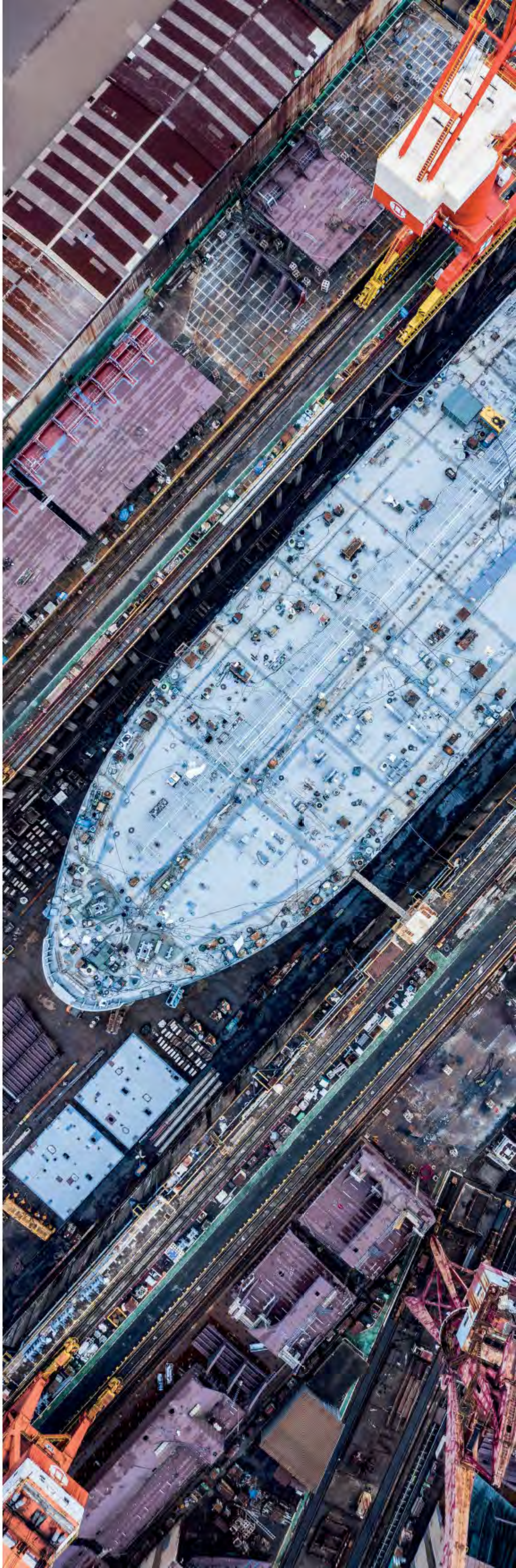
Bureau Veritas (BV) has published new classification rules for wind propulsion systems. Based on pre-existing BV rules published in 1987, the new Wind Propulsion Systems (WPS) – NR 206 rule includes two new notations that provide classification requirements for modern day wind-powered ships.

While the first, WPS 1, is suited to standard rigging, the second, WPS 2, is catered to standing and running rigging, but both establish load cases and coefficients for the full scope of available wind propulsion technology. Not limited to free-standing rigs, wing sails, kite sails and wind turbines.

Within the new rules, several general requirements must be addressed. Risk analysis, hazard identification (HAZID) studies, definitions of load cases, critical situations, the automation and release system, and impacts of the wind propulsion system on ship safety. As well as ship strength (how hull girder strength is influenced, etc) and local strength (connections between wind propulsion systems and the ship, including standing rigging attachments, manoeuvring systems and more).

BV's new rules also require the presence of an operational manual, covering the system's limits of operation due to its design, such as wind speed limitations.

Laurent Leblanc, senior vice president of technical & operations at BV, comments: "This is an incredibly exciting time for the industry as we revive an ancient, powerful and endlessly renewable source of energy – but with all the benefits of modern technology and materials."



SALVAGE OPERATIONS

ISU REFLECTS ON A YEAR'S SALVAGE WORK

At the ISU Annual Associate Members Meeting, held online this year due to Covid-19, the union reflected on the work completed by its members in past year through its Annual Pollution Prevention Survey for operations in 2020.

The survey found that ISU members provided services to vessels carrying a collective of 2.5 million tonnes of potentially polluting cargo across around 191 services, compared to 2019 figures of around 2.3 million tonnes in 214 services. However, ISU notes that these 2020 figures do not include the efforts of its former member, Ardent.

The above 2020 total includes:

- 111,886tonnes of bunker fuel
- 360,733tonnes of crude oil
- 112,096tonnes of refined oil products
- 133,150tonnes of chemicals
- 744,246tonnes of polluting/ hazardous bulk cargoes.
- 33,000TEU (15 nominal tonnes per TEU, which equates to approximately 502,845tonnes)

The findings also showed 51,928tonnes of other pollutants such as livestock, cars and fish, and 521,326tonnes of non-polluting bulk cargo including metal ores, sand and rock.

Reflecting on the results, Richard Janssen, ISU President, comments that it is worth considering the consequences if there were no commercial provision of salvage services. He adds: "Preventing and countering marine pollution is the core business of the members of the ISU and is facilitated by the people, the skills, equipment and innovation. Every marine casualty presents the possibility of a threat to life, to the environment, and loss of property. It is the role of the commercial salvor to intervene and prevent such losses and damages."

VESSEL PERFORMANCE

A NEW JOINT VENTURE IN VESSEL OPTIMISATION

MIROS MOCEAN - VESSEL PROFILE

BW Group and ocean measurement specialist Miros have joined forces to launch a new vessel performance optimisation application, Miros Mocean. It combines fuel oil consumption and main engine power measurements with real-time environmental conditions at the vessel's actual location.

The joint venture follows a year's cooperative development between BW Group and Miros. According to the companies, current lack of reliable ship performance information in actual operating conditions has led to variable performance data and tolerances in charterer-owner legal contracts. Further, inefficient vessel performance is heavily influenced by imprecise vessel speed control and lack of accurate data, leading to unnecessary fuel oil consumption and CO_2 emissions.

Miros Mocean is designed to resolve these issues. It allows vessel owners and operators to make real-time operational decisions to save fuel, reduce GHG emissions and enhance performance by integrating accurate weather data into existing vessel performance systems. In addition, utilising a ship's measured performance instead of warranties to optimise charter party contracts.

"Miros Mocean is leveraging the ocean insights of the Miros sensors together with the vessel performance optimisation ambitions of BW Group. Together, joining forces, we believe we have created a vessel performance optimisation application that will dramatically improve vessel efficiency and emission savings," comments Miros Ocean CEO Andreas Brekke.

CLASSIFICATION SOCIETIES

ABS PUBLISHES WHITEPAPER ON METHANOL

Classification society ABS has published a new sustainability whitepaper 'Methanol as Marine Fuel', the latest in a series that addresses shipping's fuel options.

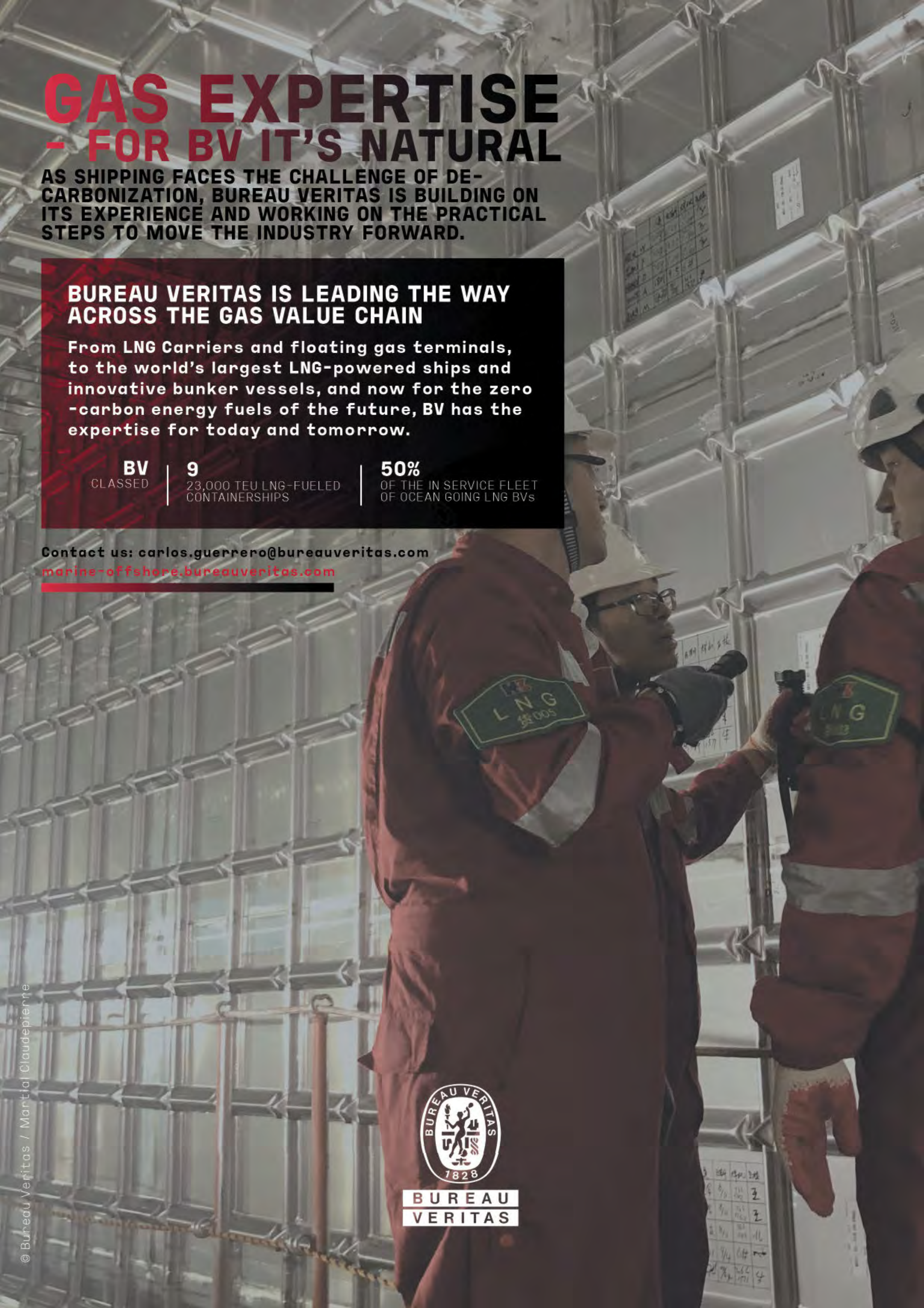
ABS's publication 'Setting the Course to Low Carbon Shipping: Pathways to Sustainable Shipping', also known as Outlook II, categorised shipping's available fuel options for decarbonisation that the classification society will address in a series of whitepapers.

In 'Methanol as Marine Fuel', ABS highlights that methanol has the upper hand over other gas fuels such as LNG due to its liquid state and ability to repurpose existing infrastructure: "Methanol is significantly easier and more economical to store onboard than gas. Retrofitting a vessel's tanks from conventional fuel oil, ballast, or slop to hold liquid methanol fuel is also easier than installing LNG tanks."

Other advantages mentioned are methanol's carbon-neutral potential. ABS states that as a primary fuel methanol reduces CO_2 by approximately 10% and in the future, it could be produced by biomass, biogas or renewable electricity. The whitepaper also highlights the available guidelines for methanol such as the adoption of MSC.1/Circ.1621, the Interim Guidelines for the Safety of Ships using Methyl/ Ethyl Alcohol as fuel by the IMO Maritime Safety Committee (MSC).

The paper covers these main advantages of methanol as fuel, as well as a detailed exploration of methanol safety, regulatory compliance considerations, design considerations, and ongoing research including industry and bunkering infrastructure projects.

It coincides with the news in March that Maersk has chosen methanol as the fuel for its first carbon neutral vessel, a 2,000TEU feeder ship due for delivery in 2023, a target achieved seven years ahead of schedule. Maersk has also become a member of trade association the Methanol Institute.


GAS EXPERTISE
– FOR BV IT'S NATURAL
AS SHIPPING FACES THE CHALLENGE OF DE-CARBONIZATION, BUREAU VERITAS IS BUILDING ON ITS EXPERIENCE AND WORKING ON THE PRACTICAL STEPS TO MOVE THE INDUSTRY FORWARD.
BUREAU VERITAS IS LEADING THE WAY ACROSS THE GAS VALUE CHAIN
From LNG Carriers and floating gas terminals, to the world's largest LNG-powered ships and innovative bunker vessels, and now for the zero -carbon energy fuels of the future, BV has the expertise for today and tomorrow.
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CARBON CAPTURE

WÄRTSILÄ INVESTIGATES SCRUBBER CO_2 EMISSION REDUCTION POTENTIAL

WÄRTSILÄ SCRUBBER

Wärtsilä has identified the potential for new technological advances to allow scrubbers to capture carbon at the point of exhaust, thus tackling maritime CO_2 emissions.

Following extensive R&D, Wärtsilä has confirmed that carbon capture and storage (CCS) on vessels is technically viable for the maritime sector. The company plans to install a 1MW pilot plant at its test facility in Moss, Norway, in order to test its CCS technologies in a range of scenarios and conditions with the goal of accelerating CCS development.

According to Wärtsilä, CCS enabled by scrubbers must take a vital role within the ensemble of solutions shipping is utilising to drive decarbonisation, such as alternative fuels and efficiency technologies. The company adds that focus should be on carbon and the ways organisations and the industry can utilise existing lessons related to sulphur.

As Sigurd Jenseen, director of exhaust treatment at Wärtsilä, explains: "Building on the success of existing and well-proven technologies, such as scrubbers, will be vital to succeeding on the industry's decarbonisation goals. Exhaust gas abatement technologies have reached a point of maturity where it is only right that we explore their wider applications beyond sulphur compliance."

He adds: "Carbon capture is exciting because it can provide significant reductions in a relatively short timeframe. This is important in the context of the industry's overall decarbonisation transition, as it will enable us to safeguard existing assets as we move to a cleaner mode of operating."

IN BRIEF

CRUISE SHIPS

LEASING CRUISE LINE ANNOUNCES VACCINATION REQUIREMENTS

P&O cruises has stated that, when it commences reduced operations in summer 2021, all its passengers will be required to have a second Covid-19 preventative vaccination before boarding. The company confirms its crew will undergo quarantine prior to boarding and regular testing onboard, and its ships will not stop at ports throughout its journey due to Covid-19.

EMISSIONS CONTROL

BIMCO AND RINA SUBMIT CALCULATION METHOD TO IMO

BIMCO and RINA have submitted a joint proposal to the 8th IMO Intersessional Working Group on the Reduction of GHG Emissions from Ships meeting, due to take place on May 24. The proposal presents a method for calculating accurate reference speed to ensure that older ships record a reliable EEXI in the absence of original sea trial data.

CLASSIFICATION SOCIETIES

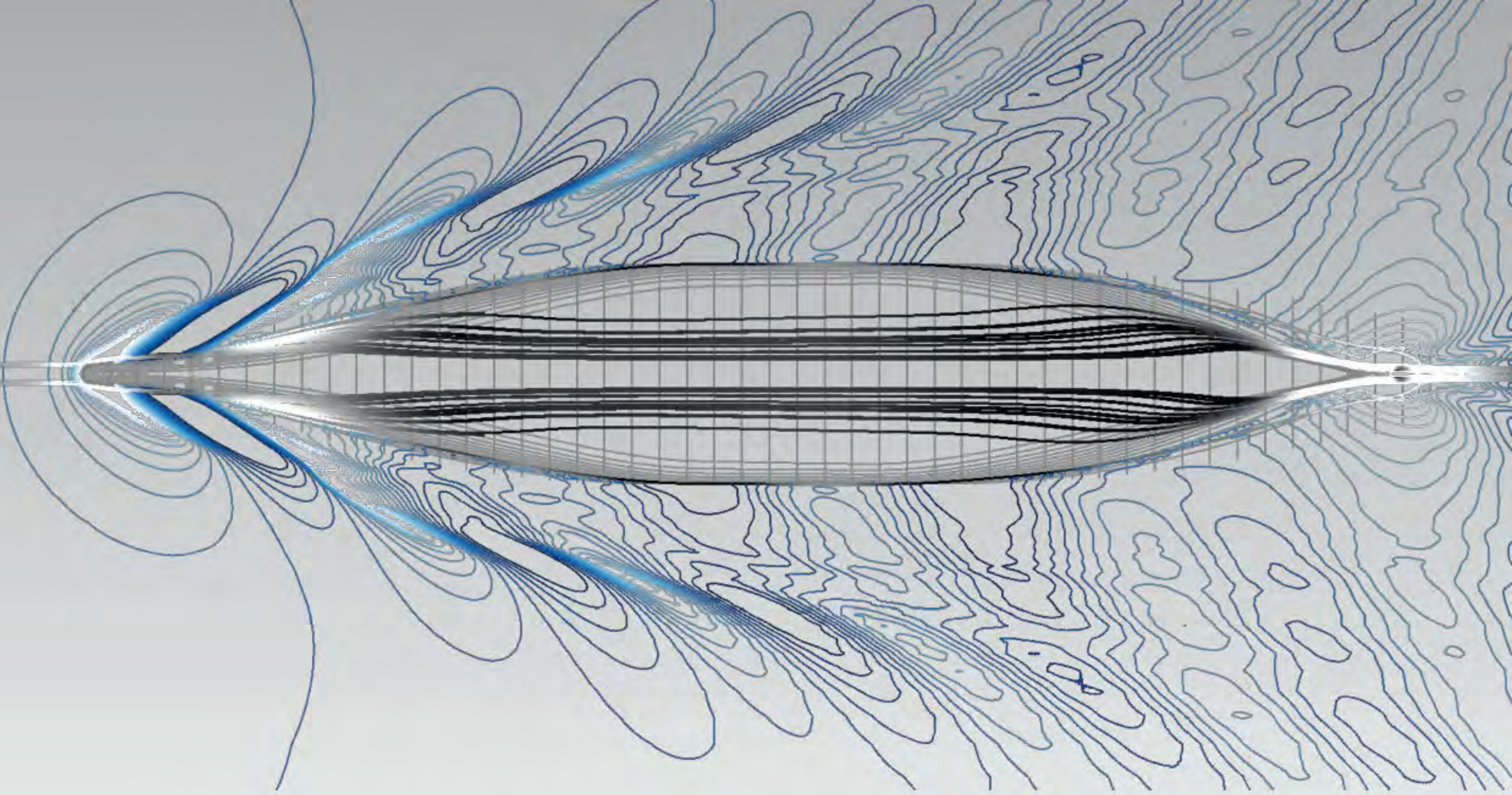
CLASSNK ISSUES AIP FOR METHANOL DUAL-FUELLED TANKER CONCEPT

Classification society ClassNK has given Approval in Principle (AIP) for Sumitomo Heavy Industries Marine & Engineering's methanol dual-fuelled tanker design. According to ClassNK, the design complies with IMO's 'Interim Guidelines for the Safety of Ships using Methyl/Ethyl Alcohol as fuels' and its own 'Guidelines for Ships Using Low-Flashpoint Fuels' published in 2019.

SALVAGE OPERATIONS

SUEZ CANAL GROUNDING POSES BIGGER QUESTIONS

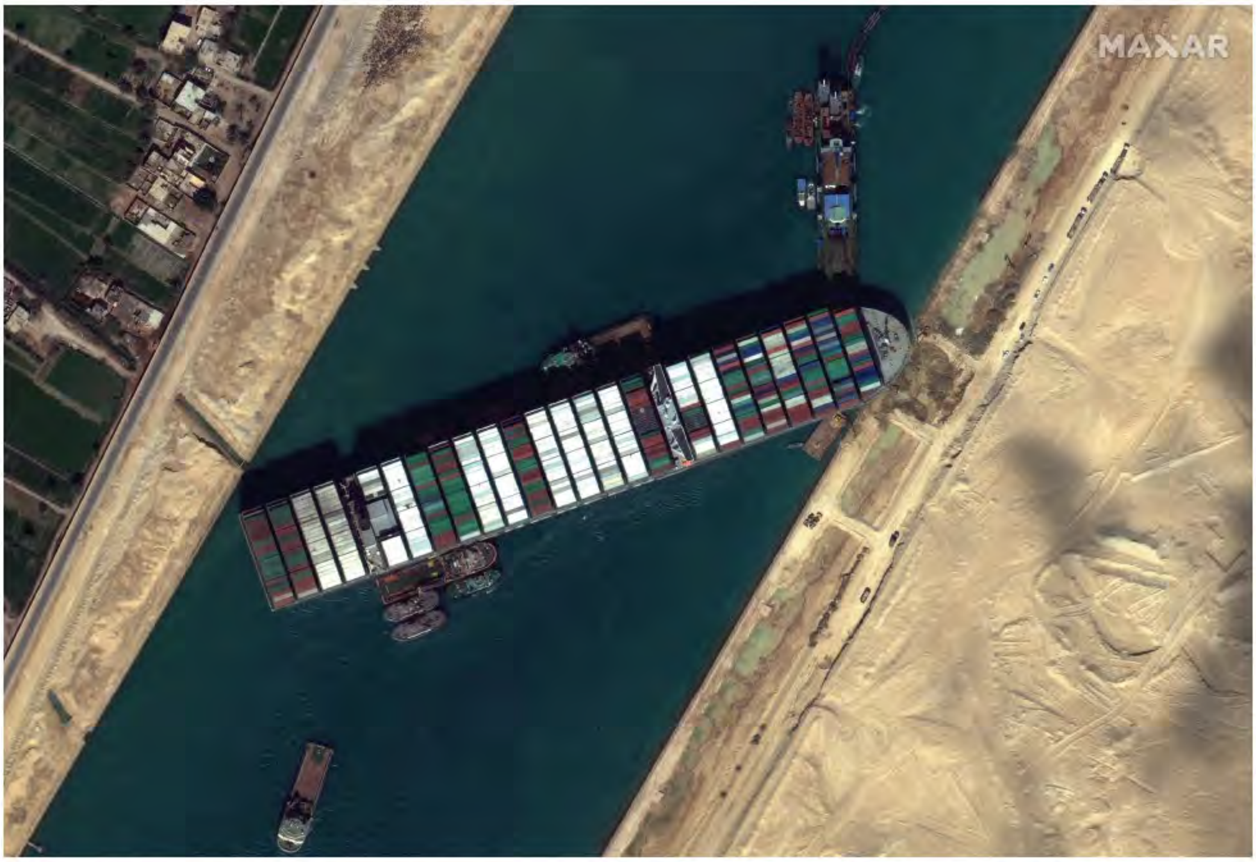
Container ship *Ever Given* recently ran aground in Egypt's Suez Canal, causing major delays. David Smith, head of hull and marine liabilities at McGill and Partners, says the event could have other significant repercussions aside from cost: "The salvage industry has been warning that container ships are simply getting too big for situations like this to be resolved efficiently and economically. This incident may force shipbuilders, owners and cargo operators to sit up and listen."



NEWS ANALYSIS

BACK TO THE FUTURE – PARALLELS 50 YEARS APART

By: **Malcolm Latarche**, Correspondent



SOURCE: MAXAR

With *The Naval Architect* being 50 years old this month, I thought back to what I was doing at the time when the first issue came off the press. In April 1971 I spent most of the month doing my 'O' level GCEs at school. Not sure whether to continue with 'A' levels and university, I spent a year in different jobs thinking about a career choice and 18 months later, in November 1972, began my shipping career working in the office at Bank Line – then probably the largest privately-owned shipping company in the UK.

Even though it was one of the UK's premier liner operators, Bank Line did not have a single container ship in its 50 plus vessel fleet. At that time a purpose-built container ship was a rare beast and most global liner services were performed using SD14 type tweendeckers. At 14,000dwt they would be dwarfed by modern box ships. Their length of 440ft and beam of 67ft are just about one third of those of a modern Ultra Large Container Ship.

By coincidence, one parallel can be drawn between 1971 and 2021 in late March and that is that the Suez Canal would be blocked. Of course in 1971 it was because Egypt had closed the canal to traffic as part of the 1967 war with Israel and the main artery of east-west trade would be shut down for eight years. In 2021, the closure caused by the 400m-long container ship *Ever Given*, when it became wedged across the 300m-wide waterway in sudden strong winds, proved to be considerably shorter. However, the cost of the resulting delays of those six days has been estimated at over US$50 billion.

It could be argued that the closure in 1967 was one spur to the ever-increasing ship size that has taken place since. Forced to travel around the Cape of Good Hope, economies of scale dictated that more cargo needed to be carried to compensate for the extra distance travelled and bunkers burned. Ironically, with over 200 ships waiting to pass through the blocked canal, operators are once again reverting to send ships around the Cape.

Suez wasn't the only place affected by war in 1971, a large number of cargo vessels were also caught up in the conflict between East and West Pakistan and several were attacked, bombed or damaged in other ways in the Bay of Bengal, including the Bank Line vessel *Teviotbank*. Similar attacks still happen today. Although now the focus has switched back to the Gulf, with car carriers and tankers having been targeted in recent months ostensibly by forces connected with Iran.

The increase in efficiency needed in the 1970s – later in the decade the oil crises would spark a new efficiency drive – is being mirrored today. In 2021, efficiency improvements are less of a voluntary economic driven choice but a regulatory one with ships being obliged to meet ever more stringent EEDI ratings as the IMO seeks to accelerate the decarbonisation of shipping.

The rising cost of oil fuel in the 1970s did spark some interest in alternative propulsion methods, with even a return to sail being considered. But as the crises passed so did the search for alternatives to oil and that is a marked difference with today. All manner of supplementary wind propulsion systems are now under development and being fitted to ships, albeit currently in small numbers. However, it is in fuel choice that the biggest difference can be seen.

LNG was in use in 1971 but only in a handful of LNG carriers and only as boil-off gas powering steam turbines. It would be almost three decades before any other ship type ran on LNG. Today's owners can choose from a number of oil fuels, biofuels, LNG, methanol, ethane and very soon ammonia and hydrogen. Such a choice would have been unthinkable in 1971 but probably very welcomed by owners of the time.

The search for efficiency in ship design in the 1960s/70s was beginning to see bulbous bows appearing on many newbuildings. The concept was not especially new at the time, but earlier versions were limited in application and were mostly limited to a bulbous forefoot rather than the protruding type that has evolved over time. Many standard ship types of 1971 including the SD14 had no bulbous bow at all, so it interesting to note that in modern times experimentation with bow form in the search for efficiency has resulted in many ship designs where once again the bulb is absent.

A lot has certainly changed since 1971, but in so many ways the industry seems to have remained much as it always has.

NEWS EQUIPMENT

BATTERIES

SPBES GAINS TYPE APPROVAL FOR THERMAL RUNAWAY PREVENTION

SOURCE: STERLING PLANB

Energy storage solutions (ESS) provider Sterling PlanB (SPBES) has received full certification from DNV for its range of vessel batteries.

After undergoing nine separate tests, SPBES has secured type approval to confirm its ESS substantially mitigates the risk of fire spreading by eliminating the propagation of thermal runaway within a battery module.

In cooperation with DNV's certified testing facility, this included thermal runaway testing to IEC 62619:2017 certification – which outlines requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications. As well as certification from independent certification body LabTest for SPBES' 75ah, 85ah and 100ah Lithium Nickel Manganese Cobalt Oxide (NMC) cells in December 2020.

SPBES is one of the first companies to meet DNV's new 2020 testing standards for commercial vessel batteries. While former requirements ceased testing at the first sign of initial cell failure but before combustion, its revised testing rules stipulate cell-level liquid cooling to prevent adjacent cells from contributing to a fire in a battery.

Brent Parry, SPBES CEO, adds: "After many months of rigorous testing, we're proud to have been certified under this new standard. While these standards from DNV are stringent, they are vital for the safety of commercial vessels using energy storage."

BALLAST WATER TREATMENT

TECHCROSS' NEW TURBIDITY CORRECTION TECHNOLOGY

Water treatment specialist Techcross has announced the development of a new electrolytic ballast water treatment technology capable of sensing the concentration of total residual oxidant (TRO) in highly turbid water conditions.

Measuring residual chlorine (oxidant) concentration and maintaining a specific level of disinfection efficiency is crucial for electrolysis water treatment, Techcross states, adding that such measurements determine the electric power level applied and amount of neutralising agent used.

An electrolytic BWTS is no exception, the company explains: "Particularly, as compared to measuring a relatively clear water quality in a fixed space such as a swimming pool, it is important for ships travelling every port in the world to ensure constant performance in any harsh environment."

Techcross conducted tests on its new system and found that measurements can be performed in very turbid water quality, up to 850NTU (nephelometric turbidity units). The company highlights that its new technology will therefore be particularly suited for vessels operating in Shanghai, China, and other areas of high turbidity, as well as for water quality inspection agencies.

Currently, the company has applied for patents in South Korea and final performance tests are being conducted. The new technology is expected to be on the commercial market by May 2021, upon completing relevant tests for approval. Techcross intends to expand its range of options to assist more customers experiencing difficulties with measuring TRO due to turbidity.

VALVES

THE WORLD'S FIRST DYNAMIC 6-WAY VALVE

COMBIFLOW 6-WAY

Danish marine valve specialist Frese has launched its COMBIFLOW 6-Way valve, a compact solution combining its 4-pipe system with its patented pressure independent control valve (PICV) technology.

Existing 4-pipe systems, consisting of decentralised ventilation units and fan coil systems, are reliant on the combination of a static 6-way valve and PICV, which requires two valves, two actuators, connecting pipes and a control box. Frese's combined solution requires only one value and one actuator to realise complete pressure independent balancing and control.

Rasmus Friman Nielsen, global product manager for Frese Marine, adds: "By integrating the differential pressure controller in the valve, you have fewer connection points, and with just one actuator you only need one data point to the ship's control system."

Frese's COMBIFLOW 6-Way valve will use a multi rotary actuator, which operates four different control signals, 0-10V and 4-20mA. It is also equipped with BACnet (building automation controls network) and Modbus programming tool to assist with flow setting, configuration and diagnostics.


ClassNK

VESSEL PERFORMANCE

DORIAN LPG APS COMMITS TO KONGSBERG DIGITAL'S VESSEL INSIGHT

SOURCE: DORIAN LPG

Owner and operator Dorian LPG ApS (DK), a subsidiary of Dorian LPG, has signed a contract to install Kongsberg Digital's Vessel Insight on its 22-vessel fleet of LPG carriers.

Vessel Insight enables vessel-to-cloud data infrastructure for safe and secure data capture. It can provide a fleet overview, vessel specific dashboards, data analysis tools, application programming interfaces (API), as well as access to a range of applications and services on Kongsberg's Kognifai Marketplace.

Due to be installed on DK's entire LPG fleet over the coming months, the company plans to use Vessel Insight to collate critical data from its VLGC fleet, acquire insights into signals from the fleet's assets and realise data-driven operations.

Andreas Jagtøyen, executive vice president, digital ocean, Kongsberg Digital, comments: "This contract emphasises the untapped potential and value of collecting data to analyse, predict and improve processes for vessels and fleets, especially given the current situation within the maritime industry, where gaining a competitive edge and decarbonising while meeting new regulations is key to survival and success."

DK plans to monitor and predict consumption/emissions data to benchmark performance between vessel types in its fleet and prepare for IMO's 2023 regulations, which the company notes will require vessels to combine technical and operational approaches in order to reduce their carbon emission.

COATINGS

CHUGOKU EXPANDS ANTIFOULING RANGE CONTAINING SELEKTOPE

Japanese coatings manufacturer Chugoku Marine Paints (CMP) will feature I-Tech AB's antifouling technology, Selektope, in its new domestic marine coating range.

After reviewing its Sea Premier range earlier this year, CMP opted to use Selektope in two new antifouling paint products suitable for coastal ships: self-polishing, silyl resin-based coating Sea Premier 3000 PLUS 1 and 2000 PLUS. This expands on the products in CMP's Sea Premier range already using Selektope, including Sea Premier 200Plus, 1000Plus, 1000Plus H and 3000 Plus 2.

Developed by I-Tech AB, Selektope is an organic molecule used in paint systems that temporarily and naturally stimulates barnacle larvae, repelling them from attaching to a ship's hull. This reduces friction between the ship and the water its travelling through, thus reducing fuel consumption.

CMP will also use Selektope in another new product, 033 Seajet Premium, suitable for the Japanese leisure boat market. The company stresses that the antifouling needs of coastal vessels differ from their oceangoing counterparts; they have shorter docking periods, are smaller and are sailing in biofouling hotspot's off of Japan's coast.

Philip Chaabane, CEO of I-Tech AB, comments: "CMP has a leading position in their home market, Japan, and with this introduction of two new products they have no less than six Selektope-based products for the domestic coastal vessel market. This is a sign that our recent regulatory investments in Japan has been important to support product expansion."

SYSTEM INTEGRATION

HØGLUND TO SUPPLY IACS FOR VLEC NEWBUILDS

SOURCE: HØGLUND MARINE SERVICES

Høglund has signed contracts with Jiangnan Shipyard and Babcock LGE to provide its integrated automation and control systems (IACS) and gas handling for two very large ethane carrier (VLEC) newbuilds owned by Tianjin Southwest Maritime.

Under the contract stipulations, Høgland will provide a fully integrated automation power management system and gas handling as well as a ship performance monitor for vessel optimisation. Currently under construction at Jiangnan Shipyard, the 93,000m^3 VLECs will begin a long-term charter for Zhejiang Satellite Petrochemical upon completion.

According to Høglund, the integration of automation and gas handling systems on newbuilds is a challenging area in ship engineering, where insufficient consideration results in ships that are difficult to operate and maintain.

"These challenges can only be overcome with effective collaboration between yards, suppliers and marine solutions specialists on the design and installation of integrated systems. Joint efforts between partners is key to guaranteeing that these VLEC newbuilds will have significantly enhanced reliability, efficiency and simplified lifetime maintenance upon delivery," Høglund explains.

The new contracts follow on from the company's previous work with Jiangnan Shipyard and Babcock. Høglund supplied the same IACS and gas handling systems for two VLEC newbuildings owned by Pacific Gas in August 2020.

16 - 17 - 18
NOVEMBER 2021
RAI AMSTERDAM

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OPINION

SHIP DESIGN HAS TO START THINKING OUT OF THE BOX

By **Janne Uotila** Managing Director, Deltamarin

A new approach is essential given the IMO's very ambitious greenhouse gas (GHG) targets both in the shorter and longer term. These include acceleration of EEDI requirements, retroactive application of the energy efficiency index for existing ships (EEXI) and a mandatory Carbon Intensity Indicator (CII) and rating scheme. Other initiatives include the EU's plans for including ships in ETS and the Poseidon Principles implemented by ship-finance institutions to align their portfolios to incentivise decarbonisation.

Deltamarin has recognised a change in industry mindset when it comes to GHG-related issues. Traditionally, shipowners and brokers have approached designers with a rather well-defined idea of the ships they want to build. Many of the customers have now realised this approach needs to be revised, and that more alternatives need to be analysed and taken into account in the early stages of the design. There has also been an increasing "let's do something new" attitude among projects from cargo owners and charterers – be it in new fuels, wind power or electrical applications. For example, we are right now working with Cargill on strategic development of wind propulsion. They came to us because we are thinking along the same lines. Cargo owners and charterers will be the ones eventually paying the bills and responsible for emissions in future, and there is a clear desire to strive towards achieving a step change in carbon intensity.

The earlier EEDI requirements for new ships have been reasonably easy to fulfil by "conventional" methods. The main ways to improve CO_2 footprint have been to optimise hull forms and/or propulsion arrangements, reduce operational speeds and switch to LNG as a fuel. While it's always possible to further tweak hull/propulsion forms and engine performance, the bag of conventional tricks is running low especially considering the step-change that will be required in the coming years. Slowing ships down will certainly not work forever simply due to the laws of physics.

Calculating real-life operations and real emissions

The step change in carbon intensity means we have to rethink the next generation of ships. And the time to do it is right now – especially if you're thinking about ordering a vessel even in two years' time when it will be exposed to the new regulations for sure. This requires even more emphasis on designing for optimal efficiency – not only to have a 'pass' on EEDI after sea trials. Looking beyond a single operating speed and figuring out real-life operational profile and conditions from the start is vital. Building an efficient ship then operating it willy-nilly simply will not work.

Another essential issue is to understand the complete well-to-wake emissions for the ship and the selected fuel, which means

JANNE UOTILA

including the emissions created in production, refining and transportation of the fuel before it is bunkered to the vessel. While this topic is currently not in the scope of the regulations, it will definitely be on the table in the coming years. The analyses we have prepared in our projects have shown that you cannot really put the different fuels in generic order according to their GWP (global warming potential) unless the analysis is prepared for the exact machinery configuration and trading profile of the ship.

With the design process having become more diversified and complex, Deltamarin has expanded into data analysis using advanced tools to determine the reference vessel and how we can improve from there. Early-state simulation provides not only the basis for optimising hull form and propulsion systems, but also data on the cost/benefits of various ESDs (Energy Saving Devices) for a given vessel or operational profile. Modelling real-life intended trading means we can ensure low fuel consumption in all modes.

Although more complex in terms of systems, ro-ros and certain passenger ships designed for dedicated routes are classic examples where you can optimise both a ship's hull and

DELTAMARIN DESIGNED THE RO-PAX *STENA ESTRID*, WINNER OF LAST YEAR'S SHIPPAX AWARD. © STENA LINE

systems throughout its operational range and environmental conditions because they are already well defined. It's very different for an oceangoing merchant vessel with unpredictable trading patterns. We gather statistical data on the most common projected routes and simulate these for a multitude of routes to get the optimal configuration.

LNG bridges the gap

On the fuel front, for most of the oceangoing merchant fleet the realistic options today and in the near future are limited to either conventional maritime fuels or LNG – which can, in my view, soon be considered a conventional maritime fuel. Although there is some hoo-ha over methane slip, LNG's core advantage is as a bridging fuel to other alternatives not yet mature. One drawback is if the ship is destined for trading where LNG is not easily available, in which case a step change in design is crucial for practical reasons.

Low-carbon biodiesels will likely not be available in the short to medium term in large enough quantities (looking at global production volumes, road traffic will consume most of it and has better capability to pay), and the development of worldwide production and marine distribution infrastructure for alternatives such as ammonia and hydrogen are still at least a decade ahead. There is growing interest in these in the shortsea/domestic segments where GHG considerations are more urgent and local supply and distribution ecosystems will be faster to set up. The Covid-19 situation looks to have accelerated this process.

Designers should check the current and future availability of the alternative fuels for each case depending on the ship's intended trade. Vessels can be also designed "future fuel ready" with certain provisions made regarding, for example, the fuel tanks and pipe/cable routings, and of course keeping this in mind when selecting the prime movers. However, this is not as simple as it sounds. It will usually require some extra investment at the newbuilding stage to ensure conversion is "designed in" from the outset. Alternative fuels also often come with less energy density, which calls for extra storage space. You need true retrofit capability, not just theoretically on paper. To prepare for wind, for example, you don't only need sufficient space and supports to accommodate the sails, it has many other implications that also need to be taken into account in the design.

Thinking out of the box

There are no one-size-fits-all solutions, neither in fuel choice, ESDs or vessel particulars. This means that both ships and ESDs need to be designed together for optimal performance. Often multiple technologies will be implemented simultaneously. You can't just drop such systems in later and expect the ship to work optimally. Every time we widen the criteria of optimisation, we need to make compromises. Clever customisation is key. When a client can't decide on route A or B you need to prepare for both. The process usually results in a design rather different to the initial concept – which is very important if you are considering, for instance, wind, where commercial viability depends on where and how the ship will trade.

At Deltamarin, we are independent of solutions and makers. There are plenty of technologies to choose from, but when you look at the suitability of these options and cost/benefit/fuel availability for a given case, the list gets shorter. We make no recommendations before the client case has been analysed. The key is to be open-minded, copy only the right things and change what's needed. The challenge is figuring out what the right things are, because every design case is different.

Customers come to us because we can prepare both the prototype rooted in their needs and follow through during the entire design and build period. To our credit, we have been involved in hundreds of newbuilds built in different countries around the world. As ships become more complex, plugging the gap in the build process where yards may lack resources or competence will become even more important in future. We are ready to hear from you.


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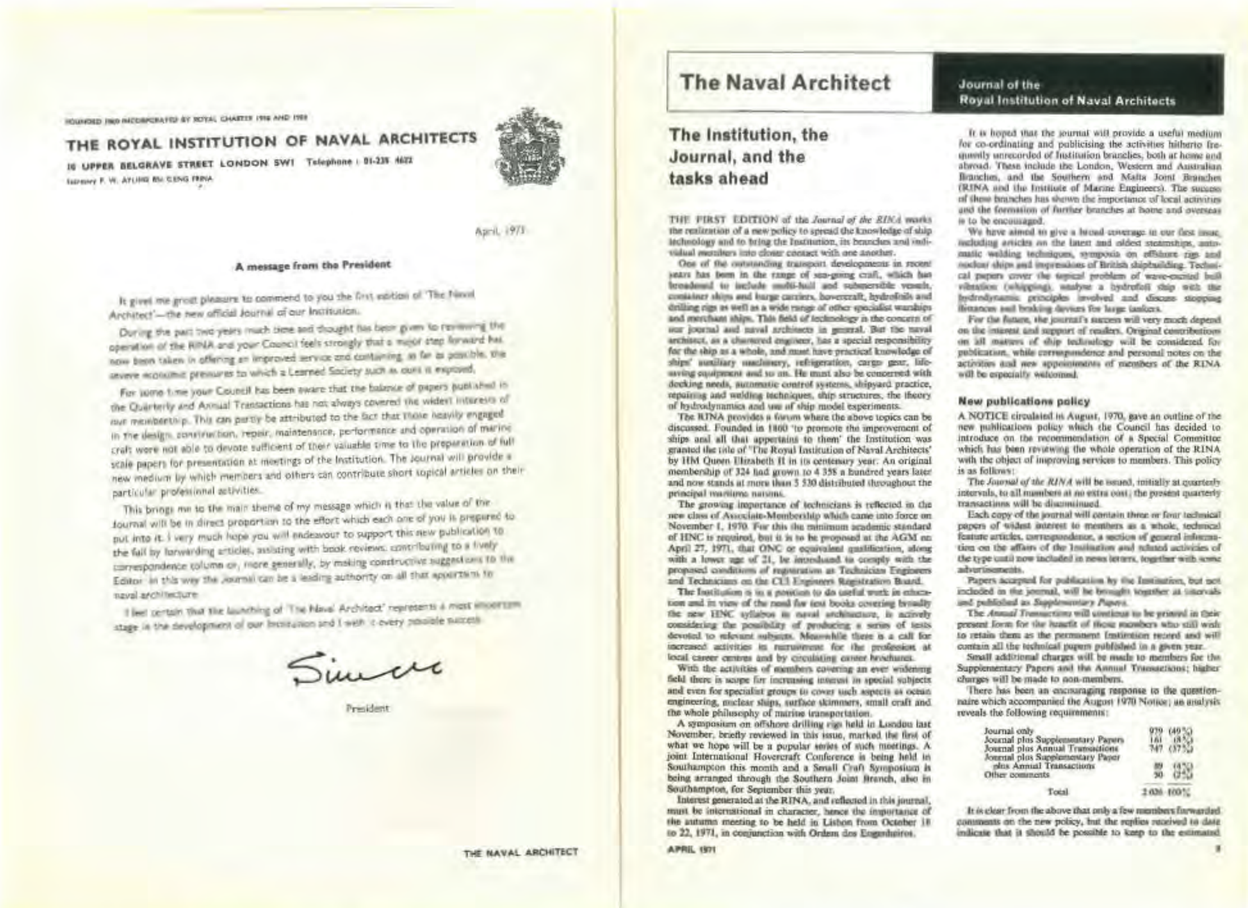
THE COVER OF THE NAVAL ARCHITECT'S FIRST EDITION

50TH ANNIVERSARY

50 YEARS AND COUNTING

By **Richard Halfhide**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16 UPPER BELGRAVE STREET LONDON SW1 Telephone: 01-235 4622

Secretary F. W. AYLING BSc C.ENG FRINA

April, 1971

A message from the President

It gives me great pleasure to commend to you the first edition of 'The Naval Architect'—the new official Journal of our Institution.

During the past two years much time and thought has been given to reviewing the operation of the RINA and your Council feels strongly that a major step forward has now been taken in offering an improved service and containing, as far as possible, the severe economic pressures to which a Learned Society such as ours is exposed.

For some time your Council has been aware that the balance of papers published in the Quarterly and Annual Transactions has not always covered the widest interests of our membership. This can partly be attributed to the fact that those heavily engaged in the design, construction, repair, maintenance, performance and operation of marine craft were not able to devote sufficient of their valuable time to the preparation of full scale papers for presentation at meetings of the Institution. The Journal will provide a new medium by which members and others can contribute short topical articles on their particular professional activities.

This brings me to the main theme of my message which is that the value of the Journal will be in direct proportion to the effort which each one of you is prepared to put into it. I very much hope you will endeavour to support this new publication to the full by forwarding articles, assisting with book reviews, contributing to a lively correspondence column or, more generally, by making constructive suggestions to the Editor. In this way the Journal can be a leading authority on all that appertains to naval architecture.

I feel certain that the launching of 'The Naval Architect' represents a most important stage in the development of our Institution and I wish it every possible success.

Simon

President

THE NAVAL ARCHITECT

The Naval Architect | Journal of the Royal Institution of Naval Architects

The Institution, the Journal, and the tasks ahead

THE FIRST EDITION of the *Journal of the RINA* marks the realization of a new policy to spread the knowledge of ship technology and to bring the Institution, its branches and individual members into closer contact with one another.

One of the outstanding transport developments in recent years has been in the range of sea-going craft, which has broadened to include multi-hull and submersible vessels, container ships and barge carriers, hovercraft, hydrofoils and drilling rigs as well as a wide range of other specialist warships and merchant ships. This field of technology is the concern of our journal and naval architects in general. But the naval architect, as a chartered engineer, has a special responsibility for the ship as a whole, and must have practical knowledge of ships' auxiliary machinery, refrigeration, cargo gear, life-saving equipment and so on. He must also be concerned with docking needs, automatic control systems, shipyard practice, repairing and welding techniques, ship structures, the theory of hydrodynamics and use of ship model experiments.

The RINA provides a forum where the above topics can be discussed. Founded in 1860 'to promote the improvement of ships and all that appertains to them' the Institution was granted the title of 'The Royal Institution of Naval Architects' by HM Queen Elizabeth II in its centenary year. An original membership of 324 had grown to 4 358 a hundred years later and now stands at more than 5 530 distributed throughout the principal maritime nations.

The growing importance of technicians is reflected in the new class of Associate-Membership which came into force on November 1, 1970. For this the minimum academic standard of HNC is required, but it is to be proposed at the AGM on April 27, 1971, that ONC or equivalent qualification, along with a lower age of 21, be introduced to comply with the proposed conditions of registration as Technician Engineers and Technicians on the CEI Engineers Registration Board.

The Institution is in a position to do useful work in education and in view of the need for text books covering broadly the new HNC syllabus in naval architecture, is actively considering the possibility of producing a series of texts devoted to relevant subjects. Meanwhile there is a call for increased activities in recruitment for the profession at local career centres and by circulating career brochures.

With the activities of members covering an ever widening field there is scope for increasing interest in special subjects and even for specialist groups to cover such aspects as ocean engineering, nuclear ships, surface skimmers, small craft and the whole philosophy of marine transportation.

A symposium on offshore drilling rigs held in London last November, briefly reviewed in this issue, marked the first of what we hope will be a popular series of such meetings. A joint International Hovercraft Conference is being held in Southampton this month and a Small Craft Symposium is being arranged through the Southern Joint Branch, also in Southampton, for September this year.

Interest generated at the RINA, and reflected in this journal, must be international in character, hence the importance of the autumn meeting to be held in Lisbon from October 18 to 22, 1971, in conjunction with Ordem dos Engenheiros.

APRIL 1971

It is hoped that the journal will provide a useful medium for co-ordinating and publicising the activities hitherto frequently unrecorded of Institution branches, both at home and abroad. These include the London, Western and Australian Branches, and the Southern and Malta Joint Branches (RINA and the Institute of Marine Engineers). The success of these branches has shown the importance of local activities and the formation of further branches at home and overseas is to be encouraged.

We have aimed to give a broad coverage in our first issue, including articles on the latest and oldest steamships, automatic welding techniques, symposia on offshore rigs and nuclear ships and impressions of British shipbuilding. Technical papers cover the topical problem of wave-excited hull vibration (whipping), analyse a hydrofoil ship with the hydrodynamic principles involved and discuss stopping distances and braking devices for large tankers.

For the future, the journal's success will very much depend on the interest and support of readers. Original contributions on all matters of ship technology will be considered for publication, while correspondence and personal notes on the activities and new appointments of members of the RINA will be especially welcomed.

New publications policy

A NOTICE circulated in August, 1970, gave an outline of the new publications policy which the Council has decided to introduce on the recommendation of a Special Committee which has been reviewing the whole operation of the RINA with the object of improving services to members. This policy is as follows:

The *Journal of the RINA* will be issued, initially at quarterly intervals, to all members at no extra cost; the present quarterly transactions will be discontinued.

Each copy of the journal will contain three or four technical papers of widest interest to members as a whole, technical feature articles, correspondence, a section of general information on the affairs of the Institution and related activities of the type until now included in news letters, together with some advertisements.

Papers accepted for publication by the Institution, but not included in the journal, will be brought together at intervals and published as *Supplementary Papers*.

The *Annual Transactions* will continue to be printed in their present form for the benefit of those members who still wish to retain them as the permanent Institution record and will contain all the technical papers published in a given year.

Small additional charges will be made to members for the Supplementary Papers and the Annual Transactions; higher charges will be made to non-members.

There has been an encouraging response to the questionnaire which accompanied the August 1970 Notice; an analysis reveals the following requirements:

Journal only	979	(49%)
Journal plus Supplementary Papers	161	(8%)
Journal plus Annual Transactions	747	(37%)
Journal plus Supplementary Paper plus Annual Transactions	89	(4%)
Other comments	50	(2%)
Total	2 026	100%

It is clear from the above that only a few members forwarded comments on the new policy, but the replies received to date indicate that it should be possible to keep to the estimated

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THE NEW JOURNAL WAS INTENDED TO REFLECT A WIDER RANGE OF MEMBERS' INTERESTS, BEYOND JUST TECHNICAL PAPERS

'During the past two years much time and thought has been given to reviewing the operation of the RINA and your Council feels strongly that a major step forward has now been taken in offering an improved service and containing, as far as possible, the severe economic pressures to which a Learned Society such as our is exposed,' wrote John Gilbert Simon, 2nd Viscount Simon and the serving president of The Royal Institution of Naval Architects, in his introduction to the first edition of *The Naval Architect* in April 1971.

It was felt that the balance of technical papers published in the Institution's quarterly and annual transactions, wasn't reflecting, to use Simon's words, *'the widest interests of our membership'*. Simply put, most naval architects employed throughout the maritime sector were unable to devote enough time to contribute their expertise. Additionally, a few months previously RINA had introduced Associate Membership to allow technical engineers and technicians to join the Institution's ranks. *The Naval Architect* was intended as a medium by which these members might contribute shorter, topical articles and correspondence reflecting their work and experiences in the industry, while still publishing three or four technical papers in each issue.

The Institution recruited Robin Burnett to edit the new journal, a recently qualified naval architect and elected RINA member. Burnett had spent nearly two decades at sea in merchant shipping before coming ashore. Having completed a degree in Maritime Studies at the University of Cardiff, in 1969 he embarked on a career as a maritime journalist for *The Motor Ship* (then published by IPC Magazines).

It was an exciting time to be writing about the maritime industry. Ro-ro ferries were undergoing significant advances with the introduction of novel bow and stern doors that made it possible for vehicles to be driven through. Notwithstanding the adverse publicity of 1967 Torrey Canyon oil spill, tanker sizes began to increase exponentially, while bulk carriers were now attaining up to 150,000dwt. Meanwhile, specialist container ships and dedicated terminals to receive them were fundamentally changing the nature of transporting goods by sea.

Nonetheless, Burnett's challenge in developing the new journal was a daunting one. He recalls: "In 1971, there were just me and an editorial secretary working on the new editorial, with [Secretary of the Institution] Peter Ayling editing three technical papers. There was no advertising department, and a long postal strike, but with some arm-twisting help from Members of Council we managed to pick up seven commercial ads: International Paints (antifouling), Materials Measurements Ltd, Adlard Coles (two books) Escher Wyss (Sulzer cp props), Watercraft, Bonnallack & Sons (containers) and Underwater Surveys Agencies. We also got classified Educational Courses and Appointments from the University of Newcastle, BSRA, UCL and Lloyds Register."

Articles in that first issue included 'Some impressions of British shipbuilding', based on a presentation to RINA's London branch by Sir William Swallow, chairman of the Shipbuilding Industry Board. Another feature, 'Considerations in the structural design of the new generation of OCL container ships' was a detailed look at the challenges British operator Overseas Containers Limited had experienced developing its 'Liverpool Bay' class of vessels, written by Blue Funnel's senior naval architect, Marshall Meek.

The early 1970s was a period that saw a host of ambitious maritime projects, including oceangoing hovercraft and nuclear-powered merchant ships. Many of these concepts were ultimately deemed impractical, but other nascent segments such as LNG transportation would prove of greater long-term influence. Meanwhile, the 1973 OPEC oil crisis put a new (albeit initially short lived) spotlight on propulsion efficiency.

In the summer of 1980, after nearly a decade, Burnett decided to step down from the editor's position and become a freelance journalist. Just a few weeks later, the sinking of the oil and bulk carrier *Derbyshire* occurred, the investigation into which would lead to increased strength requirements for hatch covers and corrugated bulkheads, something advocated by several *The Naval Architect* contributors.

1980s

Burnett's successor was Michael (Mike) Wake, who had studied naval architecture at the University of Newcastle. With the world on the cusp of a computing revolution, Wake was struck how by basic the facilities were. He explains: "When I joined RINA as editor of *The Naval Architect* in 1980 it was like stepping back in time. The accounts and membership records were still manually updated on ledgers and all that was in my allocated office was a desk, a chair, a telephone and an ageing manual typewriter.

"In parallel with maintaining editorial matters the main task was to make the journal commercially competitive with other maritime publications. Extra revenue allowed us to acquire some second-hand desktops and slowly but surely the transition to computer-based journalism and administration. Sadly the computers were well-used British-made Apricots which were not universally compatible with operating systems, but it was a start."

The earliest CAD systems had emerged in the late 1960s (see also p34-36), but while the first International Conference on Computer Applications for Shipbuilding (ICCAS, an event nowadays organised by RINA) was first held in 1973, it remained the domain of outliers as far as merchant ship design was concerned.

IN THE 1980S RINA INVESTED IN NOT QUITE STATE-OF-THE-ART APRICOT PCS

Wake says: "I remember writing several articles in these early years about the future of computers in ship design and analysis. The debate centred on the limited capabilities of desktops and essential requirement for mainframe computers. I had begun my naval architect career at Swan Hunter Shipyards in 1975 at Wallsend on the River Tyne. There were some at Swans that thought the company was leading the way in computer-based design and manufacture with a computer the size of a very large room and software developed by Lockheed called CADAM.

"Nowadays those same calculations and very much more can be readily completed by laptops in a fraction of the time. At university I was trained to draw a ship's lines on paper using battens and weights, and with planimeters for calculating areas. Today I can do this on my phone!"

Tim Knaggs, who joined *The Naval Architect* as Associate Editor in 1986 (like Burnett and Wake he had also worked on *The Motor Ship*), is quick to praise Wake's forward-thinking outlook. He comments: "[Computing] revolutionised not only our office work but the whole of the marine industry, and CAD/CAM (computer-aided design/computer-aided manufacturing) has become a byword. Eventually, naval architects could view their creations in 3D with walk-through effects, while computerised fluid dynamics (CFD) now enable them to study hull/propeller interaction, along with other aspects of ship design and construction, in the greatest detail."

Wake's tenure coincided with a period during which the withering of British shipbuilding industry had become a subject of enormous concern. Having been responsible for the construction of around half the global fleet after the Second World War, British shipbuilding had dwindled in the face of the more economic production models found in Scandinavia

and the Far East. The Labour government's solution was to nationalise the yards, incorporating British Shipbuilding plc in 1977, but like so much in British politics during that decade, it wasn't straightforward and perhaps doomed from its conception. By late 1982, British Shipbuilding had closed half of its yards and under the terms of the then-Conservative government's British Shipbuilders Act 1983 the remaining assets were sold off piecemeal.

"The implementation of the nationalisation policy had been postponed for some years and many at that time believed that the delay in its implementation (it was first announced in 1974) was the death nell for the industry at a time when Japan and to some extent South Korea were becoming dominant forces. The threat of nationalisation starved the industry of investment," Wake recalls.

"As editor I had the task to cover the gradual decline of shipbuilding in the UK. I remember writing to the British Prime Minister Margaret Thatcher asking for her to give British shipbuilding a break and create an investment environment to support the industry. She did reply and the letter was published in *The Naval Architect*. The content was quite definite that essentially no further support would be forthcoming."

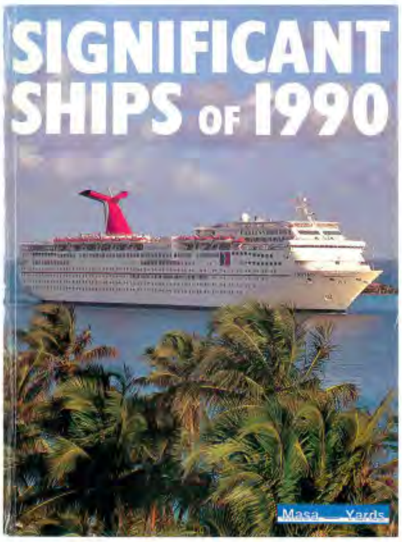
PRIME MINISTER MARGARET THATCHER WAS UNREPENTANT IN HER VIEW THAT BRITISH SHIPBUILDING WAS A "SUNSET INDUSTRY"

Instead *TNA*'s editorial focus turned increasingly towards developments overseas, particularly Asia. "I would like the thank the Japan Ship Exporters' Association (JSEA) and the Chinese Society of Naval Architects and Marine Engineers (CSNAME) and many others for their magnificent support," says Wake. He left RINA in 1990, taking up a role at Australian-based shipping company Austal, for whom he continues to serve as a representative to this day.

1990s

During the 1980s and early 1990s RINA's editorial department expanded to reflect a wider scope of naval architectural interests, with the launch of *Small Craft Technology* (subsequently absorbed into *Ship & Boat International* after the latter's acquisition), *Shiprepair and Conversion Technology* (today known as *Shiprepair & Maintenance*), and the *TNA* supplements *Warship Technology* and *Offshore Marine Technology*.

Tim Knaggs, who stepped up to the editor's role for what would eventually become a 16-year incumbency, highlights another notable addition, which has just celebrated its own (30th) anniversary. "In 1990, we published the first edition of the annual, *Significant Ships*, which proved most successful. *Significant Ships* was another brainchild of Mike Wake. Each featured a concise description of approximately 50 ships, written (up till 2008) by John Lingwood, MRINA. The publication proved a useful reference and continues to be produced."



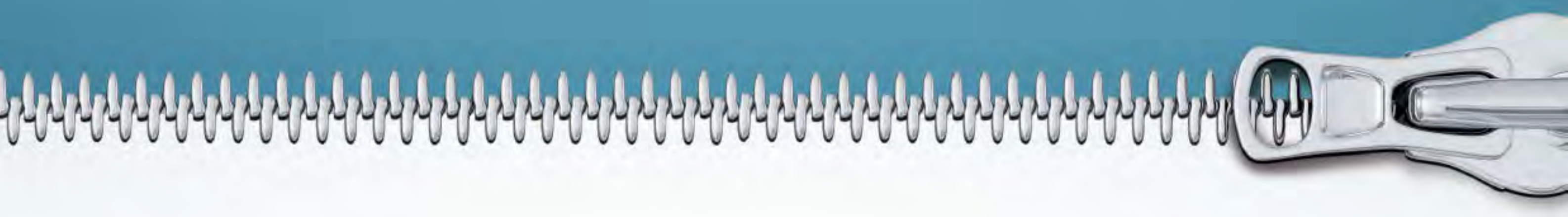
AS RINA EXTENDED ITS EDITORIAL PORTFOLIO, *SIGNIFICANT SHIPS* WAS LAUNCHED AT THE START OF THE 1990S

Knaggs' spell at RINA coincided with two of the most shocking maritime disasters in modern times. In March 1987, 193 passengers and crew died in the capsizing of 139.9m-long *Herald of Free Enterprise* outside Zeebrugge. The sinking, caused when the ship's bow doors were left open as it left harbour, remains the highest death count of any peacetime maritime disaster involving a British vessel. At a regulatory level it had profound repercussions for ro-ro design, including a SOLAS mandate to increase the ship's freeboard and the prohibiting of undivided decks on vessels of such length.

A second major tragedy would follow in September 1994, when the cruise ferry *Estonia* sank in the Baltic Sea, claiming 852 lives when the bow door became separated. The precise cause of the incident remains the cause of speculation to this day, but it would lead to the enhanced stability requirements of SOLAS 90 and the 'citadel concept' of ship design to ensure that damaged ships retain enough buoyancy to stay afloat.

THE 1980S AND 1990S WERE OVERSHADOWED BY THE *HERALD OF FREE ENTERPRISE* AND *ESTONIA* FERRY DISASTERS

Knaggs recalls: "Significant marine innovations during my time included hatch coverless container ships, a new generation of large LNG tankers, a resurgence of diesel-electric propulsion machinery, greater use of azimuthing propulsors (especially on cruise liners) and a general recognition of the need to be much more environment-friendly, particularly in matters of air pollution from diesel engine exhaust gas."



If the progress towards Emission Control Areas for NOx and SOx proved to be a slow burn, not enforced until around the time of Knaggs' retirement in 2006, others arrived in the public consciousness far more catastrophically. In March 1989, the tanker *Exxon Valdez* ran aground on Bligh Reef, Alaska, spilling 37,000tonnes of crude oil. It prompted a comprehensive review of IMO's MARPOL convention, including the requirement that all new tankers of 5,000dwt or greater – as well as tankers 600tonnes dwt or greater carrying heavy grade oil as cargo internationally – be equipped with double skinned hulls.

2000s

"I joined *The Naval Architect* as editor in December 2006, fully aware of the esteem in which the publication was held and of my predecessor's 20-year contribution to it," remembers Hugh O'Mahony. "As I met with an increasing number of naval architects, engineers and yard executives, and the wealth of expertise available from the Institution and the publication's established writers became clear, I got to grips more fully with his achievements."

As the former technical editor for *Lloyd's List*, O'Mahony's agenda was distinctly more news driven than those before him, something which set him in good stead for the controversy that had began to ensnare classification societies. In 2006, marine equipment manufacturers lobbied the European Union (EU) to compel class societies to agree to 'mutual recognition' of one another's certificates. Estimates suggested mutual recognition could save equipment suppliers as much as €1 billion, although the International Association of Classification Societies (IACS) put the figure at just a quarter of that.

IN A LONG-RUNNING SAGA, CLASSIFICATION SOCIETIES FELL FOUL OF THE EUROPEAN UNION

While IACS, which stressed the difficulty of establishing consistent standards for the hundreds of class certified products and materials onboard a vessel, still had the support of the majority of shipowners, the European Commission complicated matters further with its request for the recognition of three non-IACS organisations. By 2008, allegations that IACS was being operated as a cartel had led to coordinated police raids of the leading class societies, but the EU proposals were ultimately accepted.

O'Mahony's three-year incumbency came during a period of unprecedented growth for the industry. "My tenure coincided with an extraordinary shipping super cycle, with rates across multiple sectors in the ascendant and cruise guest numbers reaching new heights. These were shipbuilding boom times, ahead of the Asian financial crash, with one highpoint being the largest ever issue of *The Naval Architect*, in September 2008, at a mighty 216 pages!"

2010s

In July 2009, O'Mahony left RINA to become director of public relations at maritime and offshore agency JLA Media. His successor, Nick Savvides, was likewise a seasoned journalist who had worked at *Lloyd's List*. Savvides' eight-year tenure coincided with some major developments in the design of vessels, not least of which were the repercussions following the loss of the 8,000TEU container ship *MOL Comfort*, which suffered structural failure while travelling off the coast of Yemen in June 2013.

THE LOSS OF *MOL COMFORT* IN 2013 RAISED QUESTIONS ABOUT THE STRUCTURAL INTEGRITY OF MODERN CONTAINER SHIPS

He recounts: "I happened to be travelling to Japan for RINA shortly after the *Comfort* was lost and was able to speak with all the appropriate authorities in government, at ClassNK, MOL and the shipbuilder, Mitsubishi Heavy Industries in Nagasaki.

"In addition, I discussed the loss with some well-known naval architects of the time and built up a comprehensive and detailed picture of the apparent causes and the areas in which the investigation into the accident was concentrating. *MOL Comfort* had suffered a crack amidships and broke in two. Many naval architects at the time believed that the cause was the thin steel plating that had been used on the 12 vessels in this design. The use of ultra-high strength steel was meant to reduce the weight of the ship overall."

The precise cause remains uncertain, but operator Mitsui OSK Lines withdrew the *MOL Comfort*'s sister ships from operating the same route until they had undergone upgrades to their longitudinal strength.

Savvides adds: "As a result of the *MOL Comfort* investigations IACS tightened their design criteria with particular attention to the strength of hull plating. Stories on the *MOL Comfort* were complex and initial coverage of the disaster required RINA's technical experts to scan and consider the details for three days, delaying publication, before the story was passed for printing. It remains a memorable event in both my 30-year career as a journalist and a stand-out moment of my time at RINA."

That same year, 2013, also saw another container vessel make the headline for quite different reasons. As the lead ship in Maersk's much-vaunted Triple E class of vessels, the 399m loa, 18,270TEU *Mærsk McKinney Møller* was symbolic not only of the seemingly limitless potential for vessel upscaling but also the growing prominence of efficiency measures such as waste heat recovery systems, a slower design speed and a 'cradle-to-cradle' design principle for increased recycling at the end of its operational life. In 2012, IMO had adopted the Energy Efficiency Design Index (EEDI), which established defined targets for the greener design, construction and operation of vessels, although these would not apply to newbuildings until 2015.

EXPECTED TO BE DELIVERED LATER THIS YEAR, *YARA BIRKELAND* IS WIDELY CONSIDERED A MILESTONE IN THE DEVELOPMENT OF AUTONOMOUS SHIPPING

Timeline

1973	First OPEC oil crisis
1977	British shipyards nationalised
1980	MV *Derbyshire* sinking
1987	*Herald of Free Enterprise* capsize
1989	*Exxon Valdez* oil spill
1994	*Estonia* sinking
2000	South Korea overtakes Japan as the world's biggest shipbuilder
2008	Global financial crisis. Global orderbook slumps.
2013	*MOL Comfort* sinking
2018	IMO agrees GHG strategy
2020	Global sulphur cap implemented

The present

It seems appropriate that the current editor add a few closing thoughts about his four years (to date) on the title. Maritime historians might well look back on this as a period defined by two mega trends. Firstly, the advances being made in digitalisation, connectivity and the impending arrival of the first autonomous and unmanned vessels. Although delivery of *Yara Birkeland*, the 120TEU autonomous container ship that will operate on routes in coastal Europe, has been delayed by Covid and other factors, it's a widely seen as the acid test for such concepts.

Even more important was the adoption of IMO's initial greenhouse Gas (GHG) strategy in 2018, which effectively committed the maritime industry to developing carbon-neutral solutions within the next decade. The scale of this challenge is as formidable as anything shipping has faced in the past half century. As an editor the challenge is trying to reflect the ebbs and flows of the debate in *The Naval Architect*'s coverage. Will the answer come with new fuels and propulsion concepts? Is this the swansong of the internal combustion engine?

There remains enormous uncertainty and even the most astute soothsayers are likely to be hedging their bets. But although the names and faces may change, *The Naval Architect* hopes to be there for the next 50 years. ■

50 YEARS OF SHIP HULL OPTIMISATION

By **Volker Bertram**, DNV

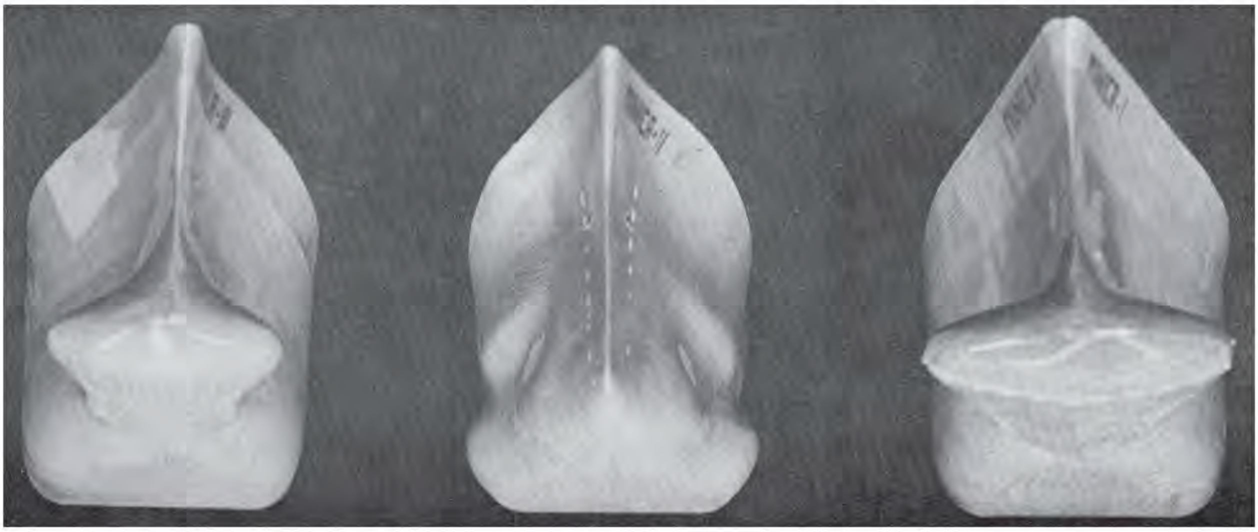


FIG 1: FROM HSIUNG'S 'OPTIMAL SHIP FORMS FOR MINIMUM WAVE RESISTANCE' (1981)

The introduction of computers in the shipping community after the 1960s has changed how we design ships forever. Rapid development of information technology (IT) has been mirrored by a corresponding evolution, or even revolution, in hull design methods. 50 years of *The Naval Architect* is an ideal occasion to look in time lapse at just how far we have come in the last five decades.

Hull design is traditionally based on model tests and/or numerical simulations. Both trace their very roots back to the 19th century. In 1861, British naval architect William Froude presented a paper to the Royal Institution of Naval Architects, outlining similarity laws for model tests. In 1879, the first model basin was built in Torquay, soon to be followed by many others around the world. For almost a century, model tests would be used virtually exclusively by the industry to evaluate hull forms and guide hull form optimisation.

By the early 1960s, computers became available to selected naval architects. These were central computers with punch cards or punch strips as input and their first applications were in hydrostatics. German professor Heinrich Söding developed Euklid in around 1967, the first practical software to describe arbitrary ship hull shapes. This software was subsequently commercially used by Schiffko, a company later acquired by Wärtsilä. That same year, the Technical University of Denmark's Eliezer Kantorowitz developed a similar approach. Ship designers used series such as Series 60 or the Tayler-Gertler method in manual lines design, then model tests for selected improvement. Numerical hydrodynamics to assess ship resistance was yet to evolve. Academic attempts to combine thin-ship or slender-body theory with formal optimisation to derive 'minimum resistance' hull design resulted in shapes that invariably looked strange with wavy waterlines or decanter-like hull sections in the bow (Fig 1).

Increased power and availability

In the 1970s and 1980s, computers became more powerful and more widely available, e.g. in the form of personal computers. Interfaces moved from line-oriented text to graphical user interfaces (GUIs). In the wake of growing hardware power, we also saw rapid developments in CAD (computer-aided design) techniques, CFD (computational fluid dynamics) and optimisation strategies. Genetic algorithms were described in 1975 by American professor John H. Holland as the application of evolutionary strategies in computer simulations. They were largely ignored for years to come, as on single-processor computers they were computationally much less efficient than classical optimisation algorithms.

Following the pioneering work of Charles W. Dawson in the 1970s, panel methods for 'fully non-linear wave resistance' computations evolved throughout the late 1980s and drifted rapidly into industry applications to improve ship hulls, with key model basins such as HSVA (Germany), MARIN (Netherlands) and SSPA (Sweden) emerging as technology leaders. The standard hull development process in the 1990s was a two-step approach. Experts investigated a handful of candidate hull designs and studied details like pressure distribution and wave making. Based on those insights the design was then modified and reanalysed, typically involving 1-3 loops. Resistance prediction was deemed to be still too inaccurate for formal (automatic) optimisation. Hull improvement through CFD was largely limited to the bow region, as viscous flow computations required for the aft body design called for resources excessive for the industry at that time (Fig 2).

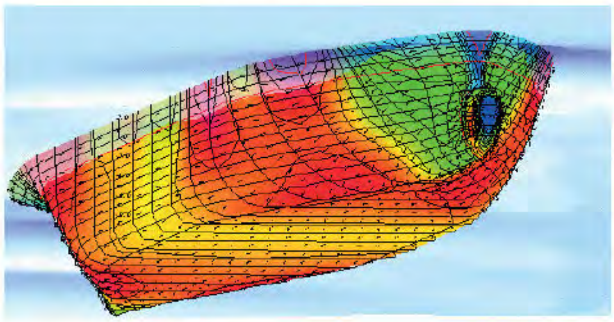


FIG 2: HULL DEVELOPMENT IN THE EARLY 1990S MAINLY FOCUSED ON THE BOW

Moving on to parametrics

At the Technical University of Berlin (TU Berlin), Professor Horst Nowacki developed the concept of parametric ship hull descriptions. In hindsight the idea was simple, but a crucial breakthrough for ship hull optimisation. Rather than using offset points (each described by three coordinates), parameters for smooth curves and surfaces were used, reducing the number of free variables and thus computational effort drastically. The approach limited the possible hull forms but resulted in generally reasonable and smooth designs. Another important building block from a ship designer's perspective was coupling mathematical form parameters to naval architectural parameters, such as block coefficient, longitudinal centre of buoyancy and length between perpendiculars. This allowed designers to think in naval architect terms and made subsequent software much more user-friendly for the maritime community.

Concept exploration models (later labelled Design of Experiments or DoE) are merged with formal optimisation under the misnomer 'multi-criteria optimisation', charting the influence of design parameters on multiple objectives before deciding on constraints and weights for individual objectives. While the terminology may be debated, the approach allows design elucidation, helping users to decide what they want and are willing to trade off in a design.

By the late 1990s, Dr Stefan Harries combined parametric hull variation, CFD-based resistance and formal optimisation, paving the way for market-ready applications in the following decade. Various developments contributed to the uptake of hull optimisation at this time. Parallel computing became broadly available and affordable. 'Open' became a widely embraced buzzword in the IT community, with open operating systems such as Unix, open software shared on the internet, and open minds in research and industry connecting software across continents, operating systems and dedicated software systems. Island solutions were connected through software like the Friendship-Framework (now CAESES, see Fig 3), and multi-disciplinary design optimisation (MDO) platform, modeFRONTIER.

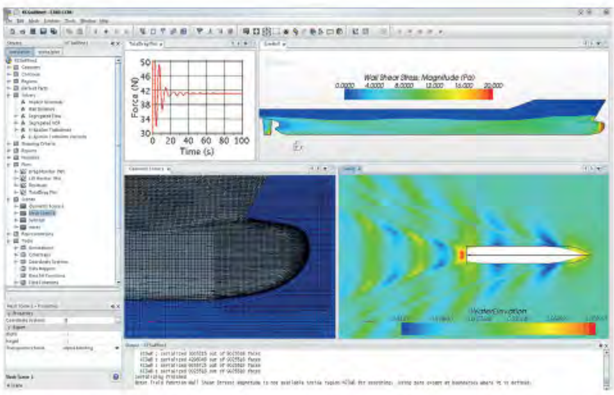


FIG 3: FRIENDSHIP FRAMEWORK, NOW KNOWN AS CAESES – CAD FOR AUTOMATED SHIP OPTIMISATION

While wave resistance codes remained popular, we began to see the emergence of free-surface RANSE solvers in CFD during this time. These codes capture breaking waves, boundary layers and propellers, allowing the simulation of ship and propeller together, moving from resistance to power and from numerical towing tanks to numerical sea trials.

Turn of the millennium

The first 10 years of the millennium may be described as a decade of commercial professionalisation for ship hull optimisation. All the building blocks were in place: parametric descriptions allowing for efficient automatic design generation of realistic hulls, CFD methods for sufficiently accurate assessment of the hydrodynamic performance, robust optimisation algorithms enabling parallel exploration and optimisation of designs, IT infrastructure to manage diverse software across different locations and operating systems, and a work force skilled in performing these tasks.

Focus was no longer on the methodology but on the applications, which covered a wide range of ships, from slow tankers to fast semi-displacement yachts. Applying hull optimisation had become widely accepted as best practice in the industry, with most new designs in Europe and the Far East subject to some sort of lines optimisation. The scope and sophistication of the employed computational models still varied, especially on the CFD side, but hull optimisation had become a standard requirement in building contracts.

A typical case study may illustrate how state-of-the-art hull form optimisation was applied in 2010. The 2008 fuel price shock had boosted the adoption of hull optimisation in the industry and the previous copy and paste approach to ship design had been replaced by the quest for fuel efficiency, paired with the adoption of lower design speeds. The concept at hand was a 9,500TEU container vessel (see Fig 4). The starting point was a parametric hull description using 86 free-form parameters for hull form variation. The optimisation used a low-fidelity CFD solver (wave resistance code) first and then refined the search using fewer variations and a high-fidelity (RANSE) code. Base design and optimised design were tested at the Hamburg Ship Model Basin (HSVA) showing a two-digit improvement in the required power of the optimised design. Such a change could save some US$90 million over the lifetime of each ship in the series. Based on these results, the cost of the optimisation would be recovered within just the first few days of operation.

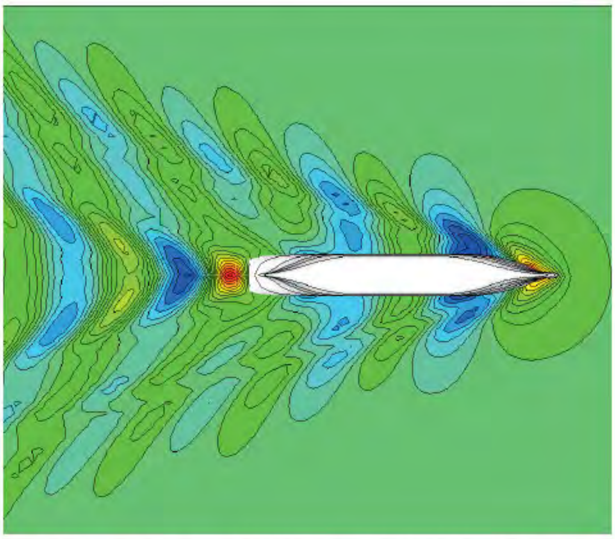


FIG 4: CONTAINER SHIP HULL OPTIMISATION USING LOW-FIDELITY CFD SOLVER AND RANSE

Varied results

Potential for improvement varies, depending on ship speed and on how much effort was already spent on the base design. The yearly fuel consumption for propulsion (excluding hotel load) may improve by up to 20%, but 4-6% is the typical result in many projects.

The development of hull optimisation continues to evolve, not least as energy efficiency is once again on everybody's agenda as a result of rising fuel prices due to the 2020 global sulphur cap and IMO's decarbonisation targets. Cloud computing – renting 'unlimited' hardware and software as a service over the internet – has been one of the latest developments. The growth in computing power, available for everyone, lays the foundation for more advanced optimisation applications. More sophisticated models are also evolving, adding complexity in various forms.

We have progressed from optimisation for a design point to optimisation for operational profiles, reflecting more realistic variations in speed and draft. The logical continuation is also considering realistic ambient spectra, rather than adding a traditional 15% for all designs as a 'sea margin'. Optimisation for slower speeds, reflecting the added resistance in waves, may lead to designs with straight bow contours and no bulbous bow.

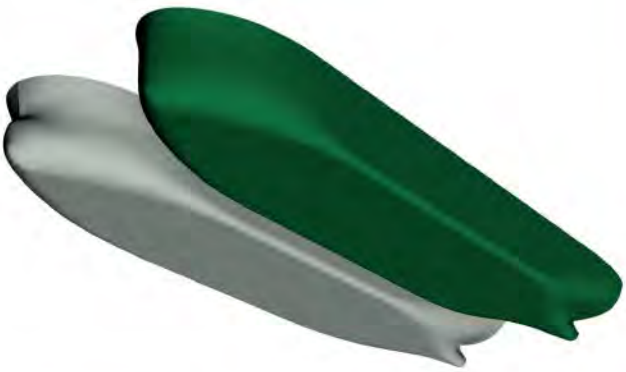


FIG 5: HULL OPTIMISATION FOR SUB-OPTIMAL SPEEDS

Both geometrical and hydrodynamic models are increasing in complexity. What was once a bare hull is now a hull with propeller, rudder and appendages, such as propulsion improving devices and asymmetric hull geometries in the aftbody. This comes with a more sophisticated hydrodynamic model to achieve full-scale, viscous flow computations. The computational price for such high-fidelity models is high, but the additional gains of 2-3% are well worth it in most cases.

Over the past 50 years, hull optimisation has progressed from exotic research to the widely accepted state-of-the-art in hull design. And we haven't reached the end of our journey in this field. There is still a lot to be optimised about optimisation...

SHIPPING'S SMARTER TOMORROW

Although still in its relative infancy, digital shipping is opening up possibilities that were unimaginable half a century ago, says naval architect Paivi Haikkola, Ecosystem Lead at One Sea, the Finnish-led multi-company partnership that's aiming to realise an autonomous maritime ecosystem by 2025.

She comments: "Today, digital tools are central to the evaluation ship performance through all stages of design, with software and data analytics deployed to optimise everything from structures to ship layouts and propulsion performance.

"Where hydrodynamics have long relied on model testing, for example, the picture is slowly changing as CFD programs better emulate real conditions. FEM, meanwhile, has been used for some time in ship design, but here too increased computing capacity is helping designers offer novel solutions covering structural strength, using calculations to meet goal-based rules. These tools are supporting the design of ships that are safer and offer larger carrying capacities and – at the same time – use less energy.

"The use of digital technologies is therefore the smart thing to do, but this does not a 'smart ship' make. Rather, One Sea's members and other actors aim to create a vessel with the technologies onboard which makes it operationally 'smart'.

Trim optimisation, remote systems monitoring and advanced voyage planning, for example, are becoming increasingly common onboard new ships, while situational awareness and advisory systems have been widely acknowledged as tools which enhance safety. And, if ships can be smart today, digitalisation in harbours, enhanced ship-shore connectivity and the emergence of Edge Computing suggest that, tomorrow, ships will be smarter still."

PAIVI HAIKKOLA

HOW CAD TOOLS HAVE CHANGED SHIP DESIGN AND CONSTRUCTION

By **Rodrigo Perez Fernandez**, SENER

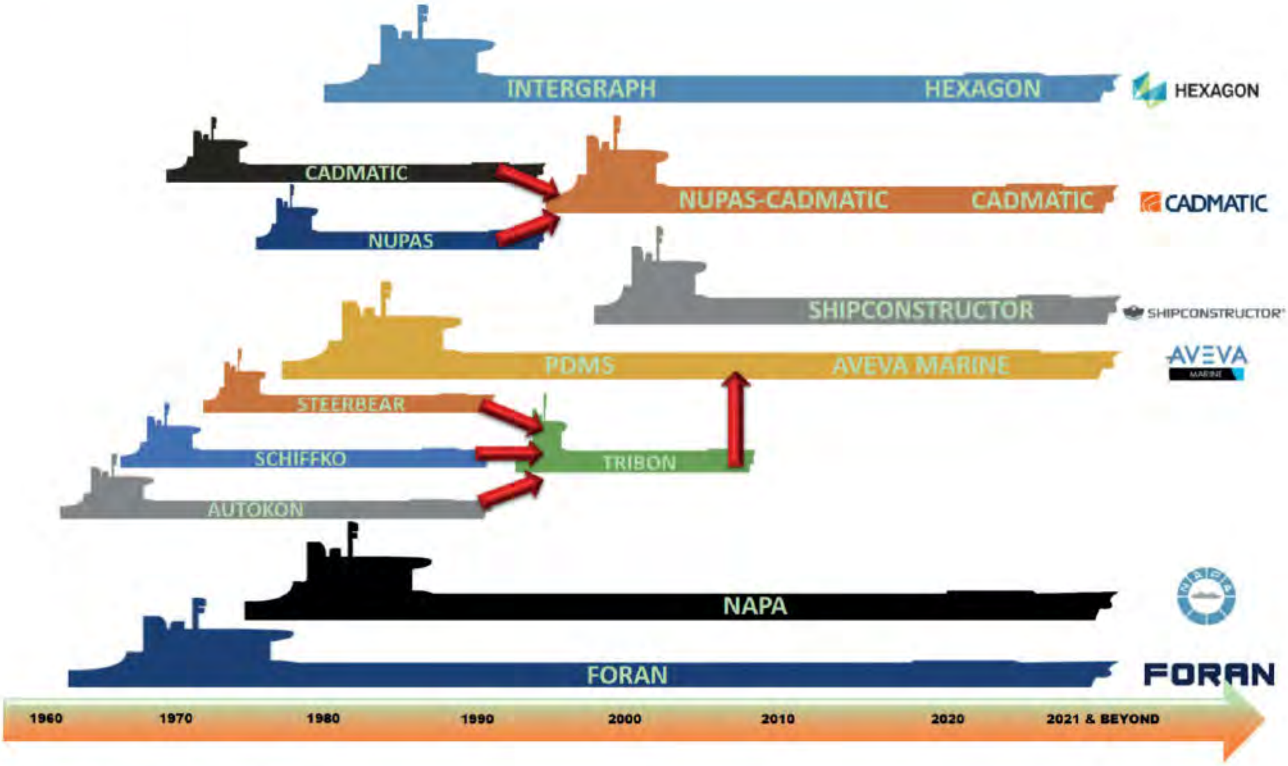


FIG 1: HISTORICAL CAD SYSTEMS TIMELINE

There are many advantages of using computer-aided design (CAD) systems in shipbuilding, be it ease of design, speed of construction or the use and reuse of information. It is expected that in the future CAD tools will advance further and allow greater information management though artificial intelligence and virtual access on smart devices. In general, CAD systems provide tangible benefits while the process is optimised, reducing design time and production, and therefore costs.

Other compositions usually accompany the acronym CAD, such as computer-aided manufacturing (CAM), computer-aided engineering (CAE), and computer integrated manufacturing (CIM), including instructions to computer numerical control (CNC) machines.

One could claim that these CAD/CAM/CAE tools had their origin around the year 350 BC, with Greek mathematician Euclid of Alexandria. Many of the postulates and axioms used by today's CAD systems are based on Euclidean geometry. Some 2,300 years later, most see the birth of 3D CAD with the work of Pierre Bezier, a French engineer at the Arts et Métiers ParisTech. After his mathematical work concerning surfaces, he developed (between 1966 and 1968) a CAD system to ease the design of parts and tools for the automotive industry, known as UNISURF. This became the working base for the following generations of CAD software. Only one decade later, CAD systems were introduced in academic courses. But the real breakthrough came, logically, with the development of computers, and during the 1980s the application of CAD systems matured to a similar stage as is seen today.

The history of CAD systems

It can be argued that the first shipbuilders were the Egyptians, with sewn joints observed on the Cheops Ship – a boat discovered near the Great Pyramid of Giza thought to originate around 2600 BC. All Mediterranean civilisations (Greeks, Carthaginians and Romans) subsequently improved their fleets, as they were established as naval and military powers. These techniques were perfected by the Venetians from the 13th to 16th century, when they began to define the form of a ship's frames in terms of tangent continuous circular arcs, or 'biarcs' in modern dialect. A biarc is commonly used in geometric modelling and computer graphics; it is composed of two consecutive circular arcs with an identical tangent at the connecting point. The ship hull was obtained by varying the frames' shapes along the keel, an early manifestation of today's tensor product surface definitions.

In the late 19th and early 20th centuries, the frames of a steel ship were stood up on the keel like those of a wooden ship and the plates attached later. Frames had to be shaped to match the curves of the hull design. Each one was heated in a forge and then hammered or jacked to match the shape of its template. At the time, it was not easy fairing the hull. Flexible sticks called battens were used for fairing the lines, which were then transferred onto full-sized moulds (or patters) sawn from thin wood.

Throughout the first half of the 20th century, ships were getting bigger and it was necessary to work on larger scales. Vessel templates allowed for different options, such as the widely used 1:10 scale. But with ship sizes growing, the moment came when it was no longer practical to use them. This happened at a time when the first computers came into the industry, promoting the development of ship design CAD systems.

Traditionally, most shipbuilding CAD systems focused on hull form definition, naval architecture calculations and structural design. This changed with new challenges in shipbuilding, demanding closer coordination between hull structure and outfitting. Some marine CAD systems started developing particular outfitting tools, others tried to find closer integration with existing plant design oriented systems. Ship design has problems to be resolved, regulations and working procedures that are so particular to the specialism that it is convenient to have a dedicated tool, rather than try to adapt an existing one. As time goes by, outfitting tools have had an increasingly broad scope of support.

Today, tools usually include environments for equipment modelling and layout, piping and heating, ventilating and air conditioning (HVAC) ducts routing, definition of auxiliary structures and of distributor supports and hangers. In some cases, electrical and accommodation aspects are also considered. Particularities of outfitting design require work in a pure 3D environment and with a friendly and suitable user interface, but new developments in outfitting tools have been always handicapped by the available technology. Nowadays, it is commonly assumed that these tools should be able to work in a solid visualisation method, with huge amounts of information on the scene being dynamically handled.

Origin and evolution

FORAN, a Spanish acronym of FORmas ANalíticas (ANalytic FORms), has probably the longest tradition among the shipbuilding software currently in the market (see Fig 1). It was developed using mathematical formulas to represent the underwater hull in a system structured on modules. Soon it was realised that mathematical descriptions of ship hull forms could be used not only to represent or fair existing hull forms, but also to generate new forms starting from a set of main ship dimensions and coefficients. At the same time, another successful CAD/CAM program, Autokon, was first used in 1963. It was promoted by Trygve Reenskaug, a Norwegian computer scientist and professor emeritus of the University of Oslo.

From the 1970s, CAD tools functionalities were expanded to include structure, machinery, piping, electrical and beyond. This evolution ran parallel to the course of computers, from large units operated with punching cards and modules running on mainframes only available for the largest shipyards, through to the mini-computers like PRIME or VAX with monochrome graphical screens. The UNIX operating system quickly followed, moving work on PCs forward, with amazing graphics and computing capabilities.

The current situation

One of the first tasks in CAD is the definition of hull forms, including external hull, decks, bulkheads, appendages and superstructures. In CADs, the geometrical representation for all these surfaces is frequently based on trimmed non-uniform rational basis spline (NURBS) patches, Bezier patches, ruled surfaces and implicit surfaces as planes, cylinders, spheres and cones. More recently, some systems have incorporated an additional functionality based on the latest generation of mechanical design that, by means of target driven deformation to improve design creativity and final shape quality, can be used to further develop hull forms, thus implementing parametric design and global surface modelling.

For the hull structure definition, there are several approaches according to the philosophy of each CAD system. There are mechanical, parametrical and topological ones. Despite the capabilities of 2D or 3D structure modelling, an important aspect refers to the design-for-production concept, which is based on build strategy; the CAD system must be able to establish and organise a project in accordance with the manufacturing and assembly processes taking place in the shipyard.

The full product model is typically organised into a hierarchy of intermediate products and may create alternative build strategies. This allows for the creation of interactive intermediates functions, allocation of parts, the possibility of classifying using the configurable attributes for each product type, and the definition of the assembly sequence, so that drawings and intermediates lists can be generated automatically. Currently, CAD systems can independently calculate welding lengths and type classification according to various criteria (position and assembly interim level), yielding welding reports and drawings. The systems generally provide solutions to produce nested plates and profiles in line with the standards of the yard, its means of production and manufacturing methods.

Shipbuilding's trend towards pre-outfitting blocks and sections to the highest possible level makes it compulsory that outfitting must be fully coordinated with the rest of the design. All aspects of the design become small pieces of the vessel puzzle, and failure in any one of them could produce failure in others. The earlier such problems occur, the more serious the consequences are. It is therefore essential to have a complete control of the design, particularly for the outfitting phase. Here, modifications affect all the stages, normally due to starting activities early when the design is still immature. Changes due to class society comments, owner requirements and availability of equipment are common, as such it is imperative to manage these outfitting alterations efficiently.

Efficiency benefits

Although there are large variations due to ship type, on average 50% of the design cost is related to outfitting tasks, 40% to hull structure and the remaining 10% to electrical. Based on these numbers, and assuming 7-10% of the total price of the ship are attributed to design, we have outfitting design accounting for 3-5% of the vessel's entire budget. Not only that, but an efficient outfitting design equates to a quality project and this has a direct impact on the cost of overall construction. Considering that, within this construction cost, 40% is related to outfitting tasks, decisions taken during the outfitting design phase impact more than 35% of the total cost of the ship. An efficient outfitting design is an opportunity to dramatically reduce charges and improve productivity.

Achieving 100% valid production information requires an interference-free design. It is necessary to identify interferences between all the elements of the 3D model directly when an element is added or modified in the model. This must take into account not only the elements visible but also any stored in the database, including insulation, operating spaces, escape routes and more. The CAD system must provide tools to classify the detected interferences (soft or hard), to eventually approve them, and to generate detailed reports. On top of that, suitable tools must solve interferences identified in an online regime. Interference detection algorithms must be optimised to avoid negative effects on performance and system response time due to the online calculation process.

The future of CAD tools

There are a number of fields where CAD systems could improve in the near future. Most of them related to the Fourth Industrial Revolution (Industry 4.0) with its digital twins and artificial intelligence. These technologies will take the automation of manufacturing processes to a new level by introducing customised and flexible mass production technologies. Machines will operate independently or cooperate with humans in creating a customer-oriented production field that constantly works on maintaining itself. The manufacturers will be able to communicate with computers rather than operate them.

To perform all the above integrations a network is required, which will support different ways of connecting specific devices, for example Internet of Things (IoT). This could access data, creating and modifying it in a separate layer, which then affects the basic information layer created by the CAD system in the shipyard.

The coming years bring with them several scenarios for improvement. Some may seem unrealistic in the short term, but reality often exceeds expectations in any field and probably even more so in technology.

FIG 2: IDEALISTIC REPRESENTATION OF A 3D CAD MODEL AND ITS CONNECTION WITH THE FOURTH INDUSTRIAL REVOLUTION

FIVE DECADES OF EVOLUTION IN SHIP AND PORT SIMULATION

By **Keith Hutchinson**, Senior Consultant, Safinah Group

First introduced exactly half a century ago – the same time as the publication of the first issue of *The Naval Architect* – the use of ship and port simulation has a long and interesting history at South Shields Marine School. The school is the world's oldest purpose-built maritime training centre, founded in 1861, and has constantly been at the forefront of the education of mariners from both the North East of England and the world. It is one of the global leaders in the use and development of marine simulation techniques not only for the training of both deck and engineering officers but, because of their capabilities in ship and geographic digital modelling, also for research, forensic analyses and design evaluations by naval architects and civil engineers. In recognition of its expertise, it was awarded the prestigious Queen's Anniversary Prize for Higher and Further Education in 2019. This article briefly describes the evolution in ship and port simulation over the past 50 years through discussing the developments at South Shields Marine School.

First generation

The earliest simulator installed at South Shields Marine School was a Solartron Type SY2010 Marine RADAR Simulator, in 1971. This solid state electro-mechanical RADAR training aid was only capable of producing a RADAR display on one Decca 808 Transar RADAR set. At the time, the standard installation was two 'own-ship' cubicles with a RADAR set in each, but by adding another equipment and splitter boxes it was possible to control four cubicles. Each exercise was controlled by the instructor via adjusting various analogue knobs, switches and dials, with the 'own-ships' being operated at either a 0-30knots range for displacement ships or 0-90knots for hovercraft and hydrofoils. Wind effects on the 'own-ship' were an optional extra and tidal effects only affected displacement ships. This simulator was obviously very limited, however it facilitated understanding and the practical use of a moving RADAR display, which 50 years ago represented a significant advancement.

Second generation

By the late 1970s there had been much progress, and between 1979 and 1982 two new ship simulation systems were installed, namely the Racal Decca Nocturnal Ship Simulator, developed for the Ship and Marine Technology Requirements Board of the Department of Industry, and the Solartron SY 2086 Schlumberger / PDP11 RADAR Simulator.

As can be seen from Fig 1, the Racal Decca system provided a realistic one bridge 'ship-handling' environment for route navigation and collision avoidance etc. utilising real bridge instruments and controls but, due to the technical limitations of the time, the visual presentation was only that of a night scene. By shining spot projectors, which were controlled to move side to side onto a translucent screen, a feeling of movement could be created, and utilising a photograph on an overhead projector transparency a surprisingly convincing visual of the deck ahead of the Bridge could be created. The simulator was able to reproduce the characteristics of four ships, ranging from a coaster to a 500,000tonne deadweight oil tanker. It used a 2 Degree of Freedom (DoF), namely surge and sway, mathematical model developed jointly by the National Physical Laboratory (NPL) and Decca. The system had other limitations, namely there was no modelling tool to create additional ship models and there was limited support from Racal Decca.

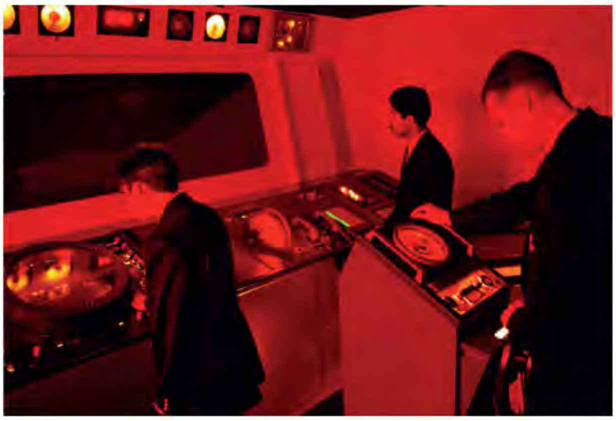


FIG 1: RACAL DECCA 'NOCTURNAL' SHIP SIMULATOR

Third generation

During the 1990s the rise of the personal computer and ethernet networks resulted in the power and sophistication of ship simulation systems becoming less a function of hardware but rather the development of software. Software-based solutions result in systems with greater flexibility, more functionality, have a modular and hence scalable architecture, as well as providing easier and more cost-effective installation and maintenance. Most importantly, such digital computer technologies offered significantly greater processing power and hence the ability to model the behaviour of ships far more realistically, including daytime visuals and in 6-DoF.

In 1997, it was decided to invest in this new generation of simulator. Those chosen were the Kongsberg Maritime Polaris Bridge and Neptune Engine Simulation systems. These were housed in the new Marine Simulation Centre, which remains one of the most advanced and capable navigational bridge and machinery simulators in existence today. The software and hardware have been continually updated and the capabilities of the simulator enhanced to incorporate facilities such as dynamic positioning, ice interaction, Voith and ASD propulsion, ballasting, power management, etc.

The Polaris Simulator consists of a total of six navigational bridges with photo-textured day / night visuals and full instrumentation, controls, RADAR / ARPA, ECDIS etc. – two of which are full mission bridges with 360-degree field of view (see Fig 2) and four bridges with a 120-degree visual field of view. All bridges have the capability to be used in various configurations, together or individually, to support training, consultancy, forensic analyses, design, and research requirements. There are also eight secondary bridges for NAEST and ECDIS courses. The simulator may be configured with one or more instructor stations to design exercises, select


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FIG 2: BRIDGE SIMULATOR: MAIN BRIDGE 'NORTHUMBRIA'

geographic 'areas', 'own-ships', 'targets' and environmental conditions, and control and monitor the exercises; networked with one or more full mission bridges, other bridges are available via multiple desktop stations.

The Neptune Simulator is a full mission control and engine room simulator consisting of a control room (with consoles that house main engine controls, plant alarm, generator control, pump and compressor controls and oil-fired boiler control panels), an engine room area located on two levels with full sound and environmental conditions (as shown in Fig 3), watch keeping cabin for Unmanned Machinery Space (UMS) operations and an emergency switchboard room. Various propulsion configurations can be simulated, such as various liquid and dual-fuel large slow-speed diesels, liquid and dual-fuel medium-speed diesels, diesel electric power plants, dual-fuel steam turbines, gas turbine installations, etc.

There is also a separate Vessel Traffic Services (VTS) simulation suite. This, together the bridge and engine simulators, can also be combined into a joint exercise, in addition to obviously being operated independently.

Fourth generation

The requirements for additional functionality and improvements have made the upgrading of the Polaris software for higher end simulation increasingly difficult. Therefore, over the past few years the next generation of Kongsberg simulator, K-Sim, has been extensively evaluated and has now been implemented alongside the Polaris platform.

FIG 3: ENGINE SIMULATOR: MAIN ENGINE ROOM FLAT

One of the main features of the K-Sim platform is that instead of simple 'targets' there are also hydrodynamic 'objects' which possess full hydrodynamic properties, hence facilitating full interaction between 'own-ships' and 'objects'. Therefore, previous 'target' tugs are now replaced by hydrodynamic 'objects' having all the physical properties of the tug. This is equivalent to using an 'own-ship' under operator control, which facilitates much greater fidelity to the simulation. All 'own-ships' now feature a fully-fendered 3D 'mesh' hull which allows the 'own-ship' model to interact correctly with 'objects' such as piers, fenders etc. and respond accordingly to other stimuli and forces, and so the intricacies of design details can be robustly evaluated and correctly configured.

The advanced mathematical software core also allows items such as containers to be loaded on deck and the ship model will subsequently heel and trim appropriately in real-time. It also facilitates precise stress levels of ropes, lines, and chains to be evaluated and incorporated into simulations. Cargo holds / tanks, pipes, valves, pumps etc. can be accurately modelled, facilitating real-time alteration of a ship's loading condition. Likewise, propulsion systems can incorporate fuel consumption, fuel tanks, valves etc. together with generator sets and power management systems. Hence, there is now the ability to fully simulate scenarios such as float-off operations from barges. This includes ballasting down of the barge and the subsequent float-off of the cargo, such as those undertaken recently for the hull sections of the Royal Navy's new Queen Elizabeth Class aircraft carriers.

The instructor station running the simulation now gives a 3D view in addition to a 2D one, which gives the operator greater control over the operations. Another feature is that the simulation can run across geographic 'area' databases if they overlap, which allows for longer continuous voyages. As can be seen from Figs 4 and 5, today the visuals are extremely realistic and are either projected on to screens or displayed on 4K monitors, hence simulators are now actively used for producing presentation videos for ship and port designs. Bridges with a 360-degree field

FIG 4: TYPICAL GEOGRAPHICAL 'AREA': THE RIVER TYNE WITH A CRUISE SHIP, TUG AND PILOT LAUNCH

of view are common, as are subwoofers, and some simulators include motion platforms.

Modelling of bespoke ships, ports and advanced simulation

Simulation can be broadly divided in to three categories:

1. **Training** – Initially this was simply for navigation but, as simulators developed, ship handling was added. With more realistic systems, simulators became a technical training tool for RADAR, ECDIS, GMDSS, etc. Recently, human element training has also been introduced;

2. **Consultancy** – Research, forensic analysis, exploration of design / operational envelopes and development of solutions / procedures for ships and ports by naval architects and civil engineers;

3. **Human Factors** – Traditional design procedures typically neglect the human interface and real-life dynamic demands, however these are implicit within a 'real-life' simulator. To be successful, it is important that designs match human capabilities and account for personnel with the appropriate, not expert, skill levels. In addition, Bridge and Crew Resource Management (BRM / CRM), risk assessments, leadership and management, decision making etc. are coming to the fore in the maritime industry. Simulation is becoming more acknowledged as a key tool in both ship and port design, but it is imperative that this is included in the earliest phases in order to identify issues before the designs are frozen.

Most institutions only undertake simulator training. However, South Shields Marine School undertakes all the above aspects. Since the late 1990s, it has been one of only two centres in the United Kingdom, and the only teaching college, to create bespoke, accurate mathematical models together with detailed 3D visual representations of ships, ports and marine geographic sailing 'areas'. Such modelling requires specialist knowledge of naval architecture and marine engineering, ship operations as well as the simulation and 3D graphical systems. This modelling is predominantly undertaken by the in-house team. However, occasionally the author, as a ship designer, supports the team as required – an arrangement that has existed for over two decades.

Over the past two decades an enviable digital library of models for over 200 'own-ships', such as shown in Fig 4 containing the correct hydrostatic / hydrodynamic / resistance and propulsion characteristics etc., and 120 ports / sea 'areas', such as shown Fig 5, have been created. These have been utilised by a variety companies and ports authorities / pilots for bespoke training of key personnel and development of procedures, by experts undertaking forensic analyses of incidents and by naval architects and civil engineers undertaking design evaluations for ships, ports, channels, bridges, etc. In addition to formal commissions, other models such as the iconic historic ships *SY Turbinia* and *RMS Mauretania* have also been created.

A regular request by port authorities and pilots is the trialling of new ships and then studying how the vessels will impact on the existing, or improved, port berths and assessment of any changes to ship handling procedures. Such a commission requires both modelling of the proposed new berths as well as the ships. In addition, this type of simulation typically needs the provision of qualified and experienced personnel to act as Masters, Pilots and Tug Masters, all of whom can be provided as and when required.

Simulation is being increasing used in civil engineering projects where the assets directly interact with the marine environment. Commissions have involved several bridges where there were concerns for the safe navigation of ships given the wind and current conditions and also the safety of the bridge from damage by vessels. Tasks have even included determining the most effective layout of navigation lights.

Advanced simulation is now frequently being used in the determination of power management programmes, incorporating human frailties rather than purely physical drivers. Similarly, the ability to accurately measure fuel consumption during a simulation has allowed ferry companies to develop standard manoeuvring procedures for berthing and unberthing to minimise fuel consumption.

Conclusions

The significant development of ship simulation over the past five decades is without doubt. However, what has not changed is the requirement for accurate information describing the ship, geography and environment. In fact, given the sophistication of the current systems this has become more important, as for example the best simulations now use 3D winds and currents rather than homogenised values.

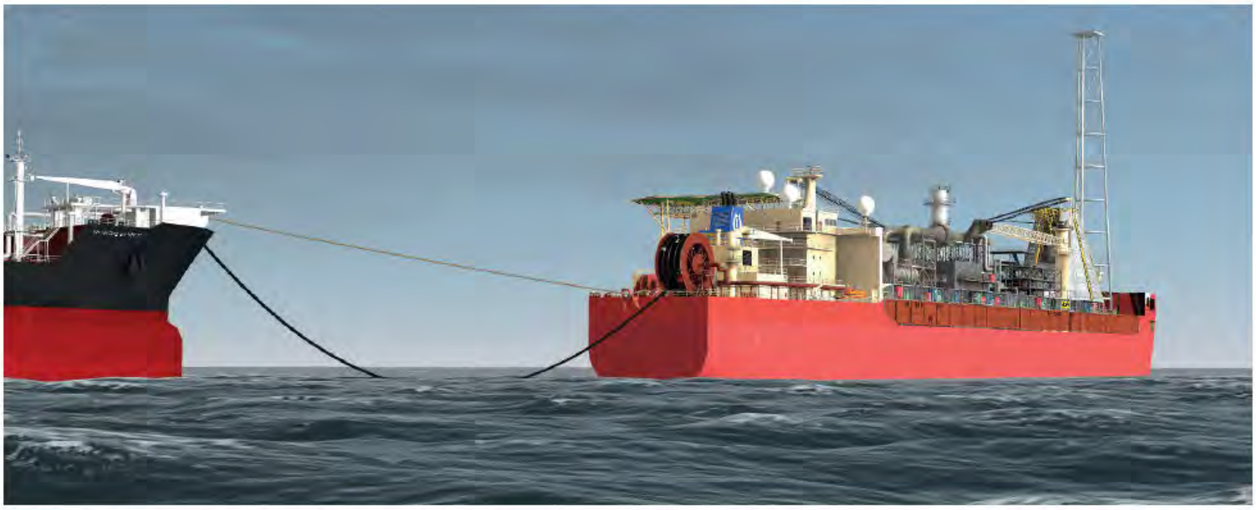


FIG 5 – TYPICAL SHIP MODELS: FPSO OFFLOADING TO A SHUTTLE TANKER

Simulators facilitate limits and boundaries to be explored in a safe and efficient manner, and simulation is no longer simply a training tool but rather an important part of the naval architect's or port designer's toolbox. Therefore, it is imperative that simulation is employed during the earliest possible phases to ensure that any design deficiencies are identified promptly and rectified whilst it is still feasible to do so.

Disclaimer

The views expressed in this article are those of the author and do not necessarily represent those of the organisations with which he is affiliated or the professional institutions of which he is a member.

Acknowledgement

The author would like to acknowledge the assistance of Mel Irving, Research and Development and Advanced Simulation Manager within the South Shields Marine School, for his assistance in the production of this article.

50 YEARS OF PROPELLER DESIGN WITH COMPUTERS

By **Don MacPherson**, HydroComp

When asked to reflect on the use of computers for propeller design over the last 50 years, my first reaction was to think about my own history. I painted houses one summer in the mid-1970s to buy a TRS-80 micro computer system that I took with me to university. One of my first programs at school was to code the B-series KT-KQ (thrust coefficient-torque coefficient) polynomials published just a few years before. That auspicious start offered me the distinct privilege of a career both as a propeller designer and as a developer of design tools. My work has always focused on the practical applied-engineering side of propeller design and computers have been an essential tool from the very beginning.

The use of computers for any engineering design task offers but two significant potential benefits – to minimise the amount of time spent on a task, or reduce the uncertainty of the task's output – and the principal disciplines of propeller design, production and performance, fall in opposite camps.

3D SCAN OF PROPELLER

Design for production

Using computers in the production of propellers distinctly points to the first benefit, reducing the time spent on a task. This is possible only because the result of the task is already known. The deliverable is a representation of the propeller suitable for manufacture. We tend to think of computer-aided design (CAD) as the principal design task for production, but over the last 50 years computers have come to play a much more comprehensive role in geometric design, manufacture, and post-delivery quality assurance.

In some ways, manufacturing processes and design tools evolved hand in hand. Propeller-specific CAD progressed from home-grown spreadsheets producing drawings for the manual layup of patterns, to commercial tools providing outputs for 3D manufacturing technologies. Design drawings and offset tables may seem old-fashioned, but they are still a very important CAD task for documentation and regulatory compliance (such as for class societies). Of course, many production processes are now direct-to-3D, so the computer tools must replace manual lofting and pattern-making skills with expert system guidance.

The introduction of computer numerical control (CNC) milling for propellers also brought about challenges for 3D geometric design. Back when the shapes depicted by drawings and offsets could be manually modified or altered during lofting, a certain amount of tolerance in the representation of the propeller geometry could be accepted. That is not the case with a direct-to-3D representation, since this is the exact shape to be manufactured. Algorithms used for 3D surface modelling often encountered issues at the propeller tip, as the numerically lofted surface converged on a singularity. This required new computer design options for blade stacking and curvature control to create 'CAD-friendly' blade tips.

Post-delivery inspection for quality assurance or repair has also evolved from manual to computer-based processes over the past half-century. With the advent of personal computers, traditional polar-coordinate drop-rod devices were instrumented with digital pickups for use with inspection software. Unfortunately, criteria for acceptable tolerance has not likewise evolved, so the newly connected inspection tools were (and still are) subject to traditional manual-process criteria. Even so, the reduction in time spent on inspection was substantial, bringing about significant improvements in cost and process efficiency. New devices and software are also being integrated with repair equipment, leading to further benefits in cost, time, and even technician safety.

Recent advances in 3D scanning technology have made the development of in-situ propeller inspection possible. While this is currently applied as a 'virtual' device that mimics the traditional polar drop-rod methodology, it is generating interest for the development of new 3D-specific tolerance criteria. In fact, some of our most interesting in-house 'innovation studies' are about matching propeller geometric tolerance to performance outcomes.

Design for performance

Unlike design for production, I hold no illusions that computers offer any time savings in design for performance. It seems like we take more or less the same amount of time now as we did 50 years ago to complete a propeller design task or hydrodynamic study. The real benefit is improved clarity, reduction of uncertainty, and the elimination of over-cautious design margins.

Short of building a propeller and testing it, design for performance is about using proxy models for how a propeller will generate thrust, absorb torque, develop cavitation and noise, and to find the appropriate design parameters that will optimise some of these and limit or avoid others. The evolution of computer hardware and propeller design software over the last 50 years has indeed been remarkable, but has not changed our overall design process all that much.

Let me explain by following the typical propeller design process:

Propeller parameter selection for system design

During initial design, the objective is to determine the principal propeller parameters that will allow the vessel-propulsor-drive system to best function. Parameters might include diameter, mean pitch, shaft rpm, blade area or number of blades. At this stage, we are a long way from needing the fully 3D representation of the propeller. Our proxy performance model is typically semi-empirical and based on systematic series, with corrections as needed to correlate the series to expected in-the-water performance.

Those of my generation will remember the various propeller series 'design charts', such as the Bp-Delta plots. These allowed for hand calculations to identify diameter and pitch for a given propeller type, number of blades, and blade area ratio that will match a prescribed ship speed, power loading and shaft rpm. Secondary design for suitable blade area used other plots that also had an empirical basis. To me, this is 'propeller matching' or 'propeller specification', but regardless of what you call it, these calculations have been made more useful, comprehensive, and essential because of computers. More than just digitising the charts, computer solutions integrate the propeller optimisation function, provide constraints for acceptable cavitation, consider the effect of limitations of engine power production, and can even conduct multiobjective optimisation and evaluate metrics for noise and vibration.

Conduct a wake-adapted propeller design

Once the principal parameters have been established, the following step is to produce a design that is more closely matched to the specific ship and its inflow characteristics. In the earliest part of my career, we relied on a manual combination of charts and hand calculations using a technique called 'circulation theory'. This was a blade-element method that matched the pitch and camber at each radius to the corresponding mean inflow velocity. Blade thickness and chord length were then reviewed for strength and cavitation metrics, while skew and rake were determined based on typical design practices or rules of thumb.

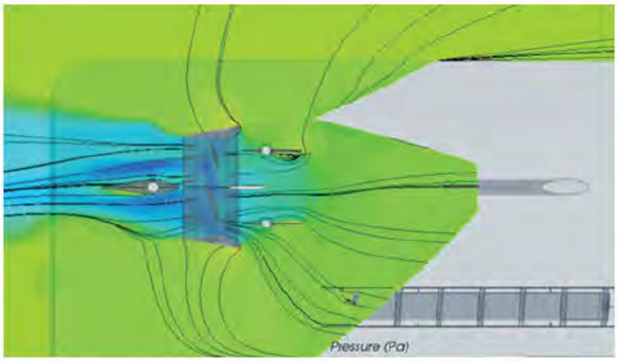
Computer influence on wake-adapted design was indeed significant, as it allowed for better management and evaluation of the various design objectives. Hardware speed improvements (and its effect on the number of computations that could be conducted) opened the door for new analytical code development. Today's wake-adapted propeller design codes are robust, quantitatively very strong, and provide a necessary launching point for the next stage of propeller design that would not be possible without recent advances in computer hardware and software.

Full 3D numerical analysis

Even with the capabilities of wake-adapted computer design tools, there are instances where full 3D numerical analysis codes are essential. These codes are most widely represented by general purpose CFD tools and there are numerous propeller-specific flow codes (used principally by propeller specialists) that would fall into this category.

The significant advantage made possible by these tools is to incorporate hull-propeller interaction into the process, which allows for observation of flow and a level of detail that previously would only be possible with extensive model testing. They can help a designer determine the full inflow wake field, including the effect of appendages or incorporating upstream vortex turbulence that might be shed into the propeller.

Contemporary blade-element and 3D codes offer the best outcomes when used together. As well as mutually validating performance predictions, they can be coupled to take advantage of the hull-propeller interaction provided by 3D codes with the computational efficiency of wake-adapted blade-element tools. This is state-of-the-art design for performance and is something that we could not imagine 50 years ago.



'The evolution of computer hardware and propeller design software over the last 50 years has indeed been remarkable, but has not changed our overall design process all that much.'

The future of propeller design

As we read the tea leaves and prognosticate what another five decades may bring, I reflect back on the early days of personal computers and how we greatly misunderstood the arc of their influence on our lives. It will be very interesting to see the ways new innovation in hardware and software affect how and what we design.

Ever-increasing computational speed means that we can achieve greater precision in in our design, which is undoubtedly a good thing. Yet I wonder how much of the "art of design" will be lost as we place a larger burden on computer codes to conduct propeller design. Hydrodynamics is a messy business. Will we continue to know what design objectives are important? Can the computer juggle all of the design requirements that we as naval architects currently manage? Does it matter?

I think it does. But don't take this as a complaint, a dire warning, or even a longing for "the good old days" (although I suspect I am periodically accused of the latter). Take this as a challenge. To advance our understanding, education and training in the discipline of propeller design in the context of new computational power, and to apply these tools for the best possible outcomes for our clients and customers. Just like we have for the last 50 years.

IMAGE: SHUTTERSTOCK

INLAND & COASTAL VESSELS

HIGHWAY TO ZERO-CARBON SHIPPING

MarRI-UK working group chair, Richard Westgarth of BMT, and MarRI-UK coordinator Dr Tiffany Imron of the University of Strathclyde speak with *The Naval Architect* about the industry-led initiative's latest project, the Zero-carbon Coastal Highway

By **Sophie Collingwood**

It is no secret that the UK's shipbuilding industry is not the powerhouse it once was. But with the publication of the UK Government Department of Transport (DfT)'s long-term strategy for the UK's maritime sector, 'Maritime 50: Navigating the Future', in 2019, ambitious plans for the industry's future are emerging. One particular proposal by industry-led initiative Maritime Research and Innovation UK (MarRI-UK) seeks to both dramatically alter the UK's reliance on road haulage and establish the country as a frontrunner of maritime innovation, its representatives tell *The Naval Architect*: "The ambition being to enable a fundamental shift from traditional transport to one where concepts such as automation, alongside data-driven insights, digitalisation and decarbonisation acquire real meaning and scale for the coming decades."

Jointly developed in 2020 by BAE Systems, Babcock, BMT, Lloyd's Register (LR), Shell, QinetiQ, as well as the University of Newcastle, Southampton, Strathclyde and University College London, the Zero-carbon Costal Highway (ZCH) proposal comprises parallel development of a newbuild fleet and the coastal highway it will operate on. As MarRI-UK explains: "The concept consists of the creation of a clean, digitally-enabled coastal highway that links the UK's existing coastal infrastructure with fit-for-purpose, rapid logistics port interchanges to green, smart and autonomous ships that benefit from the latest advances in autonomy, design and manufacture."

Specialised smaller-scale, technologically advanced shipbuilding, internationally recognised leadership in marine safety and certification via organisations such as LR, and global leadership in small scale naval autonomy, are just a few strengths MarRI-UK regards as proof of the UK's existing maritime expertise and its opportunity to scale up and exploit the ZCH concept. "The UK must drive forward its high-value research and industrial capability in these areas (as opposed to volume manufacturing), where it has the edge and can compete and win globally," MarRI-UK's representatives comment.

The fleet

Central to the coastal highway is the creation of a purpose-built, zero-carbon automated fleet, and MarRI-UK is approaching this task and the wider proposal through three stages of development.

The project will begin in Phase Zero. According to MarRI-UK, this step seeks to use a simulation/model-based approach to establish the economic and operational viability of the concept, which it regards as "an embryonic digital twin". The outcomes of this formative stage will become the

basis for more detailed specification of the project's future design and development activities. At the same time, Phase Zero will consider the corresponding suitable routes, shore infrastructure and ongoing links to a local distribution network through UK road, rail or inland waterways.

Phase One focuses on the actual design, construction and demonstration of a zero-carbon coastal freighter. "(It will be) purposely designed to embrace best-in-class hydrodynamics through innovative coatings and air lubrication, environment-assisted power, coupled with a zero-carbon power-train; overseen by high levels of automation and autonomy to improve efficiencies, safety and scheduling, demonstrating the UK as a scientific superpower in this arena," MarRI-UK states.

More specifically, MarRI-UK's representatives say that current predictions envisage a vessel of length around 80-100m, able to transport up to 200 standard containers (TEU). But they note that the ship's technical particulars are still unknown: "The exact specification will be derived from the outcomes of the Phase Zero modelling and simulation activities. From an engineering perspective, a key feature will be the development of high reliability systems and the reduction of both operating, support and maintenance costs."

The proposal's ambitions grow exponentially in its third step, Phase Two. Building upon the freighter designed in previous stages, Phase Two endeavours to create a 5–10 strong fleet of ships, the so-called 'zero-carbon automated fleet' responsible for transporting a broad range of cargoes in various operating conditions. Due to operate on the coastal highway, this phase also sees the development of the UK's major and regional ports.

The ports and infrastructure

The fleet constructed in Phase Two will operate in an "integrated coastal highway transportation system and infrastructure". Naturally, this has widespread implications on the evolution of UK ports. MarRI-UK intends to select areas for development based on initial freight and economic considerations and, in some cases, recommend transformations.

Of the 120 commercial ports in the UK, ranging from Dover's ferry port to the major container terminal at Felixstowe, up to 50 locations will be altered under the proposal: "Port infrastructure transformation will focus on the integrated Zero-carbon Coastal Highway design based on the lessons learnt and R&D innovations within the whole programme, as well as enhancing up to 50 ports around the coast.

"A key early stage will be in the local changes in port infrastructure. For instance, in bunkering of zero-carbon fuel, goods handling, learning from the many robotic solutions already applied in land-based logistic supply chains."

Measurable emissions reduction

MarRI-UK have predicted a spectrum of benefits for the UK economy as a result of the initiative, such as the creation of 39,000 jobs, an increase of £1.8 billion in coastal shipping revenues and reduction in congestion on the UK strategic road network of approximately 25%. But by far one of the initiative's biggest drivers is a forecasted overall 30–40% reduction of UK emissions deriving from road freight traffic, which MarRI-UK highlights will significantly contribute to the UK Clean Maritime Plan - the UK Government's Maritime 50 environment route map for transitioning to a zero-emission shipping future. So how has this been quantified at such an early stage in the initiative? A case study undertaken by an undisclosed member of MarRI-UK compares the emissions output for the shipment of 100 containers from Scotland to London by road, rail, sea and combinations of the three modes.

The study considered transportation exclusively by road in comparison with the combined method of road and sea. In this scenario, it was found that the average reduction of kgCO_2e/100 containers was 50%. General cargo ships came out on top, providing the maximum reduction of 66% (132,000kgCO_2e/100

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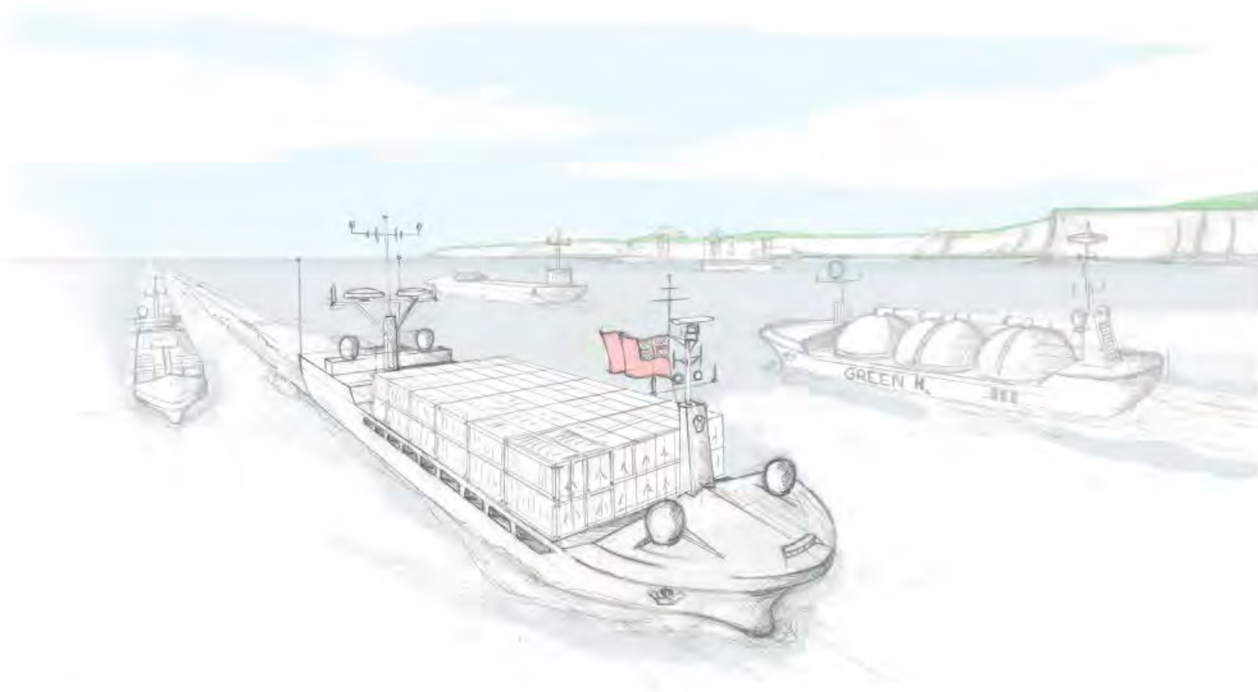


BMT COASTAL HIGHWAY SKETCH SOURCE BMT AND MARRI-UK

containers), whereas utilising ro-ros provided the minimum emissions reduction of 23% (47,000kgCO_2e/100 containers).

Needless to say, a complete move away from road to a mixture of shipping and rail transport proved to be the most efficient way to minimise CO_2 emissions. This method reduced the kgCO_2e/100-container value by 155,000, 78% of what the study recorded for pure road transportation.

MarRI-UK emphasises that the above calculations are based on conventionally powered ships. Taking zero-emission vessels into account, such as those planned for the coastal highway, as well as the above study, MarRI-UK anticipates it can reach its ambitious 30–40% target:

"THE CASE STUDY ILLUSTRATES THAT USING COMBINED RAIL AND THE ZERO-CARBON COASTAL SHIP CAN PROVIDE A POTENTIAL SAVING OF AROUND 190,000KGCO_2E/100-CONTAINERS COMPARED TO ROAD TRANSPORTATION, A REDUCTION OF 95%. BASED ON THESE FIGURES, WE BELIEVE THAT REDUCING LAND-BASED EMISSIONS BY 30-40% THROUGH OUR ZERO-CARBON COASTAL HIGHWAY INITIATIVE IS ACHIEVABLE."

Other emissions

Minimising freight brings with it huge reductions in carbon, but MarRI-UK also highlights the potential reduction in NOx and particulate emissions. According to the DfT's 2018 energy and environment data tables, in 2017 road transport accounted for 32% of total NOx pollution in the UK, 46% of which was from heavy goods vehicles (HGVs) and vans.

However, MarRI-UK's representatives acknowledge that while the coastal highway will massively reduce road transport, it will not be completely eliminated, and the project can also provide alternative ship power provision to alleviate any emissions. "The use of other forms of freight transportation provide the means to relieve pressure from the strategic road network in critical areas, providing a net benefit in terms of improving air quality, reducing carbon emissions and environmental impacts, and improving outcomes for road users," the representatives explain.

It is too early in the proposal's developmental process to say with certainty how effective this net emission approach will be. Aside from its plans for zero-carbon emissions, the project still has a long way to go in finalising its design and exploring propulsion methods and other technology onboard the ships.

The future and funding

MarRI-UK was awaiting a decision on a Comprehensive Spending Review bid it initially published in 2020. It sought £530 million of government co-investment for its Zero-carbon Coastal Highway and was supported by leaders of Society of Maritime Industries (SMI), Associated British Ports, Maritime UK, British Ports Association, UK Major Ports Group, UK Chamber of Shipping, Maritime Skill Alliance, and the Maritime and Coastguard Agency (MCA).

However, unforeseen circumstances caused by Covid-19 have meant the UK Government halting this year's spending review, and MarRI-UK intends to re-submit its bid when the next review opens. Should the ZCH programme receive funding and go ahead as planned, MarRI-UK claims that the proposal will be unlike any approach globally and could place the UK in a competitive position for the future: "Creating a radical new zero-carbon approach to transport goods as part of an integrated autonomous system has not been attempted anywhere in the world and would allow the UK maritime shipbuilding and service sector to sell to the world's ever-expanding need for high-quality advanced maritime transportation. It's also hoped a new stream of commercial opportunity could be created as well as the reignition of British shipbuilding." ■

FUTURE-PROOF TECHNOLOGY EXTENDS SUPPLY CHAIN POSSIBILITIES

By **Mark Jones**, *Scanjet PSM*

Inland and short sea shipping vessels have an essential part to play in support and replenishment applications as well as providing an internal gateway for freight. Access to new smart technology is vital in delivering the efficiency and flexibility to meet heavy operating demands, while protecting crew and valuable cargo.

The last few years have seen significant advances in digitalisation for small and medium ships, as manufacturers like Scanjet PSM work with designers, operators, and engineers to resolve operational issues while providing an economical upgrade solution that offers a comparative level of performance and sophistication with larger ship systems.

Modern digital tank gauging systems are designed to be versatile, capable of handling process control across the full range of shipboard fluid types, from fuel oil and lubricants to ballast water. Intelligent sensors collect real-time data from all onboard storage tanks including anti-rolling tanks and measurement of vessel draught and trim, as well as cargo tanks. The future of digitalisation, however, lies in continual progression and calls for a different approach to systems design to reduce the burdens on overstretched crew members.

SCANJET PSM'S DIGITAL TANK GAUGING SYSTEM (DTGS) IS EQUIPPED WITH NEXT GENERATION INTELLIGENT HYDROSTATIC TRANSMITTERS

Simplicity is key

Scanjet PSM's latest Digital Tank Gauging System (DTGS) is a new breed of tank level measurement solution designed to provide an affordable yet integrated, fully featured and above all, simple system that bridges the gap to meet the needs of not only tugs and OSV's but is also extendable to serve the requirements of larger application-specific vessels designed for inland waterway and coastal use, which may differ greatly in many features such as construction, structure, manufacture, types of transported cargo, and operating conditions.

Ease of installation without the need for specialist knowledge and with clear and versatile information display were key considerations in the development of the DTGS system. Single wire, multi-drop connection via purpose-designed termination modules offers rapid installation, with all transmitters being interrogated and controlled by a new style simple to read centralised display.

A further defining characteristic of this latest solution is the built-in flexibility that enables customer-specific customisation, multiple display locations, and upscaling within the standard design for maximum cost-effectiveness.

Fit for purpose

A key defining requirement for inland waterway and larger coastal supply vessels is the need to cover widely distributed measurement points including cargo tanks and safety monitoring to avoid the landform features and conditions which could capsize and sink larger vessels. One example of this processed by Scanjet PSM was the specification of a tank gauging system for an 80–120m vessel for use in refuelling ships at sea, encompassing 40-plus vessel monitoring points, including typically 12 cargo tanks, which were a key focus of the system.

Another application for the new style tank gauging system is monitoring tanks in barges which traverse the Rhine, Europe's most important inland waterway. These barges, while not oceangoing, are essentially large floating tankers, with fewer but larger cargo tanks.

In this situation, the 7" display VPM hubs can provide multiple distributed acquisition points around the vessel, each of which collect and process area-specific measurement data e.g.,

THE DTGS DISPLAY HUB, WHICH DRAWS TOGETHER SENSOR DATA FROM AROUND THE VESSEL

THE DTGS IS AT HOME ON SMALLER CRAFT SUCH AS TUGS AND OSV'S OR LARGER VESSELS LIKE THE SUPERYACHT *ANDROMEDA*

for fuel tanks. Linked to the central display by an Ethernet cable, these secondary units provide additional 'view on deck' opportunities, critical to the ease of use and high visibility Scanjet PSM sought in redesigning the system. They also enable the ships' crew to access function-critical information directly and swiftly.

The larger bridge areas in these vessels typically allows for more extensive displays. Screens of typically 24 inches offer further display options including graphical and tabular presentation of tabbed pages, providing the opportunity for customisable sections specific to the vessel application and key functions.

Reliability is paramount, especially for coastal vessels. Inbuilt diagnostics and the ability to interrogate all modules from any point on the network, without the need to enter tanks, means routine checks and tests can be carried out easily and quickly. The next generation intelligent hydrostatic transmitters included with this latest system can be pre-configured prior to delivery with all parameters specific to the intended application. This means installers can connect the system and set to work immediately while retaining the ability to fine tune settings on the spot using a laptop computer.

Equally important, should component replacement be required in transit, the smart technology behind the new style hydrostatic sensors allows a new transmitter to be dropped into place and instructed what to do in minutes.

On course for success

Manufacturers and suppliers including Scanjet PSM continue to support the digitalisation process through further innovation. The development of cost-effective scalable solutions is helping to bring the benefits of smart technology in digital tank gauging to medium-sized vessels crucial to the expansion of the supply chain through coastal regions and interior areas including deltas, inland rivers and lagoons, while linking to oceangoing freight and exploration industries. ■

DENMARK

DANISH PROJECT TARGETS ENHANCED VOYAGE MODELLING

An ongoing ShippingLab partnership led by Vessel Performance Solutions will improve performance prediction and decision support

By **Richard Halfhide**

OPERATORS TORM AND LAURITZEN HAVE JOINED FORCES FOR THE PROJECT

Regular readers of *The Naval Architect* may recall our previous coverage of ShippingLab, the non-profit Danish initiative that brings together public bodies, learning institutions and private companies on high-level research projects as part of the country's Blue Denmark maritime ambitions. Building upon the earlier success of the similar Blue INNOship project and supported by investment from the Danish Innovation Fund, ShippingLab is focused on creating what it describes as 'quantifiable value' in three core technology areas: Autonomy, Decarbonisation and Digital Ship Operations.

The latter project, or work package, focuses on vessel modelling with the objective of developing more accurate ship models and better estimating the effects the operating environment has on vessel and system performance. In particular, it is concerned with creating tools necessary for Digital Twins that can exploit high frequency data and improve performance prediction while the vessel is at sea. The project has been developing an advanced diagnostics engine that can serve as a decision support tool for both crew and shoreside staff. It is also working on a crew feedback module intended to promote awareness of vessel performance.

Through detailed analysis of voyages undertaken by the vessels of Danish shipping operators and project partners Torm and J. Lauritzen A/S, it is hoped to identify ways of improving prediction reliability which, despite the progress made in performance monitoring in recent years, remains highly variable. Meanwhile, academic support comes from the University of Southern Denmark, the Technical University of Denmark and the Svendborg International Maritime Academy (SIMAC). In April, it was announced that container operator Hapag-Lloyd will also be joining the group.

Vessel Performance Solutions

Leading the task is Vessel Performance Solutions (VPS), a company started in 2014 by naval architects Kristian Bendix Nielsen and Jakob Buus Petersen, former employees of Maersk Maritime Technology. VPS got an early break when it secured funding for Innoplus, a vessel decision support tool that was developed under the Blue INNOShip umbrella.

"The reason for that was our background at Maersk, and the idea was that competency in vessel performance might be spread out to other Danish shipping companies," Petersen tells *TNA*. "We had funding to do development for three years and it was possible for us to hire people and get a program running. Towards the end of the project the two participating shipping companies [Torm and Lauritzen] were committed to significant fuel savings supported by the software we had developed."

Further growth would come when two additional major shipowners became VPS clients within a short time – namely Maersk Tankers and Hapag-Lloyd – so that the company now

VPS FOUNDERS KRISTIAN BENDIX NIELSEN AND JAKOB BUUS PETERSEN (RIGHT). SOURCE: VPS

provides its solutions to around 1,000 vessels and might be considered one of the major players in this field.

The secret, Petersen believes, is a foundation in the basics: "A lot of people talk about Big Data and the Internet of Things (IoT) but the core element in our service is the old-fashioned noon report. The fact is that every ship operator has an ongoing noon reporting system because they need this data to monitor the ships and for charter party claims, among other things. We're not saying we don't want to have automatic updates, but it's something that's enriching our platform with data, not what we're basing our analysis on."

That pragmatism extends to focusing on vessel performance, rather than spreading into services such as data performance or notoriously complex areas such as weather routing. "We keep to our core competency; to determine and establish the performance of the vessel. Even with poor data we are able to deliver speed and consumption tables and convey to our clients a fast and efficient overview of not only the individual vessel but converting that to establish KPIs for entire fleet performance."

"What we would like is to become a provider of calibrated ship models, with the right speed and consumption. As part of this project we're trying to make RPM predictions an integrated part of this service, which would take our analysis to a whole new level."

Data sources

Petersen stresses that by far the most important thing in vessel modelling remains hull and propeller performance, as well as how the ship compares with the reference levels established immediately after a drydocking. But another source for the VPS application being developed under the ShippingLab project is IoT; collecting information from different onboard sources and combining it in new opportunistic ways. This includes AIS and hindcast weather data; sources which may prove more trustworthy than the noon report. Unlike conventional weather routing, which typically takes a standard route and then applies a variable 'weather factor', Petersen says the project is taking a more academic approach in its voyage modelling.

"What is the weather factor? It's a combination of wind resistance, wave resistance, ocean currents and also takes account of deviation from the shortest route. What we're doing with this project is to take the weather factor and split it up into components, making sure that we calculate each of those as accurately as possible in each and every case. By doing that we hope to be able to take out a lot of uncertainty about the weather factor. Of course, we will also do calculations of the optimum yield, with a combined charter rate and voyage cost, but the difficult part is to calculate those voyage costs as precisely and early as possible."

He speculates that it could ultimately lead to VPS offering weather factors as part of its modelling services. "I don't know the business perspective of this but the partners we have on the project are interested in this calculation of voyage costs becoming more precise, because you don't really know what your profit is going to be until the voyage is done. There's a lot of uncertainty and of course we want to take some of that out."

Benefits of collaboration

Petersen says that ShippingLab, which will now run until August 2022, has brought some notable advantages when it comes to developing VPS's services. He explains: "Everybody says that you need to listen to what the client wants but unless you're in a project with them you're not sure they are committed enough to offer you precise information.

The second major advantage, as a small company without the huge money of Wärtsilä or DNV GL, is we get some funding from the Danish Innovation Fund. In a project like ShippingLab we are forced to develop the right things first, not just do something and see whether the client likes it or not. You have to promise deliverables that the partners actually want."

An additional benefit comes from the involvement of the academic partners. As a highly complex subject, there are obvious benefits to having PhD or postdoctoral students conducting in-depth investigations of the data from a theoretical perspective over an extended period. "The benefit for the universities is that they get access to data and, in us, subject matter experts. We can guide them to research that is not only interesting from an academic point of view, but research that can actually add value for the industry."

There has been some suggestion that a few maritime universities may have been lagging behind when it comes to vessel performance analysis, but Petersen highlights the academic work being done in this field not only in Denmark but also at British campuses such as Southampton and Newcastle. "You can't become an expert at university doing a masters thesis on vessel

THE SHIPPINGLAB PROJECT IS USING HISTORICAL DATA FROM TORM AND J. LAURITZEN A/S, DERIVED FROM AIS, TO IMPROVE ROUTING. SOURCE: SHIPPINGLAB

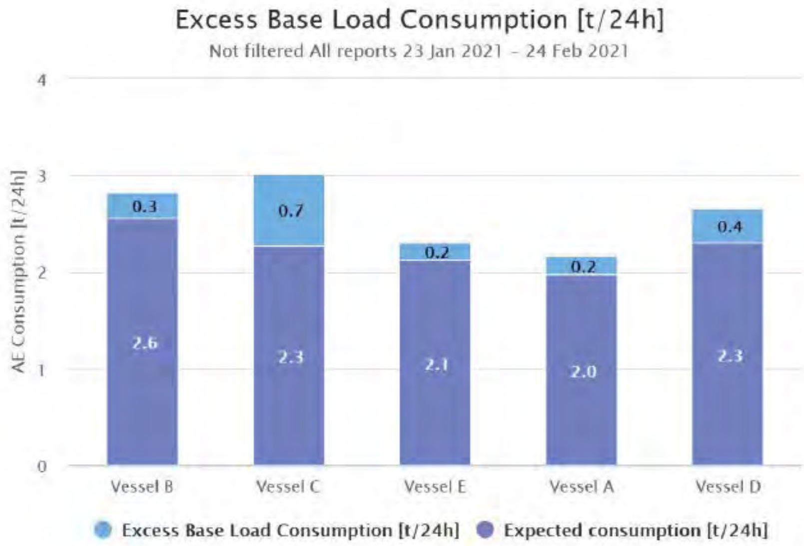


FIG 1: THE CREW FEEDBACK MODULE ALLOWS VESSELS TO SELF-BENCHMARK AGAINST THEIR PEERS. THIS GRAPH SHOWS THE EXPECTED AND ACTUAL DAILY FUEL CONSUMPTION FOR THE AUXILIARY ENGINES ON SISTER VESSELS IN A FLEET. SOURCE: SHIPPINGLAB

performance, but you do develop a good knowledge about what is really happening with a ship at sea and learning about data quality which, with any engineering project, is essential."

Crew feedback

With regards to the feedback module for crew, Petersen says that SIMAC's participation has been invaluable. "If we can somehow design the software in a way that seafarers become interested and pay more attention then the idea is that the process of implementing a scheme to improve vessel efficiency should somehow become self-learning, so it can help the seafarers to help themselves. We hear the same problem from all the shipping companies; they don't have time or money. So we have to find other means of getting seafarers involved in the process. From SIMAC's point of view they would like to be able to teach seafarers something about efficiency on the ship."

Already in its advanced stages, the module is being rolled out on some of the project partner's vessels and fully configurable so that shipping companies can choose what's shown to the crew according to their particular priorities. "They can see things like the fuel performance and consumption, as well as instructions from the office and check how they are performing compared to that... For a shipping company it's a good selling point to take responsibility for educating the crew with a piece of software, however it creates some requirements in terms of the quality of the feedback that you're sending out to the ship, because if the vessel sees something that is not correct they will lose trust in the software immediately."

A further complication could arise if the operator is unwilling or unable to provide the shoreside support to respond to that feedback. Petersen admits this could prove a deterrent to some less progressive operators taking up the module, at least to begin with, since they are asset-light and charter in vessels from owning companies that in turn will see no commercial advantage to improving their performance in this way.

An evolving discipline

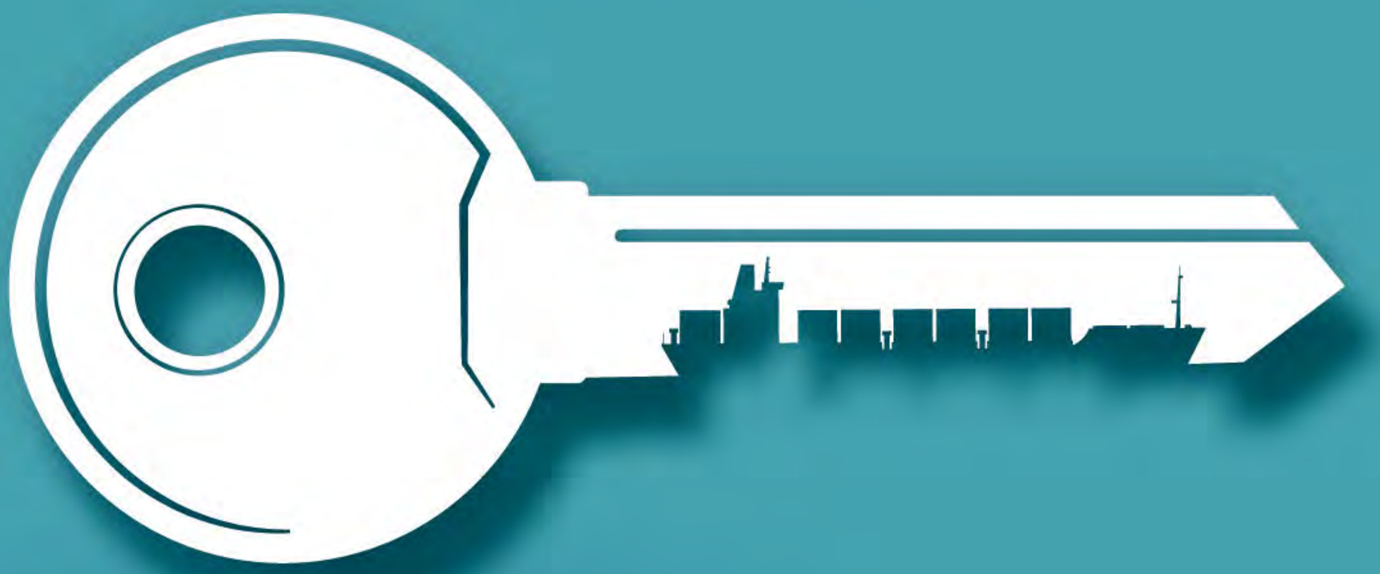
Vessel performance analysis is a subject about which there remain misconceptions and a general lack of expertise. The quality of data obtained from ships can vary enormously. Even those that have been automatically logging data for years may find it proves worthless if the sensors haven't been working correctly for periods of time without detection. "People need to understand that fuel savings don't come from software, but the actions that people make based on the decision support you get from that software," cautions Petersen. He adds: "One of the challenges in this area is that people are reporting to fulfil the charter party requirements and not necessarily what is happening on the ship."

Likewise, the improved modelling that's making higher order diagnostics possible cannot compensate for a lack of qualified personnel at the shipping companies, given that vessel performance management and analysis is a relatively new discipline. "We have just released the first advanced diagnostics rule where there will be a direct recommendation to the superintendent or crew that something seems to be wrong.

"Shipping companies don't want to have an army of people working on this, they would rather it could be solved by itself. It's a bit naive but we can see that there will be a demand in the future for suppliers that can give you that ability to bypass having an army of detectives and performance analysts and give you an immediate conclusion.

"Ten years ago, the function of a vessel performance department didn't exist. Today you see it in every shipping company; sometimes it's a big function, sometimes a small one, sometimes they report to the CEO and sometimes far down in the organisational diagram. There are many people working in this area, but very few real experts. Vessel performancce and optimisation is something you have to do by working the data, either directly within a shipping company or using external service providers. The advantage of using an external service provider is that your data and algorithms are in a "safe house".

Petersen's point is that smaller and medium sized companies run a risk by developing their own software and competences, as such developments will always depend on a few experts that can quickly decide to pursue new adventiures in other positions. "I think it's fair to say that for shipping companies learning how to use that information and make it part of their procedures is a huge change management process," he concludes. ■



MAN SHOWCASES ME-GA ENGINE

By **Richard Halfhide**

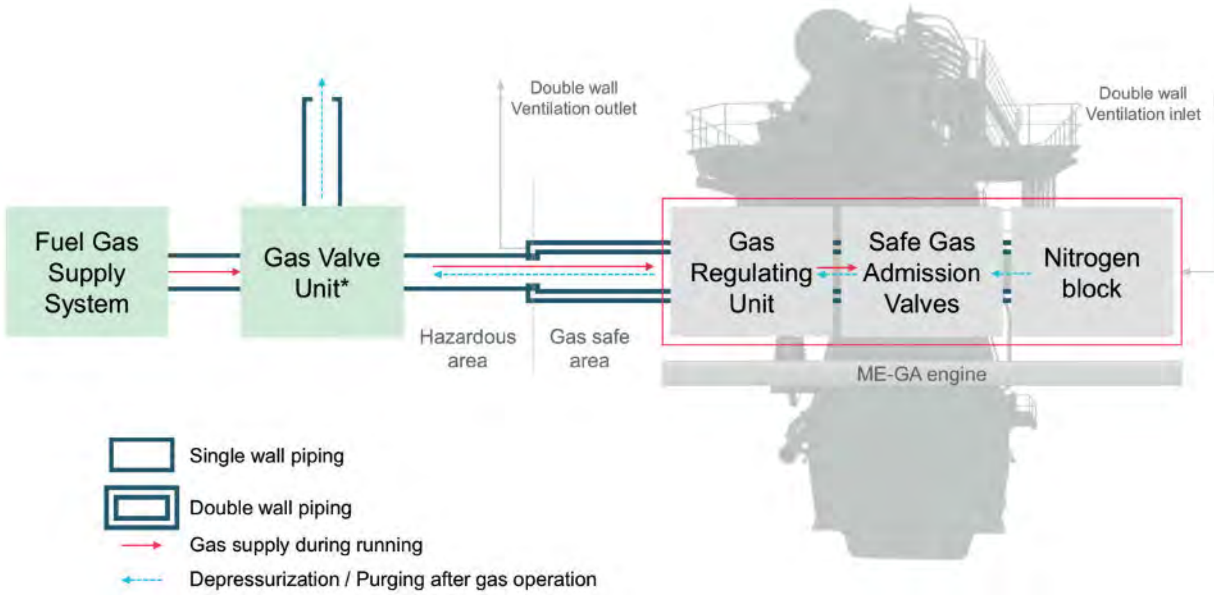


FIG 1: THE MAN B&W ME-GA'S GAS SYSTEM

MAN Energy Solutions takes pride in having an engine solution for whatever its customers need, but in the past few years it has been overshadowed when catering for the fast-growing LNG carrier segment. WinGD's X-DF series has found a niche in offering engines that operate in the Otto cycle in gas mode, establishing itself as the best-selling low-speed dual-fuel two-stroke engine in the maritime market.

MAN will be hoping that might be about to change following the unveiling of its MAN B&W ME-GA engine at a live-streamed demonstration event at its Copenhagen R&D facility in March. The new engine is an Otto-cycle variant of its existing ME-GI model but specifically designed for LNG carriers, with low capex, although with some scope for wider application in vessels such as Aframax tankers. First announced nearly two years ago, the ME-GA has been undergoing rigorous testing, drawing upon the experience gained from the ME-GI, particularly with regard to the use of MAN's proprietary exhaust gas recirculation (EGR) system.

Whereas the ME-GI applies the Diesel principle of non-premixed combustion, whereby the fuel is injected at high pressure and burned directly, Otto cycle combustion pre-mixes a combination of fuel and scavenging air during the compression stroke, which is then ignited with the aid of a small amount of a VLSFO or diesel pilot fuel (see Fig 2). Otto cycle admits the gas at a much lower pressure and allows for a more economic gas supply system, particularly with LNG carriers that can utilise boil-off gas from their cargo.

Gas admission system

The ME-GA uses an efficient ignition concept and unique gas-admission system that the company says delivers safe and reliable operation (see Fig 1). Rather than have one for supplying gas to the engine and another for purging, a single double-walled bidirectional pipe is used, reducing capex and maintenance. Meanwhile the gas valve unit and gas regulating unit are separated. This allows the gas valve unit to be located on the shipside, away from the gas safe area, and giving shipyards greater freedom in how they integrate it into their design. There are also regulatory advantages since the gas valve unit is not then subject to the additional safety requirements.

Another notable feature is the Safe Gas Admission Valve (SGAV) developed to enhance engine operation, a feature also found in the ME-GI. Each SGAV, found on the side of every cylinder, has a window valve incorporated consisting of two mechanical valves controlled by individual electronic circuits. In order for gas to enter the engine then both valves must open, meaning that no single failure can cause an accident.

Because Otto cycle engines are susceptible to knocking, particular care needs to be taken with cylinder condition. To mitigate this, MAN says it has based its piston ring pack on the running hours of its G70 ME-GI engines, which have shown such good performance that the time between overhauls of the piston rings for its gas engines has been increased by 50%.

Tier III compliance

While the ME-GA will be compliant with NOx Tier III requirements without the use of abating technologies when in gas mode, for fuel mode there will also be the option of EGR or selective catalytic reduction (SCR) systems. The former has become a particular specialism of MAN, who style themselves as "world champions" when it comes to two-stroke EGR, with proven design that has been installed on more than 120 vessels currently in service and a further 250 on order. The compact, high-pressure engine-mounted design is also said by MAN to be more cost efficient and shipyard-friendly than the low-pressure bulky EGR solutions some rivals are using (an apparent reference to WinGD's ICER system, see *TNA* September 2020).

During testing it was found that, in addition to the obvious emission reduction advantages, EGR also had some profound effects on combustion during the Otto cycle, lowering the rate at which pressure rises by introducing higher CO_2 content into the cylinders. This also helps counteract the effects of knocking.

Use of the EGR is calculated to save around 3% in specific gas consumption and more than 5% in its fuel oil equivalent. This increased efficiency also translates into reduced methane slip, while the very process of recirculation gives methane a second chance to be combusted. However, by its very nature, an Otto cycle engine will always leak more methane than the ME-GI, which is reckoned to be 10 times more efficient.

Commercial testing

MAN Energy Solutions aims to start testing the first commercial ME-GA design by the end of this year, with the first actual delivery coming in early 2022. Initially the ME-GA engine was launched in a 70 bore version, however its latest programme also includes a 60 bore version to cater for LR1 and LR2 tankers, as well as Panamax bulkers and feeder container ships. An S50 version is also expected to be added.

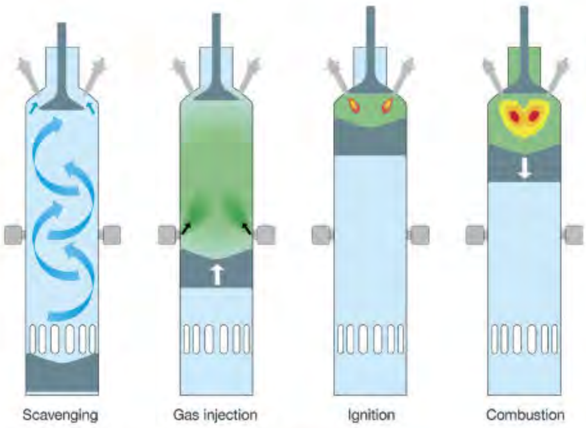


FIG 2: THE OTTO CYCLE COMBUSTION PROCESS

The company has paid tribute to the important role played by its development partner Hyundai and while no actual orders for the engine have yet been formally announced it seems inevitable that HHI-built LNG carriers will be among them. The ME-GA is part of MAN's broader strategy to become the standard bearer for dual-fuel engine technology, not to mention the pursuit of decarbonised solutions. MAN is also targeting the launch of an ammonia burning engine in 2024. ■

CAD/CAM

AVEVA E3D DESIGN TECHNOLOGY HELPS RENOVATE A BRITISH ICON

In a partnership that celebrates the best of British engineering, the historic Scottish steamship TS *Queen Mary* is being given a new lease of life with AVEVA's futuristic digital twin engineering software

By **Hervé Lours**, VP - Marine, AVEVA

TS *QUEEN MARY* NEW FLOODLIGHTING AT GSC NO3

If ships could speak, the TS *Queen Mary* would have enough riveting yarns to rival Scheherazade. But her own story outdoes anything that might have occurred onboard her distinguished decks. From ferrying royalty across the realm to near demise on the scrapheap, the iconic steamship will soon roar back to life as a heritage destination and educational maritime experience for schoolchildren and tourists – having been rescued by a diverse crew that includes the ship's friends, the Princess Royal, actor and writer Robbie Coltrane, and AVEVA, one of the very first computer design companies in the United Kingdom.

TS *Queen Mary* transported more than 13,000 passengers a week *doon the watter*, as they say in Scotland, in the years after she was built in 1933. The Glasgow Boat, as locals called her, sailed daily from Broomielaw, but really came into her own during World War II (having temporarily changed her name to accommodate the Cunard liner). Pressed into maintaining vital transport links on the River Clyde, Britain's finest pleasure steamer became an unlikely war participant, serving as lifeline for Scotland's island communities and carrying King George VI, Queen Elizabeth the Queen Mother, the young Princesses Elizabeth and Margaret, and Mrs. Eleanor Roosevelt. As passenger sailings declined after the war, the TS *Queen Mary* retired to London to host functions at Victoria Embankment for more than 20 years.

With an uncertain future and the scrapheap on the horizon, the dowager finally returned to Princes' Dock in Glasgow in 2016 after 40 years away for a new role befitting her pre-eminent status. But to reconnect visitors with one of the most storied periods in British history, this member of the Core 40 fleet of the UK's National Historic Ship register must undergo a £3.5 million facelift.

British heritage at its best

In a convergence of British brands, AVEVA has donated over £100,000 worth of 3D engineering and design shipbuilding software and training to support the restoration of this exemplary Clyde steamer. AVEVA provides world-leading marine software solutions for the design, production, and modification of large and complex projects in the offshore and shipbuilding industries. Through the TS *Queen Mary*'s restoration in 2022, AVEVA will supply the illustrious steamship with its purpose-built solution for shipbuilding, which offers integrated 1D, 2D and 3D engineering and design tools. The pro bono contribution will support the Friends of TS *Queen Mary* charity and naval architects Brookes Bell in reconditioning the steamer. Anne, Princess Royal, has been a patron of the TS *Queen Mary* since 2019.

Craig Hayman, CEO of AVEVA, says: "AVEVA is incredibly proud to be supporting the Friends of TS *Queen Mary* with the restoration this historic vessel. The *Queen Mary* is a shining example of the UK's history of innovation and design and this restoration and preservation opportunity, taking advantage our state-of-the-art software is an accolade that we are proud to earn. This project will not only enable us to learn more about this historic ship and its famous predecessors but will also provide great insight and know-how for the future development and restoration of similar vessels."

'THE SOFTWARE USED PREVIOUSLY WAS NOT PARAMETRIC, MEANING IT REQUIRED A GREAT DEAL OF MANUAL INPUT, INCREASING THE RISK OF INACCURACIES IN MODELS AND DRAWINGS, RESULTING IN MORE DESIGN ITERATIONS'

Friends of TS *Queen Mary* and Brookes Bell chose AVEVA's shipbuilding solution to capture the complex shapes of her design to help with the preservation process. The software used previously was not parametric, meaning it required a great deal of manual input, increasing the risk of inaccuracies in models and drawings, resulting in more design iterations. AVEVA's advanced shipbuilding software has enabled the original vessel structure to be 3D-modelled accurately and in detail, seamlessly linking the model to construction and production drawings, so shipyard production information for steel renewals can be efficiently produced.

Andy McGibbon, senior naval architect, Brookes Bell, says: "This is a very exciting project, and with AVEVA's Shipbuilding & Marine Lifecycle Solutions, we're able to completely transform the design and restoration process – driving huge improvements in design efficiency, quality, and ensuring that the design is fault free and the vessel is sympathetically restored for the benefit of future generations."

Iain Sim, Chairman of Friends of TS *Queen Mary*, comments: "Having a fully functional 3D model is a key part of our conservation plan for TS *Queen Mary*. With AVEVA's support, we can improve the accuracy and efficiency of the detailed design and steel renewal phases. The commitment to TS *Queen Mary* from the British marine sector is overwhelming; we are truly grateful to the whole AVEVA team."

AVEVA's shipbuilding technology is the most complete in the market, integrating the entire shipbuilding process from engineering and design through construction management to smart production, asset performance management and monitoring and control. Once the design phase is complete, AVEVA will use the ship's data – in partnership with the Friends organisation – for training and product testing to support the development of future vessels.

Globally distributed design and production

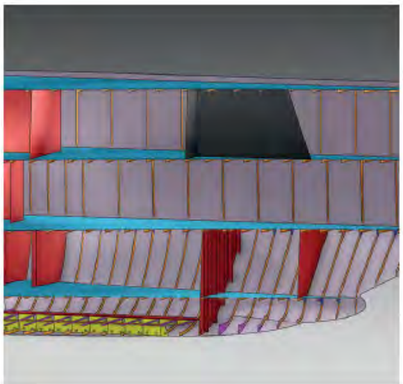
AVEVA's own history dates back to 1967 when the Computer-Aided Design Centre (CADCentre) was established in Cambridge, England by the UK Ministry of Technology, with a mission to develop and promote the use of CAD techniques in European industry. From its inception, AVEVA's software has revolutionised the way designers work and remains a design standard for thousands of engineering companies around the world. The acquisition of Tribon Solutions in 2004 set AVEVA on the path to develop a complete proposition for the shipbuilding industry. Since then, AVEVA E3D Design – together with AVEVA Marine – has become the de facto industry-standard design tool, delivering superior data transparency and quality alongside enhanced engineering efficiency. AVEVA 3D Design is available on the cloud via AVEVA's secure cloud platform, AVEVA Connect, to deliver clash-free hull and outfitting basic design of ships and offshore vessels. Consequently, projects are delivered on time and within budget even when constrained by a round-the-clock, globally distributed design and production process.

"AVEVA E3D Design allows ship design and construction engineers to quickly identify design changes, work with design teams around the world, achieve 3D coordination early in the design phase, issue and revise drawings that have been mapped directly to the 3D model, and manage changes in the design phase to maintain a consistent, error-free 3D digital twin while allowing for real-time feedback on the 'as-built' captured data," says Marcus Bole, RINA fellow and principal consultant at AVEVA. "If any of these fail, costly rework is generated during fabrication and production. AVEVA E3D Design circumvents that possibility."

CRAIG HAYMAN, CEO OF AVEVA

Also being used on the TS *Queen Mary* is AVEVA Point Cloud Manager, a cloud-enabled 3D data capture solution for registering, processing and visualising point cloud, 3D model data on brownfield, greenfield and maintenance projects. This ensures the digital and physical representations are aligned for optimum decision making, reduced project rework and improved asset safety.

For preservation projects such as the TS *Queen Mary* as well as newly commissioned vessels, AVEVA Point Cloud Manager serves as a visual reference. It utilises laser scan technology and integrates seamlessly with AVEVA E3D Design's Hull Basic Design Module to map the as-is design of a ship's hull structure, and support key decisions regarding naval architectural characteristics, space management, outfitting design, and drawings.



CAPTURING THE COMPLEX SHAPES OF TS *QUEEN MARY'S* DESIGN USING THE AVEVA E3D PLATFORM WAS THE FIRST STAGE IN THE RESTORATION PROCESS

As a 90-year-old vessel, the TS *Queen Mary* is not without challenges, Bole explains: "As a thoroughbred of the seas, the vessel's slender structure experiences distortion between the drydocked and floating condition, introducing a higher degree of uncertainty into the measure data as compared with the survey experience on land."

Having spent 20 years on the Thames as a bar and restaurant, preserving the vessel as a static attraction is a major thrust of the renovation, he says: "The ship's deteriorated riveted structure must be replaced with the modern welded equivalent, sympathetically integrated into the original structure. The exterior planked wooden decks are no longer weathertight, and the existing structure needs to be reverse engineered to allow installation of new steel decks."

He explains how the software works in context of the project. "Innovation is essential since 1930s construction techniques differ vastly from modern configurations. In this context, communication of the design intent between stakeholders is essential. AVEVA E3D Design provides the digital twin to mock up solutions, review, rapidly generate traditional drawings and output the production information needed to fabricate new steel once the designs have been approved."

3D virtualisation in action

Among its advantages, AVEVA E3D Design quickly develops the hull basic design model to serve design certification and preliminary analysis, while reducing the costs, timescales, and commercial risks for both newbuild and brownfield capital engineering projects. Since it automatically divides a ship's hull design into spaces, AVEVA E3D Design enables the efficient design of the most complex ships. Logical dependencies between designed objects and the space attributes retain design intent while the layout evolves.

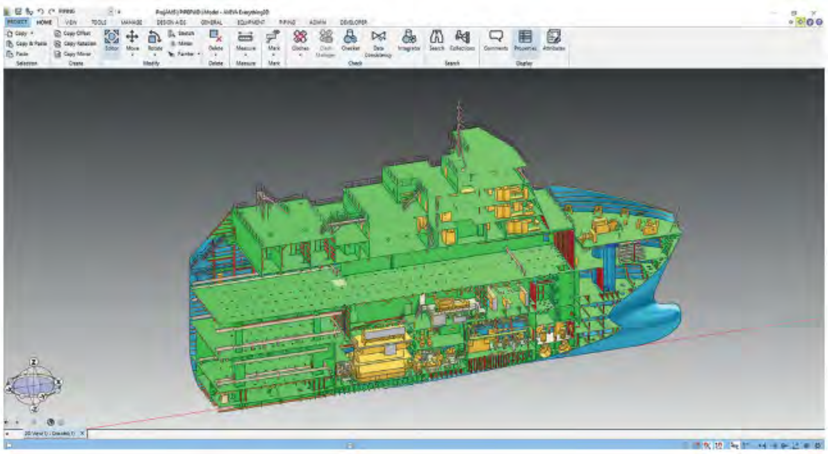
The panel concept offers an example of how AVEVA E3D Design technology works. A panel is a functional structure ranging in size from a small, bracket-like structure to the level of webs, girders, decks, and bulkheads. A panel, with its plate parts, profiles, brackets, and so on, is the basic modelling unit in AVEVA E3D Design. Associated piece parts are generated automatically from the panels.

Similarly, designers construct a highly intelligent database for the whole ship by using parametric components from a controlled catalogue. Each object, such as a valve, pump, or pipe, has an associated extensive library of attributes and association data. Fully interactive outfitting and an easy-to-use 3D design environment provides every designer on the project with modern 3D graphical interaction tools – offering full 3D visibility of the entire design at all times.

"AVEVA E3D Design can be customised by the user to suit individual, industry or project requirements, or to add further design rules or automation functions," says Gauthier Stonestreet, product manager for AVEVA E3D. "As an intuitive, collaboration-focused software, E3D is also well suited to restoration projects such as the TS *Queen Mary*, thanks to AVEVA's historic leadership in cloud and artificial intelligence solutions."

When this grande dame of the seas opens to visitors next year, she will offer a window into a seminal moment in British nautical history – and simultaneously demonstrate the nation's world-leading expertise in the technologies of the fourth industrial revolution.

A MULTI-DISCIPLINE OUTFITTING DESIGN BASED ON THE REAL HULL DATA



IN ANOTHER NINE YEARS, WILL CHINESE SHIPBUILDING SOFTWARE BE REPLACED?

By **Ship Economy & Trade**

A blueprint for the development of China's domestic shipbuilding software has been preliminarily drawn up, with the support of several undisclosed universities, institutions and companies. It outlines 'three steps' for the country's shipbuilding software industry, to be realised within the next 15 years. That is, achieving basic autonomy of software by 2025, implementing this replacement technology by 2030, and surpassing other software with its own by 2035.

Industry experts believe that, in order to reach this goal of independent and controllable technology, China's shipbuilding sector still needs to place added emphasis on software development. Further, that relevant industrial sectors and leading enterprises should have a unified understanding and join forces, playing a key role and participating in the long-term development and application of marine industry software.

China's shipbuilding software is highly reliant on imports. The characteristics of shipbuilding - complex systems, changeable technical processes, long industrial chains and life cycles - determine the complexity of the industry's software design process, its repeated design modifications, analysis and evaluation procedure, large amounts of data and difficulty of integration.

From the perspective of the main software development process, the fundamental driving force for research and development (R&D) is major industrial enterprises, not the software industry. Consider the large-scale ship computer-aided design (CAD) software, Napa, which has its origins in the shipbuilding industry, the computer-aided engineering (CAE) software, Ansys, derived from the nuclear industry, the Siemens NX system drawn from the machinery industry, or the French multi-platform software suite CATIA, which originated from aviation. These aforementioned software have had a profound impact on the shipbuilding industry following years of market application and industry expansion. Therefore, to move away from China's dependence on imports and the technology of others, it is not enough to simply appeal to its domestic software industry to keep pace. The country's shipbuilding industry itself should take action.

A number of insiders have called for Chinese industry leaders to play a central role in achieving independent marine software R&D, and experts believe that China's large shipbuilding groups should be the first choice. Along with the support of relevant ministries and commissions, and with the participation of universities, research institutes, shipbuilding enterprises, classification societies, software companies, industry associations, industrial coalitions as well as related companies, these groups can push forward the development and application of China's shipbuilding industry software.

At present, preliminary goals and their respective contents have been formulated for the progression of China's shipbuilding software. This includes the direction of advancements in intelligent ships and marine engineering, the integration of internal and external industry resources, and building a sustainable, developing ecology of independent software for shipbuilding; with CAD/CAM technologies at its core and making breakthroughs in key products such as 3D geometric modelling kernels and a computer-aided technologies (CAX) integrated open platform, as well as an intelligent shipbuilding software platform for the whole ship life cycle. Providing the industry with a safe and efficient intelligent cloud service for collaborative operations and meeting the demands of building a China 'shipbuilding superpower'.

The three-stage plan

Over the next 15 years, China will strive to meet the following 'three-steps' for the development of its shipbuilding software:

The first step is to build a software system and achieve basic autonomy by 2025. Focused on the requirements for China's ships and marine engineering equipment, this stage involves cultivating core software enterprises, establishing a data standard for ship equipment, and building a CAD/CAM-based software system with integrated/open architecture, a single data source and a unified data model. Specifically, achieving breakthroughs in the key technologies of 3D geometry modelling kernels, basic solvers, pre- and post-processing of grid adaptation, and capabilities for 3D digital design and drawing reviewal, collaborative design, analysis and evaluation, digital process manufacturing and cloud services. In summary, realising initial independent commercial operation for the entire life cycle of a ship.

The second stage is to perfect software functions and implement software replacement by 2030. Addressing goals of digitalisation, integration and intelligent/SMART technology is central to this step. The country will aim to build a successful software industry ecology; making breakthroughs in CAX 3D integration modelling, intelligent optimisation design technology, both coupled and high-precision CAE solver technology, digital ship technology, safe and reliable cloud services, and digital twin technology to support shipbuilding stages from design and manufacturing through to operation and maintenance. Ultimately, to replace foreign products and enter the international market.

For the third step, the country's goal is to further improve software performance and surpass existing technology by 2035. To satisfy the international market demand for an intelligent shipbuilding process throughout a ship's life cycle, the goal is to take steps forward in efficient, secure and optimised collaborative design technology for ships. As well as accurate online simulation technology, global remote operation and maintenance technology, and forming a fully digital integration of intelligent ship design, manufacture, operation and maintenance. Further, to continually expand the country's ability to serve related industries, enhance international market competitiveness and, finally, to make the R&D of independent marine software the main force of China's industrial software industry. ■

A version of this article was originally published in the Chinese publication 'Ship Economy & Trade'

CHINA AIMS TO TAKE CONTROL OF ITS SHIPBUILDING SOFTWARE OVER THE NEXT 15 YEARS

NOISE & VIBRATION

HIGH NOISE, HIGH BLOOD PRESSURE?

By **Richard Halfhide**

Is there a relationship between shipboard noise and hypertension among seafarers? More than 40 years after the question was first raised there are still no definitive answers

High blood pressure, or arterial hypertension, is a chronic condition that appears insidiously in middle age. The causes are difficult, perhaps impossible, to identify with certainty; it could be caused by genetics, lifestyle, related to an underlying health condition, or any combination of these factors. A further problem arises in determining what bearing hypertension may have on mortality and as an underlying cause for other afflictions such as strokes and heart disease.

The prevalence of hypertension among seafarers is well established and, some might say, unsurprising. Historically, seafarers are habitually unhealthy; smoking, high cholesterol and obesity, combined with a sedentary lifestyle in which they can spend long hours confined to increased risk. British-Danish research in the 1980s and 1990s found that cardiovascular disease (for which hypertension can be a contributory factor) accounted for 55-70% of all natural causes of death among seafarers. Another study in 2016 found that Danish seafarers were three times more likely to be diagnosed with hypertension than a reference group, with the high rate among younger seafarers being a particular cause for concern. Similar studies have found the same for French, Spanish and German mariners.

What's more contentious is the possible connection between shipboard noise levels and high blood pressure. A 2020 review of epidemiological studies by German researchers published in *The International Journal of Environmental Research & Public Health* found what it described as a 'high quality of evidence' that occupational noise exposure increases the risk of hypertension, concluding that above the 'safe' level of 85dB, 'the risk of developing hypertension was more than three times higher relative to the comparison group'.

Among the papers selected for that review was a 1986-published French study led by Dr. Dominique Jégaden, a specialist in seafarer health and subsequently president of the French Society for Maritime Medicine. For this study, 455 seafarers were recruited aged between 40 and 55 years old. The diminished hearing sensitivity at higher frequencies, or audiometric 'notch' at 4,000Hz that's typical of regular subjection to noises over 85dB, was found to be common among the 164 room personnel but not so the 291 deck crew. Furthermore, there was increased prevalence of confirmed hypertension among the engine room personnel (19%) compared to deck crew (11%, typical of the general French male population of the same age at that time).

The study found no statistical relation between hearing loss level and hypertension, and was independent of other hypertension risk factors such as obesity, alcoholism or heredity. However, it did find a link between hypertension and those seafarers who had spent more than 20 years subjected to unsafe noise levels.

"Concerning seafarers, this problem has been studied very little because I think I am the only researcher to have worked on this subject," Dr Jégaden tells *The Naval Architect*, 35 years later. "The interest of the seafarers who are included in my study was that they all came from the same region (Brittany), that they had the same way of life, that they were embarked on the same merchant ships, that they ate the same food, that they had the same average age and an equivalent smoking... In short, the only thing that differentiated them was the noise exposure among the mechanics, compared to the deck crew."

He adds: "My statistical study also showed an odd-ratio of 1.62 and an independent relationship to other causes of hypertension such as heredity or obesity. I concluded that this relationship does exist if the occurrence of hypertension is related, on the one hand, to a high level of noise (>85 dB(A)) and, on the other hand, to a duration of exposure to noise for more than 20 years."

Despite this, Jégaden is reticent to state with certainty that there is a link between hypertension and noise. "Studies where published which show that cardiovascular morbidity and mortality are important in seafarers. But it is difficult to link this to only hypertension, because other causes are also very present in this population."

The adoption of IMO's Noise Code (Resolution MSC.337 (91) in 2012 (effective since 1 July 2014)), established requirements for vessels ≥10,000gt that Jégaden believes should also be valid for smaller vessels. Nonetheless, he recommends a level of <50dB (A) for sleeping areas, since below this threshold allows for a good night's sleep.

He notes that significant progress has been made in soundproofing in recent years, particularly on cruise ships, although this appears to have been done for passengers' comfort more than that of the crew. In all likelihood most operators of merchant ships would baulk at the additional capex.

"Concerning propulsion, diesel-electric propulsion is an excellent compromise to reduce noise onboard. The automation of the means of propulsion also makes it possible to significantly reduce the working hours of mechanics, due to the noise, and therefore to reduce the risk. But maybe we will have to wait some years to hope to notice an improvement in the health of these seafarers," Jégaden concludes.

THRUSTER NOISE SPOTLIGHTED BY SMALLER CRUISE SHIPS

By **Kari Reinikainen**, Correspondent

Thrusters can be a source of noise and vibration onboard ships. Rapid expansion of expedition cruise fleets in the past few years has brought this matter to the spotlight as these vessels are much smaller than most mainstream ships, yet they cater largely for the upper end of the market. There are ways to tackle the problem, but some of them affect the wider design of the vessel.

"A problem with thruster noise is that it is usually very quiet until the thruster comes on and suddenly, the cabins in the forepart of the ship can experience a lot of noise," says Lars Myklebust, executive sales manager at Brunvoll, the Norwegian thruster manufacturer that is a leading supplier of this equipment to the cruise industry and mega yachts.

Owners sometimes think that the thrusters are not used for a long period at each time, so they can be tempted to opt for less expensive but noisier technology. "Noise levels of 75-88 dB(A) are typical in cabins next to and above conventional tunnel thrusters. Brunvoll's advanced technology can cut this by up to 15dB(A). Combined with other measures, noise reductions of up to 20-25dB(A) have been verified," Myklebust tells *The Naval Architect*.

Thrusters are, however, an investment that often lasts the lifetime of a ship and quieter sailing means better sleep, improving the alertness and efficiency of the crew, while passengers enjoy a new degree of comfort if the owner opts for more advanced technology.

In good weather conditions, only half of the power of a thruster installation is often required to manoeuvre a ship into or out of port. However, under strong winds, 80-100% of the output is needed, with a consequent sharp increase in noise levels.

Thrusters have little water around them, which can result in cavitation that causes noise and vibration. Therefore optimising the size of the tunnel and the propeller and how the tunnel is mounted to the hull are important aspects in reducing noise and vibration.

Resiliently mounted units that offer stepless speed control and variable pitch propellers produce the best results. Brunvoll's double tunnel systems feature an inner tunnel with an electric motor that is fitted with a frequency conversion drive and a controllable pitch propeller. The inner tunnel is resiliently mounted to the outer one.

"In this way the propeller and the electric drive motor is decoupled from the hull structure by elastic mounts. The idea behind this concept is to reduce the noise from the noise source itself (the thruster), which will make the noise reduction job easier on the decks above the thruster compartment to get an overall comfort for both the passengers and the crew," Myklebust points out.

BRUNVOLL AZIMUTH (TOP) AND TUNNEL THRUSTERS

Noise insulation and design

"It is very important to pay attention to the welding in of the thruster to the hull structure, to the arrangement of the tunnel entrance, design of grids, blade design, choice of electric drive motors, etc. to avoid resonant vibrations and that the noise and vibration is transmitted at a high level up into the different decks above the thruster compartment," he continued.

"Thrusters must be able to keep the ship under control while manoeuvring even in strong wind conditions. A large cruise ship can have four thrusters of 3MW each, an expedition vessel two of 1.5MW each," says Peter Albrecht, senior advisor at Elomatic, the Finnish engineering consultant company.

Several alternatives come under consideration here. The necessary thrust can be obtained by using the power to provide a rapid flow of water through the thruster tunnel. This allows reducing the diameter of the tunnel, but increases the noise level. A larger tunnel results in a slower water flow and lower noise levels, but this option obviously means that the installation will take up more space onboard the ship.

A grid is often installed at each end of the tunnel to allow adjusting the direction of the water flow – the resistance is lower when the ship is moving forward and a radial grid can increase the thrust of the installation by up to 10% compared to a traditional grid.

LARS MYKLEBUST, BRUNVOLL AS

Installation of the electric motor that drives the thruster in the propeller hub in the tunnel produces less noise and vibration than an installation where the motor is placed above the thruster tunnel and power is transmitted via shafts and gears. However, the first named option is the more expensive of the two.

Installations that feature double walls in the tunnel with the inner tunnel resiliently mounted significantly reduce both noise and vibration. Cabin decks can also be resiliently mounted, with floating floors and noise reducing materials to improve living conditions onboard.

This, however, may have implications to the wider design of the vessel as such an installation will reduce free deck height by about 5cm. This must often be compensated by increasing the deck height and as the resilient installation has to cover a number of decks, the overall height of the vessel will increase as a result.

Consequently, it will be necessary to look at the stability of the vessel. "There must be an adequate but not excessive margin in stability. Building the ship wider than initially intended would improve stability, but it would also affect e.g. the engine power requirement of the vessel," Albrecht concludes.

HURTIGRUTEN'S 2019-LAUNCHED EXPEDITION SHIP, MS *ROALD AMUNDSEN*, DEPLOYS TWO 3MW AZIPULL THRUSTERS SUPPORTED BY TWO 1.5MW TUNNEL THRUSTERS


CR OCEAN ENGINEERING MARINE SCRUBBER
THE SMART CHOICE
While Meeting the 0.1% or the 0.5% Challenges.
CROE IN-LINE SCRUBBER
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STRATHCLYDE DEVELOPS NEW SYSTEM FOR MEASURING URN

By **Prof. Patrick Fitzsimmons & Prof. Mehmet Atlar**, NAOME, University of Strathclyde

Two professors at the University of Strathclyde's Department of Naval Architecture, Ocean and Marine Engineering (NAOME) have developed a novel way of measuring underwater noise created by ships which expose vessels to detection and pose a danger to marine life.

Human-generated underwater radiated noise (URN) from the military, the oil and gas industry and shipping traffic can interfere with the ability of marine animals to hear, navigate, communicate and catch prey.

The problem was recognised by the United Nations at its Convention of Migratory Species in 2018 where it called for more research on the impact of URN and for countries to mitigate ocean noise where possible.

NAOME's Patrick Fitzsimmons and Mehmet Atlar have adapted off-the-shelf equipment to deploy the HyDrone, a waterproof aerial drone fitted with a SoundTrap hydrophone recorder to measure the URN generated by the propulsion systems of marine craft. The unit can also deploy an underwater camera, initially suspended to 2m below the surface, which allows video and sound recording of the propeller's sheet and tip cavitating vortex at 2-5m from the hull.

The HyDrone is capable of operating at distances of 1km from its launch point, landing on the sea, powering off and floating while the SoundTrap hydrophone is suspended below it. The system is then flown back to its launch point, which may be the target vessel itself.

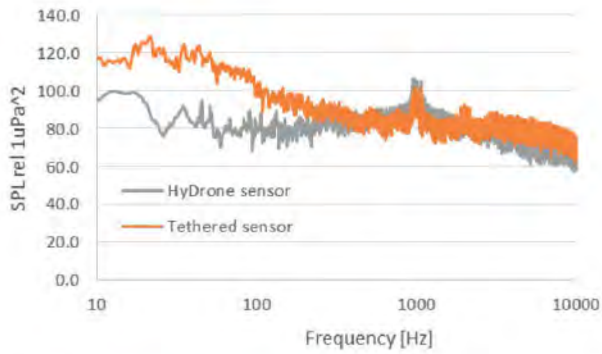
This novel configuration minimises extraneous background noise from tidal current cross-flow which affects traditional weighted-line systems, such as hydrophone arrays tethered to a buoy or support vessel or bottom mounted suspended arrays.

Environmental threat

Like carbon emissions, increasing emission levels of URN from ever-growing commercial shipping traffic in the world's ocean has become a life-threatening danger to mammals and fish whose communications, feeding, breeding and day-to-day affairs are adversely affected by high URN emission levels, generally below 1,000Hz.

The international regulatory authorities like IMO and the EU have started campaigns and launched research programmes to mitigate and prevent this harmful environmental impact. Within this context, technology like the HyDrone can simplify the practical measurement of URN from ship propellers and other sources. The unit can operate wherever the target ship is operational and so can measure noise levels in shallow waters.

The aerial platform provides a cheaper, more versatile deployment system since it can be launched quickly to sites from 5m to 1.5km from the target vessel and can be recovered in minutes, without requiring the vessel to stop to recover the alternative, heavier in-water drone or buoyed systems.



900RPM HYDRONE/TETHERED LINE COMPARISON

The HyDrone also has an onboard, low-light camera augmented with a more deeply immersed light-weight camera, which can measure temperature and salinity. The system will allow observation of ship propeller's tip vortex cavitation – the creation of vapour filled cavities in the water – and measure near-field noise adjacent to the propeller and at increasing distances behind the vessel.

This type of cavitation is caused by increased rotational speed at the propeller tips which reduces the local water pressure to the level of the critical vapour pressure. This induces so-called cold-boiling or "cavitation" which is a nuisance for propellers resulting in blade erosion, vibration and noise when such cavities implode.

Such data gathered by the HyDrone will be used by Strathclyde students and staff to validate more advanced computational fluid dynamics simulations of cavitation induced noise, which are also being developed within NAOME. The HyDrone may also be adapted to record wave motions.

Trial exercises

Proving trials for the HyDrone were recently conducted off Blyth in Northumberland where the target vessel was the *Princess Royal*, a ship which had been designed by Professor Atlar and students in his previous post at Newcastle University. The HyDrone was tested at 10m sensor immersion against a standard vertical array of tethered hydrophones.

During the trials, the background noise was measured with the vessel powered down and far from the measurement location where an array of three RTsys hydrophones were suspended from a floating buoy tethered to an anchored support vessel. At the start and end of the day's trials the ambient noise was measured in the absence of the *Princess Royal*. Measurement recordings were started with the vessel some five miles from the fixed sensors, thus giving additional 'ambient' noise levels.

The SoundTrap 300 was flown from the support boat and landed on the water with the hydrophone set at 10m depth to a point 100m off the track of the vessel some two minutes before the vessel reached its closest point of approach (CPA). After a further two minutes the HyDrone was recovered to the support boat.

The Figure shows a narrowband spectrum from subsequent analysis of the sound files recorded at the CPA on both the RTsys sensor and the HyDrone sensor at a 10m immersion depth. A singing phenomenon is observed at about 1,000Hz.

These data clearly show that the sound recorded on the tethered array is significantly influenced by the tidal race flowing past the line of hydrophones in the frequency range up to 600Hz. In addition, the current displaced the tethered line from a vertical orientation to an approximately 45 degree angle from the vertical, as estimated from aerial photos from a second drone.

Masking of the true readings of the noise signature from the *Princess Royal* occurs predominantly in the crucial propeller broadband frequency range (30-600Hz). This is the range where the cavitating propeller tip vortex is of primary interest, although violent collapse of blade sheet cavitation also has an influence.

Teething problems with the drone (received only four days before the trials) occurred due to a lack of familiarity with the rapid depletion of the main battery when carrying a 1.5kg of payload. This has subsequently been addressed by removing the heavy main camera and building a lighter hydrophone recorder.

Despite achieving only one URN recording from the SoundTrap hydrophone, the trial confirmed the ability of the HyDrone system to minimise background noise contamination since minimal cross-flow was experienced on the line between the drone and the SoundTrap hydrophone, both of which moved with the current.

Strathclyde has ongoing student projects involving a series of further tests in the Kelvin Hydrodynamics laboratory, where the crossflow effects will be measured by fixing the tethered array to the towing carriage. The students will follow up with field trials in the Clyde estuary where it is hoped to gather a body of URN and video data on a variety of vessels travelling at service speeds and at approach and departure speeds in shallow and deeper waters. The system will also be developed with the intent of achieving Class approval for quiet ship certification.

A key part of this work will be performed in conjunction with Dr Pepin Zoet of PZdynamics, a ship noise and vibration specialist experienced in performing underwater noise measurements and analysis, in addition to being a drone pilot. Zoet carried out the Blyth trials, following an accepted industry standard procedure for URN measurements. This required deployment of a weighted vertical hydrophone array at 10m, 25m and 45m. The total weight is critical for a HyDrone system comprising three hydrophone recorders. ■

UNDERWATER NOISE MEASUREMENTS AND ASSESSMENTS OF IMPACTS TO MARINE LIFE FOR WASHINGTON STATE FERRIES

By **Jesse Spence, Zachary Weiss, Ben Bonnice, Troy Cantalupo**, Noise Control Engineering

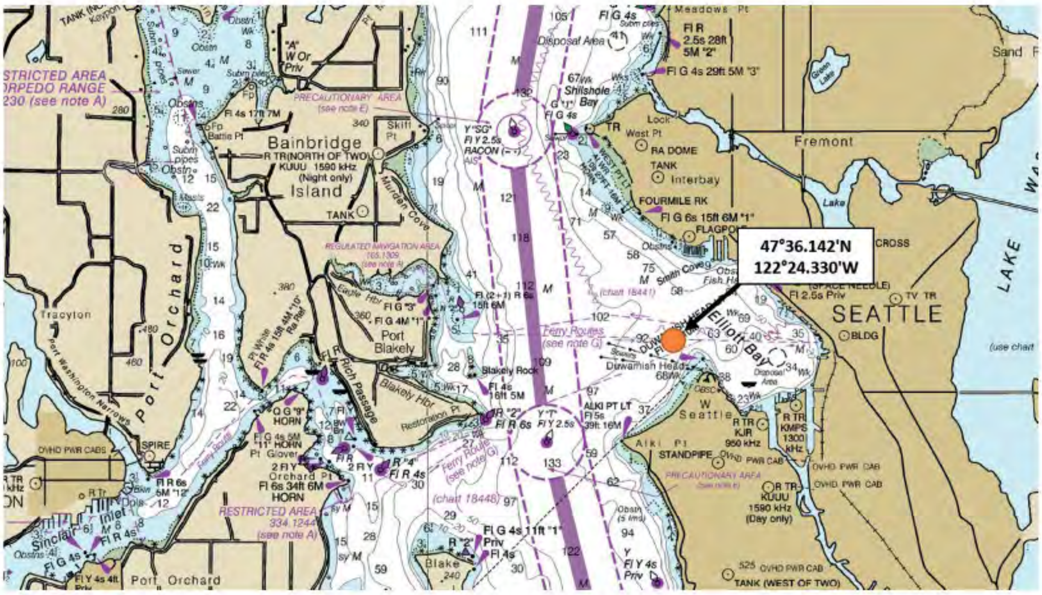


FIG 1. SEATTLE TEST LOCATION

Underwater radiated noise (URN) from commercial vessels is a growing concern as our understanding of its impacts to marine life matures. In 2004, the US National Oceanographic and Atmospheric Administration (NOAA) held a symposium to discuss the causes, potential effects, and options for mitigating noise from commercial ships. Many similar efforts to address concerns over URN have taken place since then, including IMO issuance of non-mandatory guidelines for reducing underwater noise in 2014, work by the Port of Vancouver in Canada to assess and reduce underwater noise from vessels accessing its port, and current efforts by Transport Canada to create a working group that will identify noise reduction targets for commercial ships.

One region in which underwater noise is of particular concern is Puget Sound in Washington State, US. Understanding and mitigating acoustic impacts on the endangered Southern Resident orcas makes up a major portion of this work. The governor of Washington State has ordered state agencies to take "immediate actions to benefit Southern Resident killer whales" and has set up a "Southern Resident Orca Task Force" to assist in these efforts.

As part of the pursuit to understand and reduce underwater noise impacts on orcas and other marine life in Puget Sound, the Washington State Department of Transportation Ferries Division (WSF) commissioned a study to assess the underwater noise generated by all seven active vessel classes in their fleet. The study was performed by Noise Control Engineering LLC, based in Billerica, Massachusetts, with the following overarching goals:

- Measure, assess, and understand the URN characteristics of active WSF vessels.
- Identify potential injury and harassment impacts to marine life for each vessel class using 2018 National Marine Fisheries Service (NMFS) guidelines.
- Identify primary causes of radiated noise and potential mitigation strategies for each ferry class.

Testing Approach

Acoustic measurement systems were deployed for eight days in three locations close to normal Washington State ferry routes serving Seattle, Port Townsend, and Anacortes. Water depths and details of hydrophone deployments differed between these locations. However, comparing measurements of the same vessel class at different locations showed remarkably similar results; this speaks to the validity of the overall measurement approach.

A primary requirement for the testing was to allow vessels to continue normal operations while collecting underwater noise data. Testing was performed following the general approach of ANSI S12.64, the American National Standard Quantities and Procedures for Description and Measurement of Underwater Sound from Ships. Modifications were made as needed for practical reasons, such as allowing vessels to transit over the hydrophones, and for some locations, other modifications pertinent to measurements in shallow waters.

Coordinating with the ship operators was an important aspect of successful testing. Vessel operators navigated directly over the measurement hydrophones and recorded ship operating conditions, distance to the nearest vessel, and other pertinent factors. Different operating conditions were requested for each day of testing, corresponding to several

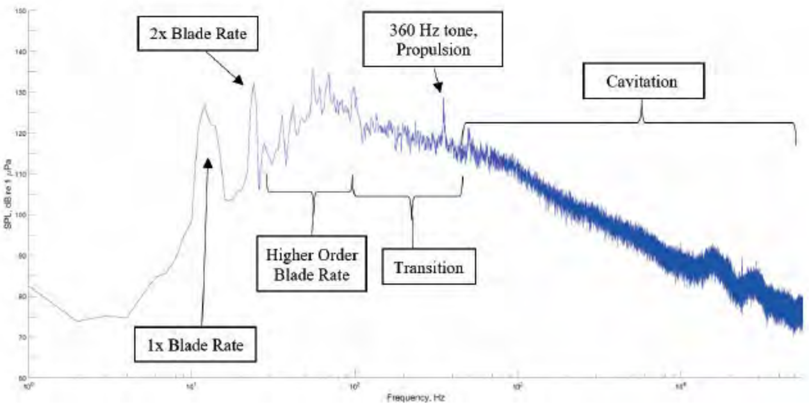


FIG 2. EXAMPLE RECEIVED NOISE SPECTRUM, WSF'S JUMBO MARK II CLASS

ship speeds: normal transit, make-up speed, and slower speeds (ranging from 75-85% of maximum speed). Multiple transits at each operating condition were recorded over the course of each day.

The acoustic data was processed to calculate noise as a function of frequency and time. Acoustic 'source level' spectra were calculated in accordance with ANSI S12.64 by combining the measurement data with logs of GPS vessel position. Care was taken to exclude any data that was erroneous based on factors such as incorrect operating conditions, proximity to nearby vessels, background noise concerns, etc. The compiled set of source level spectra enables comparisons of noise between vessel classes and forms the foundation for animal impact analyses and identification of mitigation approaches.

Noise Results

Noise created by the WSF vessels is generally dominated by phenomena related to propeller excitations. Cavitation noise is a primary component that is dominant at most frequencies. Additional tones at blade rate (i.e. the frequency of propeller blade passes per second) and harmonics of blade rate are also prominent for all vessels. Some ships also show influences from different machinery items, such as propulsion engines and motors, gearboxes, and other sources.

All WSF ferries are double-ended. Some are diesel-electric and generate thrust at both the forward and aft propellers, while others are diesel geared and only generate thrust at the aft propeller (the forward propeller is free to spin). This difference has significant implications for underwater noise; cavitation is present on both propellers for the diesel-electric vessels, whereas it is only present on the aft propellers for the diesel geared vessels.

In all cases, noise levels are reduced when vessel speed is reduced. However, noise from diesel-electric ships only drops by about 5dB (for the tested speed ranges), whereas noise from diesel geared vessels drops 10-20dB for similar speed reductions. This difference is due to the additional cavitation generated by the forward propeller on the diesel-electric ships. This means that for the diesel-electric vessels, reducing vessel speed will not minimise impacts to marine life as significantly.

It was also found that the diesel-electric vessels project sound forward of the ship, with the highest overall noise levels occurring roughly 15 seconds before the vessel is at its closest point of approach to the hydrophone (for maximum speed operations). For diesel geared vessels, the maximum levels occur when the aft propeller is closest to the hydrophone. Other effects were also observed for the diesel-electric ships, such as changes to the relative balance between noise at high and low frequencies as the vessel passes by an observer.

Impacts to Marine Life

Impacts to marine life were assessed based on NMFS metrics for permanent threshold shift (PTS), temporary threshold shift (TTS), and behavioral impacts (BI). Using the measured source levels, the minimum distance required to avoid each of these impact levels was calculated for all vessels and operating conditions. Impacts were assessed for the five mammal hearing groups provided by NMFS, of which the orcas fall in the mid-frequency cetacean category.

PTS impacts are predicted only for high frequency cetaceans. WSF's Kwa-di Tabil Class ferries (diesel-electric) were the primary source of potential impacts when operating at maximum ordered speed and make-up speed. The impact zones are generally less than 150m. TTS impacts are predicted primarily for the 'low' and 'high' frequency cetaceans, with all vessel classes creating some degree of impact. Impact zones range from 15m to nearly 2km, depending on the ship and its operating condition. Note that for both PTS and TTS, greater impact ranges may occur for some receiver positions due to the forward-projecting propeller cavitation noise discussed above. Additional diesel-electric vessels also have calculated PTS impacts when this phenomenon is considered.

BI are predicted to occur for every hearing group and vessel, at nearly all measured conditions. Impact zones are varied, ranging from around 100m to over 20km. The extensive coverage of BI impact zones is due largely to the low noise threshold for this impact category, which is an overall weighted sound pressure level of 120dB re 1μPa.

It is also important to note that a simplified model of sound spreading (the NOAA 'Practical Spreading Model') was implemented for this study. This model may overpredict the impact zones for some locations; further study would be needed to assess the actual spreading that occurs in different areas. These impact distances also do not account for real-world factors relating to line-of-sight, and the blocking of sound due to items such as land masses.

Although these issues are present, the impacts predicted by this study are believed to be more accurate for closer ranges, though are still potentially conservative. They are also instructive at least for establishing the order of magnitude for BI, and to identify the relative significance of noise from different vessel classes.

Potential Mitigation Strategies

Reducing noise from existing WSF vessels or future ship designs will require reducing propeller cavitation. There are many established methods for accomplishing this, all of which require detailed analysis of propeller geometries, flow conditions, and other factors. Note that it is not practical to attempt to eliminate propeller cavitation at all speeds. However, noise can be reduced by minimising the amount of cavitation that is created.

The propeller at the forward end of the diesel-electric vessels appears to be running 'in reverse' relative to conventional designs. This is believed to be a significant source of additional cavitation and the related noise issues. Changing the propeller to a bi-directional design may help to reduce cavitation, though doing so may impact thrust and efficiency. As an alternative, podded propulsion designs may alleviate the need for propellers to run in reverse.

Machinery-induced noise from propulsion motors, gearboxes, and propulsion engines can be reduced by isolation mounting these items. However, this would require implementing additional features such as flexible shaft couplings, which introduces differing degrees of complexity depending on the vessel design. Inherently quiet machinery designs, such as low-noise gears for gearboxes, may provide alternate options to minimise noise. As was mentioned for propeller noise, detailed analysis is generally required to identify optimal machinery noise reduction solutions.

Acknowledgements

The authors would like to thank the Washington State Legislature for its financial assistance to the Washington State Department of Transportation Research Office in support of this work. Furthermore, we would like to thank the Federal Highway Administration for their financial contributions, which allowed for on-site supervision of ferry operations. We would especially like to thank Captain Sax for his leadership onboard the ferries during testing, helping to ensure that all ferry operators understood the nature of the testing, its importance, and their roles in the operation. Captain Sax's efforts provided the guidance needed to make the testing phase of this effort successful. Finally, we would like to thank Kevin Bartoy, Colin McCann, Cotty Fay, and Jim Laughlin of the Washington State Department of Transportation for their direct support and guidance in the planning and execution of this effort.

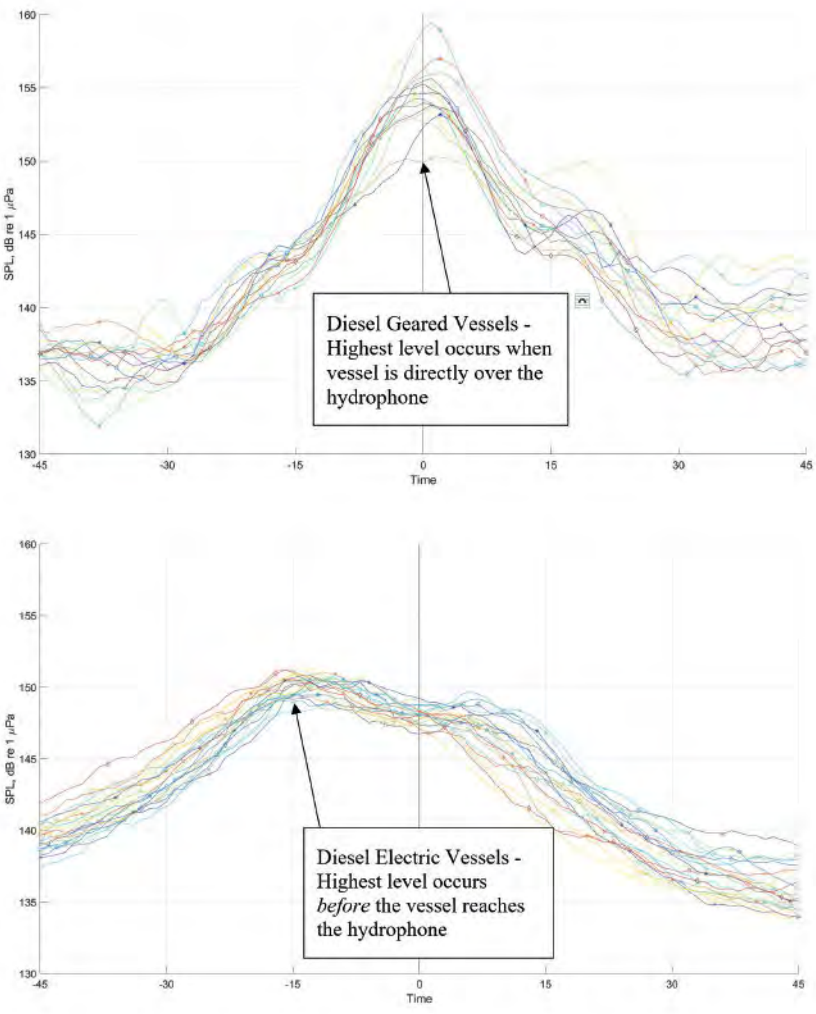


FIG 3. COMPARISON OF OVERALL NOISE LEVEL VS. TIME; DIESEL GEARED VESSELS (TOP) AND DIESEL-ELECTRIC VESSELS (BOTTOM). TIME 0 IS WHEN THE VESSEL IS CLOSEST TO THE HYDROPHONE

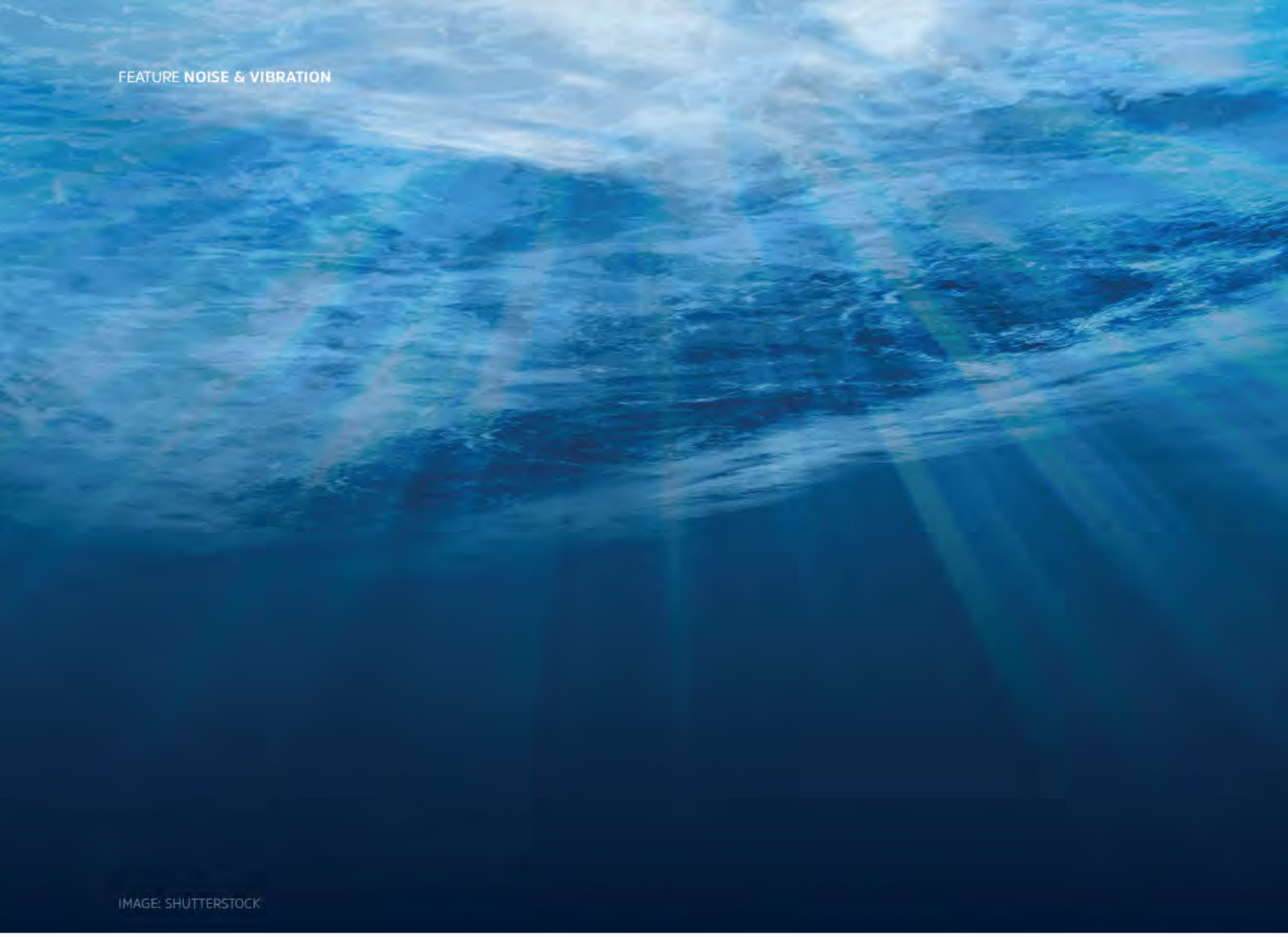


IMAGE: SHUTTERSTOCK

UNDERWATER RADIATED NOISE FROM SHIPS: STATE OF THE ART, REGULATORY FRAMEWORKS AND MEASUREMENT RESULTS

By **T. Coppola & L. Mocerino**, University of Naples Federico II, Italy
F. De Lorenzo, M. Del Principe Fincantieri, Trieste

The noise connected to maritime traffic is one of the most relevant types of emissions related to ships, together with air and water emissions (Mocerino et al. 2018, Mocerino et al. 2010). The anthropogenic noise caused by civil activities in coastal areas further adds to these sources of noise, to which marine animals are supposed to have become accustomed because of the evolutionary adaptation. All the sources together contribute to the generation of background noise, which also depends on the conditions of propagation and the water rate of absorption (De Lorenzo et al. 2013, 2015, 2017).

From a precautionary point of view, the publication of specific standards by international bodies represents an important step towards a more complete understanding of the problem (IMO 2009). Additional class notations related to underwater noise are intended to keep the noise pollution in the water below well-defined levels; a ship designed with precautions of this nature is a ship with an added value.

Statistical Energy Analysis (SEA) technology is seen as a promising investigation method, applied with the intention of predicting in detail the noise levels produced by a specific ship even before its construction (Charpentier et al. 2007). The Acoustical Society of America (ASA) Standards Committee Working Group (ANSI/ASA 2009) has established a standard for the measurement of underwater noise. Two of the most important initiatives in the field are those of the European Union that has included the issue in its Marine Strategy Framework Directory (MSFD) in an attempt to implement measurement programs and maintain "Good Environmental Status" at sea (Zampoukas et al. 2014). The second initiative provides an international involvement conducted by the International Maritime Organization (IMO), which wrote non-mandatory application guidelines, with the aim of providing suggestions for the reduction of underwater noise (MEPC.1/Circ.833 7 2014).

Noise from ships

One of the main sources of noise radiated into the water, whether commercial or military, is the movement of the propeller rotation, the machinery onboard, and the turbulence around the various appendages of the ship.

Efforts to reduce noise are more effective if they are already incorporated in the design phase, although even retrofitting ships may have high chances of success, but certainly at relatively higher costs. At low speeds, machine noise dominates and is mainly characterised by low frequencies. As the speed of the ship increases, the contribution of the flow, which produces very low frequencies, increases and at the same time the noise produced by the propeller. These assumptions are very important as low frequencies have a lower degree of dissipation in water than high frequencies.

Regulatory framework

ICES Cooperative Research Report No. 209 - 1995

The International Council for the Exploration of the Sea is an international organisation that focuses on science and technology, with the intention of guaranteeing the protection of the marine environment (Mitson 1995). The objective of this work was, on the one hand, the desire to limit the effects on marine fauna as much as possible, on the other to ensure the operation of these units, regardless of the type of service, without this being affected by noise interference. Already in 1993, a group of studies meeting in Dublin, on their 81st meeting, brought to attention the insufficiency of data and references concerning the topic of noise in the marine environment. The final report of the 'Study Group' was discussed during the 'one-day meeting' held in Montpelier in April 1994.

ANSI / ASA S12.64 - 2009

The American National Standards Institute, in collaboration with the Acoustical Society of America, established standardisation methodologies for the measurement of noise pollution (ANSI/ ASA. 2009). These standardisations can be applied to any surface vessel, regardless of size. The aim is to ensure periodic checks of the ship's signature, in this way the compliance with the contractual requirements can be verified. In particular, the standard defines three degrees of measurement, which differ in terms of uncertainty, complexity, and repeatability; in addition, they fix the degree of uncertainty of the instrumentation used for the acquisition of the signals, the test site and the arrangement of the hydrophones. Three tools are mainly required: hydrophones, data acquisition, recording, analysis and evaluation system, and distance measurement system.

All hydrophones must be omnidirectional, in the required frequency range. An analysis in thirds of an octave band is required. In particular, for a more precise analysis the narrowband analysis must be done up to 5,000Hz or more if necessary.

Verification of radiated noise

Rina Dolphin notation

Rina (Registro Italiano Navale) provides an additional notation to be applied to ensure a low environmental impact, which provides

IMAGE: ELIANNE DIPP (PEXELS)

for the issue of a certificate to those ships that meet certain requirements. Furthermore, within the same additional notation, the Dolphin QUIET Ship stands out, compatible with the limits of the figure at a speed of 10knots and the Dolphin TRANSIT Ship, compatible instead with the cruising speed (https://www.rina.org/en/media/news/2019/05/16/rina-dolphin).

Lloyd's Register

The general requirements foreseen by LR are defined in the UWN - L (XYY), in which the wording in brackets indicates with the X, in the place of which the satisfied criterion will be inserted, while in place of the YY a number is inserted which stands for indicated speed at which the criterion was met. For example, the acronym UWN - L (T20), translated means that the ship meets the transit criterion at a speed of 20knots; it is possible to meet ships with double UWN notations (Fig 3). There are three types of notations: transit, quiet and research. The first notation is attributed following tests carried out at 85% of the MCR, for the Quiet notation, the speed assumed for the test is 10knots, finally, the research at 11knots, applied only to research ships. During the measurements, all the machinery must be operating normally and work at the default loads and turns, in the design conditions of the ship (Lloyd's Register 2018).

DNV Silent Class notation 2010

The objective of the Norwegian legislation is to ensure a low environmental impact and allow the correct performance of operations for those units that use hydro-acoustic instruments in routine work (DNV 2010). The noise limits are cataloged by ship class and supplied in third-octave bands, the regulation is divided into five parts, depending on the unit of interest. The documentation provides both the noise limits imposed for each category and the methodology with which sea trials are to be carried out. In order to obtain DNV-Silent certification, The SILENV project (Ships oriented Innovative soLutions to rEduce Noise & Vibrations), it is necessary that the limits listed above are respected and at the same time, that the measurements are carried out following the procedures provided for by the regulations (DNV 2010).

Bureau Veritas URN – rule note

The purpose of the legislation is to define the limits of radiated noise for self-propelled ships in order to control and limit the impact on marine fauna. The regulation provides procedures and methodologies for both high and low water tests (Bureau Veritas 2014). The additional URN class notation must be divided into different cases: URN controlled vessel, URN advanced vessel and URN specified vessel. The first two class notations are for pleasure boats, while the last is for units engaged in particular activities such as, for example, research ships engaged in seismic surveys. The ship must be tested in its normal operating conditions or alternatively at 85% of its MCR, in addition, it is essential to ensure that the displacement respects the contractual values. During the measurement, the following must remain constant: the power of the machinery, number of turns and pitch of the propeller, loading conditions, dives of perpendicular behind and forward, operation of machinery in normal operating conditions. The measurement system is characterised by the presence of three omnidirectional hydrophones. Different limits are defined for the three types of units: in Fig 5 the limits for controlled vessel.

Measurement campaign

The measurement area is carefully chosen together with the speed trial. The position of the sonoboa is approximately 150m from the ship. For the correct execution of the measurement, it is also necessary to check the stability of the course, power, propeller revolutions, and speed, in accordance with the directives provided by the ranking chosen by the shipowner. For an in-depth knowledge of the flow around the propeller blades, three pressure switches have been placed in correspondence with the propeller tips, to record the induced pressures in broadband, paying attention to the homogeneity of the different measurements. Therefore, the pressure levels radiated by the ship are recorded, and then are compared with the limits imposed by class notations, according to the frequency.

It is observed that, at medium frequencies, pure tones are much more rarefied and of amplitude slightly higher than the ship's background noise. Here too, based on the narrowband measurements carried out on the foundations of the machinery, it is possible to trace some of these tones to PEM and alternators. To study in detail the most critical frequencies, at which the imposed limits are exceeded, it is advisable to use narrow band analysis. In addition, it has been noted that when examining the pressure values near 300Hz, a train of harmonics attributable to the operation of the Diesel Generators (DDGG) stands out, consisting of the integer multiples and means of the fundamental frequency of rpm of the diesel engine.

Conclusions

The number of hydrophones required is one or three, depending on the legislation considered. The main advantage of using three hydrophones is to mitigate the 'Lloyd's mirror effect', thus allowing to obtain the test results by mediating the sets of each of the hydrophones. The use of a single hydrophone is preferable when using lighter measurement systems such as floating devices or easier installations such as in solutions anchored to the bottom.

In general, only classification societies have requirements relating to measurements carried out in shallow water. ANSI / ASA requires a minimum of 300m (which can reach 900m for particularly long cruise ships) in order to avoid any influence of the seabed in the measurements. This depth condition often collides with the needs of some merchant ships, built or sometimes operating in shallow sea areas. However, new regulatory standards are being studied which will include specifications for measuring in shallow water in order to solve this problem.

There are different configurations of hydrophones provided by the standards: those mounted on the bottom or anchored and those suspended. In the case of fixed systems, the ship concerned is forced to go to the test site, often far from its own routes or from the shipyard, which often entails the need for long times that are not always sustainable. Mobile instruments, on the other hand, are more flexible, as they can be used in measuring areas, even if in practice systems mounted on the bottom or anchored can only be used in shallow water, due to the problems encountered in arranging them in waters deep in a short time and with reasonable costs. Finally, another problem is the drift of the hydrophone at sea when suspended systems are used.

Furthermore, the presence of a depth sensor on the hydrophone allows one to know only if the imposed limit has been exceeded, but not the actual slope of the cable, as information on the effective position of the hydrophone in the horizontal plane is missing.

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THE ENHANCEMENT OF PASSENGER SHIP DAMAGE STABILITY SINCE 1971

By **Keith Hutchinson**, Senior Consultant, Safinah Group

MONUMENT IN TALLINN COMMEMORATING THE 1994 *ESTONIA* DISASTER, IN WHICH 852 PEOPLE DIED. IT REMAINS ONE OF THE WORST MARITIME ACCIDENTS TO OCCUR IN PEACETIME EUROPE. SOURCE: SHUTTERSTOCK

The standards of residual stability for passenger ships have steadily increased over the years, often prompted by reaction to tragic loss of life following collision or other serious incidents. Fig 1 illustrates the amendments to these residual stability requirements over the past five decades. This article briefly describes some of the underlying reasons for these changes, including the major shift from a deterministic to a probabilistic approach for damage stability assessment.

SOLAS 60

The 1960 Safety of Life at Sea (SOLAS 60) Convention was adopted by the International Maritime Organisation (IMO) on 17 June 1960 and entered into force on 26 May 1965. It was the first major task for the IMO after its creation and, bearing in mind that in those days the calculation of residual stability was a most laborious task, represented a significant step forward in safety standards given the relatively limited analysis which was economically possible before the advent of electronic digital computers.

Initially, the intention was to keep the Convention up to date through periodic amendments. However, this proved to be a very slow process and hence virtually impossible to secure the entry into force of amendments within a reasonable timeframe. As a result, a completely new Convention was adopted in 1974, namely SOLAS 74.

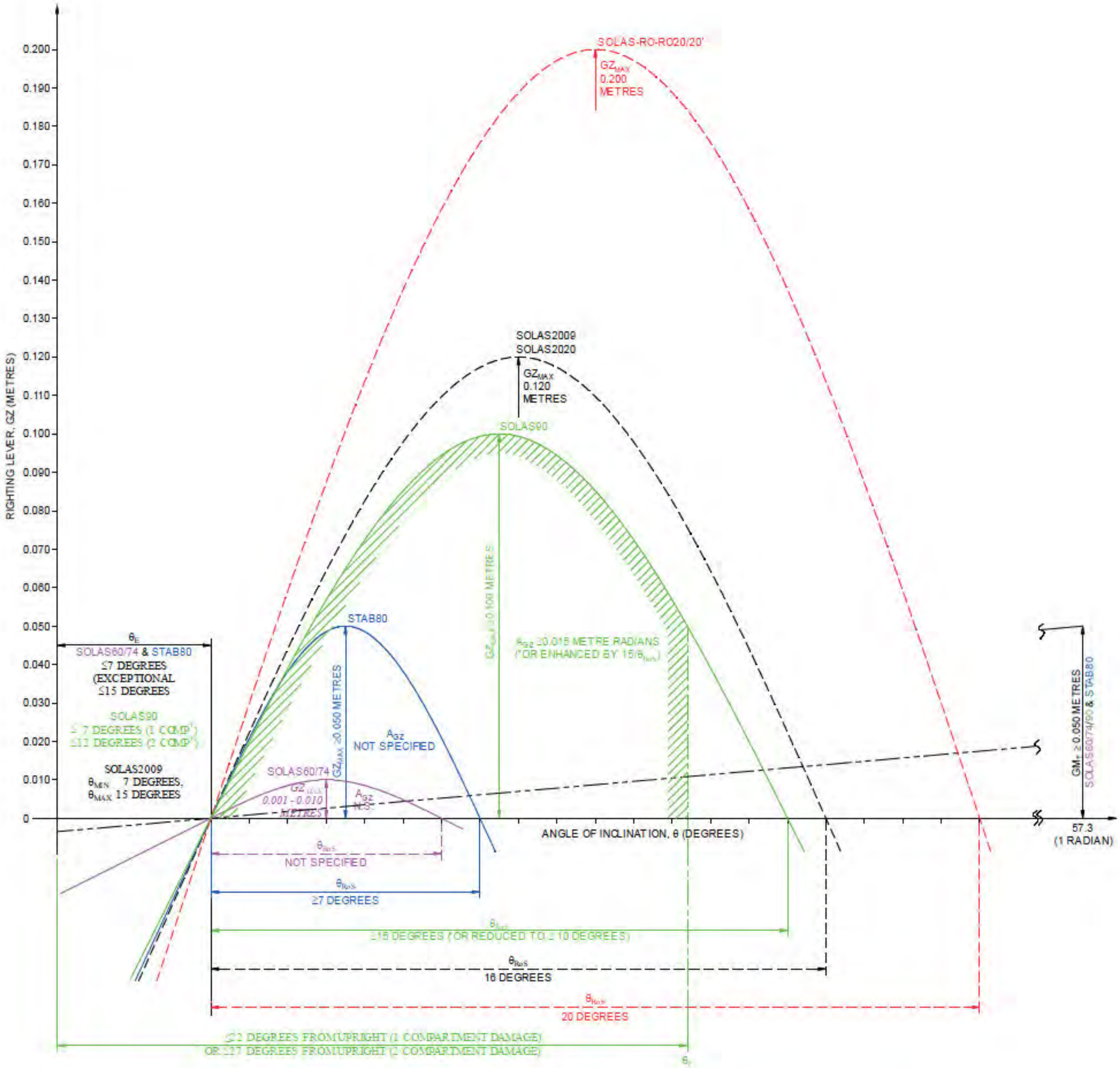
SOLAS 74

The 1974 SOLAS Convention included not only the amendments agreed up until that date but also a new amendment procedure, the tacit acceptance procedure, to ensure that changes could be made within a specified (and shorter) period of time. The tacit acceptance procedure provides that an amendment shall enter into force on a specified date unless, before that date, objections to the amendments are received from an agreed number of parties. As a result, the 1974 Convention has been updated and amended on numerous occasions and so is still referred to today as SOLAS 1974 'as amended'.

Insofar as SOLAS 74 residual stability requirements are concerned, from Fig 1 it can be seen that there were no changes to the criteria from SOLAS 60.

STAB 80

In the United Kingdom (UK) there was an increasing demand from designers to assign numerical values to the residual righting lever (GZ) curve criteria and this resulted in the UK STAB 80 regulations which considerably increased, for example, the required maximum positive righting lever (GZ_{MAX}) prior to downflooding from 0.010m to 0.050m, shown in blue in Fig 1. More importantly, these numerical values allowed for the calculation of so-called 'critical' or 'limiting' fluid vertical centre of gravity (KG_f) or (fluid) transverse metacentric height



DETERMINISTIC DAMAGE RESIDUAL STABILITY CRITERIA 1960 TO 2020 (FINAL STAGE OF FLOODING)

		DETERMINISTIC				PROBABILISTIC	
CRITERION	UNITS	IMO SOLAS60/74	UK STAB80	IMO SOLAS90		IMO SOLAS2009 SOLAS2020	IMO SOLAS2020 RO-RO'20/20'
POSITIVE RESIDUAL RIGHTING LEVER (GZ) CURVE RANGE, θ_{RoS}	DEGREES	NOT SPECIFIED	≥7	≥15	15≥θ_{RoS}≥10 (IF A_{GZ} INCREASED BY 15/θ_{RoS})	16	20
AREA UNDER THE GZ CURVE, A_{GZ}	METRE. RADIANS	NOT SPECIFIED	NOT SPECIFIED	≥0.015	≥0.015 x 15/θ_{RoS}	-	
MAXIMUM RESIDUAL RIGHTING LEVER GZ_{MAX}	METRES	0.001 TO 0.010 (UK)	≥0.050	≥0.100		0.120	0.200
ANGLE OF HEEL DUE TO UNSYMMETRICAL FLOODING AFTER EQUALISATION (DAMAGE EQUILIBRIUM ANGLE), θ_E	DEGREES	≤7	≤7	≤ 7 (1 COMPARTMENT DAMAGE) ≤12 (2 COMPARTMENT DAMAGE)		MINIMUM 7 MAXIMUM 15	
POSITIVE RESIDUAL METACENTRIC HEIGHT, GM_T	METRES	≥0.050	≥0.050	≥0.050		-	

FIG 1: COMPARISON OF SOLAS RESIDUAL STABILITY STANDARDS FROM 1960 TO 2020

(GM_T) curves by computer – a much simpler methodology for a Master to determine the safety margin of a loaded ship.

SOLAS 90

There was a step change in the residual GZ curve criteria in the 1988 amendments, which were adopted on 28 October 1988 and entered into force into force on 29 April 1990 as SOLAS 90. This was largely as a result of the MS *Herald of Free Enterprise* disaster in 1987, as shown in green in Fig 1. It was the subsequent loss of the MS *Estonia* in 1994 which acted as a catalyst for the introduction of the Stockholm Agreement (EC Directive 2003/25/EC, as amended) for roll-on / roll-off passenger (ro-pax) ships operating in European Union (EU) waters.

Issues with SOLAS 90

SOLAS 90 introduced the requirement for the assessment of damaged stability to dry cargo ships for the first time, initially for ships over 100m subdivision length (L_S) but later reduced to encompass ships over 80m. The regulations utilised the probabilistic approach utilising two draughts.

However, as with all previous amendments, SOLAS 90 continued the application of the deterministic approach to the assessment of damage stability performance for passenger ships – noting that since 1974 IMO Resolution A.265(VIII), which was based on the probabilistic approach and three draughts, could be applied as an equivalent assessment; however, this was seldom exercised. In these deterministic regulations, damage extents were limited to two or three compartments extent longitudinally and 1/5th breadth (B/5) penetration transversely. This obviously led to SOLAS 90 'paragraph designs' being created which were built to these limits. Hence, the result of exceeding these limits was not assessed and was therefore unknown.

In addition, the deterministic subdivision regulations included terms such as Criterion of Service, Margin Line, Floodable Length and Permissible Length etc. These were regarded as old-fashioned and rather obscure, having been in place since the first SOLAS Convention introduced following the loss of the RMS *Titanic* in 1912.

SOLAS 2009

It had long been realised that the determination of a passenger ship's safety level by the deterministic approach, discussed above, was rather limiting in that the assumed damage scenarios were somewhat arbitrary in terms of penetration depth, length and vertical extent. This eventually led to new set of amendments, SOLAS 2009. These were based on the probabilistic approach whereby a far wider range of damage scenarios, based on a large database of actual historical damage cases, is taken into account. Therefore, SOLAS 2009 harmonised previous regulations for passenger ships and cargo ships, namely SOLAS 90 and Resolution A.265(VIII), into one set of damage stability regulations based principally on the probabilistic approach.

In Fig 1, the residual GZ curve for the SOLAS 2009 amendments is shown by a black dotted rather than a solid line. This is because GZ curve criteria for the previous deterministic regulations represent minimum values which must be attained for each assumed damage scenario. However, in the probabilistic approach each individual scenario does not necessarily need to achieve, for example, the GZ_{MAX} of 0.120m shown in Fig 1. If a given scenario does achieve all the SOLAS 2009 criteria in the final stage of flooding of the compartment(s) under consideration then it will be assigned a (conditional) probability of survival ($s_{final,i}$) factor value of 1.0, implying that it will survive in all sea states up to a significant wave height (H_S) of 4m. Since 99% of historical damage cases have occurred in lesser sea states this effectively means that the damage scenario in question will always survive so that it can contribute fully to the attained index (A). The A index is used to determine whether the overall safety level, as determined by the required index (R), has been achieved.

For the survival $s_{final,i}$ factor, a damage scenario with, for example, a residual GZ_{MAX} of less than 0.120m may still be used in the summation of A but its contribution will be lessened because its $s_{final,i}$ will be less than 1.0. This $s_{final,i} < 1.0$ implies in turn that the ship may not survive that particular scenario in higher sea states.

From Fig 2 it can be seen that the SOLAS 2009 R index, shown in black, is a function of both L_S and the number of Persons on Board (N) together with the lifeboat capacity.

Issues with SOLAS 2009

Due to the equivalence of SOLAS 2009 with SOLAS 90, it was found that ro-pax designs optimised to meet SOLAS 2009 were vulnerable to capsize following plausible damage scenarios, even in calm water. Hence, as the $s_{final,i}$ factor obviously did not include the effect of water on deck (WOD), for ro-pax ships the Stockholm Agreement was retained for such vessels intended for service in EU waters.

It was also found that the R index was too low, and consequently too many damage cases were permitted to result in loss of the ship in question.

During the process of developing the SOLAS 2009 amendments, there were many 'loose ends' that needed tidying up or clarifying and enhancements required to the Explanatory Notes. This was undertaken post SOLAS 2009 and included inter alia issues such as improvements to the presentation of the limiting KG_F / GM_T curves, the introduction of the concept of Safe Return to Port whereby a damaged passenger ship is expected, especially in remote areas, to act as its own lifeboat to avoid dangerous evacuations, etc.

SOLAS 2020

As discussed above, research showed that the WOD effect was not fully accounted for in the probabilistic SOLAS 2009 amendments. This was overcome by the introduction of the so-called '20/20' amendments, which are shown in red in Fig 1, to the formulae for the survival $s_{final,i}$ factor for ro-pax ships. This amendment entered into force on 1 January 2020 and is designed to counteract the WOD effect by only assigning a survival $s_{final,i}$ factor of 1.0 for damages involving the garage space if the residual GZ_{MAX} is 0.200m (TGZ_{MAX}) and the residual Range is 20^{o} (TRange) in any given damage scenario.

After much research and debate both at IMO and within the EU regarding the appropriate level of safety for passenger and ro-pax ships, a new formulation of R was eventually agreed and adopted into the SOLAS 2020 amendments. This and its formulation are shown in red in Fig 2, from which it will be noted that R now only depends on N, as it was felt at IMO that it was important to focus on the safety of passengers and not necessarily on the overall size of the ship or the lifeboat capacity – this now being determined independently elsewhere

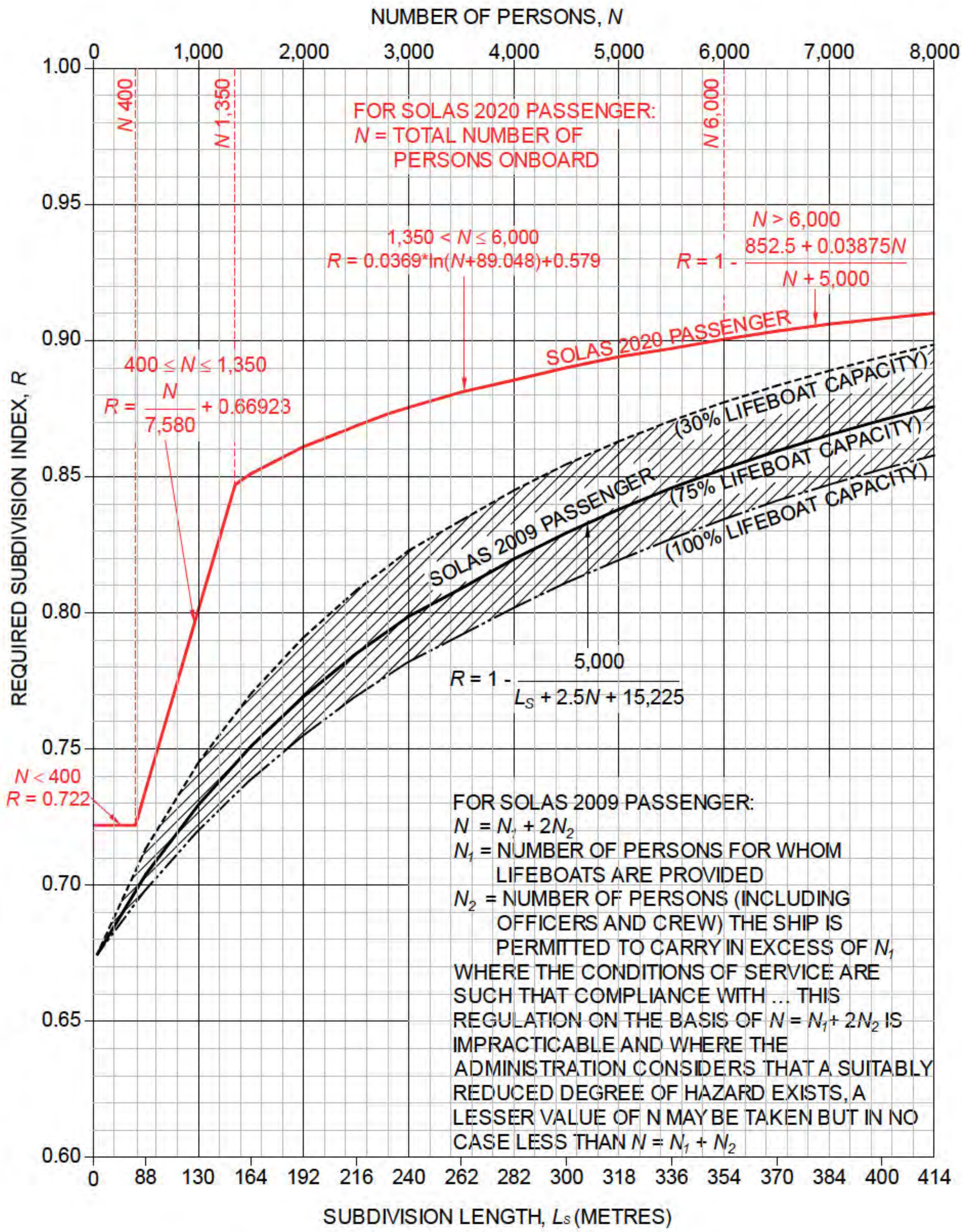


FIG 2: COMPARISON OF THE SOLAS PROBABLISTIC REQUIRED INDICES R FROM 2009 AND 2020

in SOLAS 2020. From Fig 2 it can be concluded that SOLAS 2020 represents a significant increase in safety level for all new passenger ships built since 1 January 2020.

Conclusions

The above article has briefly illustrated, through enhanced damage stability standards, the safety improvements that SOLAS has introduced to passenger ship design since the first issue of *The Naval Architect* was published in April 1971. However, work on the regulations is still ongoing as, for example, it is still to be determined whether the undoubted improvements to safety that (probabilistic) SOLAS 2020 provides are sufficient to allow the European regulatory authorities to revoke the (deterministic) Stockholm Agreement for new ro-pax ships.

Disclaimer

The views expressed in this article are those of the author and do not necessarily represent those of the organisations with which he is affiliated or the professional institutions of which he is a member.

50 YEARS OF WATCHING PAINT DRY

By **M.Raouf Kattan PhD DSc FREng,**
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Over the last 50 years the time pressure from the construction cycle, operational needs and the requirement for faster drydock turnaround have all resulted in significant technology changes concerning how ships are built, operated, maintained and repaired. During this time, increased health, safety and environmental regulations have required notable changes to coating formulation and work practices. The result is that the coating process is struggling to cope with the increasing demands placed on it.

An overview

The coating process has not changed significantly since the 1970s and still comprises three main stages: construction activities, maintenance at sea by the ship's crew or a dedicated riding squad and repair work while the vessel is not in service, in drydock or otherwise not trading. To some a fourth common activity is the touch up and repair of newly applied paint as a result of poor planning and scheduling of work.

The activities involved have also remained the same:

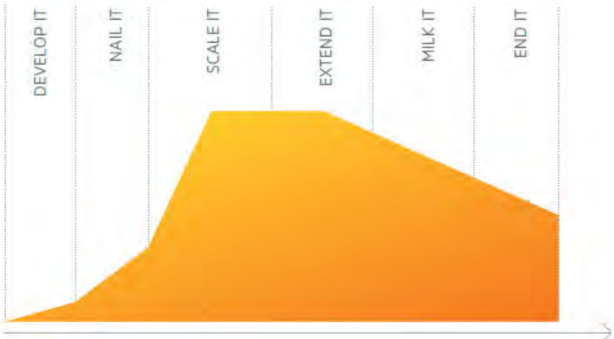
- Primary surface preparation (at construction)
- Secondary surface preparation and cleaning, using dry abrasive blasting and power assisted hand tools.
- Coating application in the form of a liquid paint
- Physical Inspection of the work followed by acceptance or remedial work.
- Repair work in drydock (or sometimes a riding squad) using ultra high pressure water jetting and hand tools for surface preparation together with airless spray, brush and roller application
- Onboard maintenance work by the crew primarily using hand tools and brush or roller application

Any technology development is usually associated with a life cycle that encompasses the following key stages, as represented in Fig 2.

FIG 1: THE AUTHOR UNDERTAKING SURFACE PREPARATION WORK AS A DECK HAND (ON A REEFER SHIP) WITH A PNEUMATIC FLAYING MACHINE IN THE EARLY 1970S

The coating process technologies are in a phase beyond maturity, often referred to as 'milking it'. During this stage the technology is being pushed beyond the limits of its capability

FIG 2: TECHNOLOGY DEVELOPMENT LIFE CYCLE FOR COATING WORK



resulting in increasing challenges at construction, repair and maintenance. These challenges have been further aggravated by an ever-increasing regulatory burden on chemicals, health, safety, and the environment which are placing the process under considerable stress.

In the last 50 years the pace of life has accelerated dramatically, and expectations have risen accordingly, but paint is not drying any quicker!

In the early 1970s, maintenance onboard ship for deckhands was overwhelmingly driven by the need to combat corrosion. Larger crew sizes meant focus could be made on maintenance work and a greater number of areas were accessible under the H&S regulations of the day.

Why do coatings matter:

For every tonne of steel produced the manufacturing process results in 1.82tonnes of Co_2 (1.3 billion tonnes of steel are produced annually[1]). It is estimated that about 20 million tonnes are used in shipbuilding each year. Without anti-corrosive coatings the typical ship built to comply with IACS rules[2] would remain compliant for about five years on the assumption of uniform corrosion rates. Given the economic life of a ship is about 20 years, it is the anti-corrosive coatings and their performance that drive a return on investment.

The world fleet consumed about 339 million tonnes of fuel (HFO equivalent) in 2018[3] . If no antifouling paint were applied, it is estimated that the fuel consumption would be significantly higher. However, for optimal performance to be achieved, the presence of antifouling paint is not enough. The coating should match the operation of the vessel.

In addition, poorly performing antifouling paint may fail to prevent the translocation of marine invasive species, which costs hundreds of million dollars per year to combat and may result in damage to local ecosystems, aquaculture, clogged water ways, reduced water quality, damage to riverbanks and structures[4].

In drydock, coating activities can account for up to 70% of the waste stream generated in the form of spent abrasives, empty paint cans (which can cost more to dispose of as a hazardous waste than the initial purchase price of the full can).

Chemicals to formulate paint are under ever-increasing scrutiny and impose restrictions on the formulators to develop longer term solutions, while environmental groups exert considerable pressure on the optimisation of local issues without consideration of the broader impact of a reduction in performance in antifouling or anti-corrosion paints or solvent emissions.

Specification

To achieve the desired performance, coatings should be treated as an engineering system. In reality the specification process is inadequate and often driven by generic solutions or 'grandfathered' specifications. This often results in irrational technical decisions driven by the pursuit of lower costs as opposed to optimal performance.

Generic paint specifications are usually developed by the paint supplier or the shipyard and tend to include basic information on product selection and specification. In contrast, an engineered functional specification considers the yard needs, the operational needs, and maintenance and repair needs, as well as health, safety and environmental issues. This approach results in an improved technical fit of the specification and the subsequent coating selection (a two-phase approach), while offering considerable cost savings at both newbuild and in service.

Productivity and process

Man-hours for coating work and associated productivity have been almost static over the last 40 years with very few equipment changes that would enhance productivity. The most common 'low cost, high productivity' techniques are still dry abrasive blasting for surface preparation and airless spray application.

At newbuild, the main tools are abrasive blasting and airless spray in combination with brush and roller application in some areas – the so-called 'stripe and build coats'.

Onboard, a range of handheld tools still dominate. Some vessels now provide airless spray equipment but most of the work is still brush and roller based, and consequently of questionable quality.

At repair, high pressure water jetting has gained dominance as it can clean surfaces and remove paint but relies on an existing profile for paint application. Airless spray application dominates with the main area of concern being anti-fouling coatings.

While little has changed in the processes, the chemistry of the coatings has evolved and they are more complex to handle in general. The challenges are increasing because of productivity gains in other processes and the tighter regulatory environment.

Inspection

This is a classic quality control inspection process that takes place after the event. It is therefore not preventative and can only result in increased work as the defects are not identified until the work is complete. The outcome is that 30% of all coating man-hours on average are to repair damages from poor integration with other processes.

At newbuilding stage, the surface preparation and coating work is inspected by up to six interested parties:

Any non-compliances are registered on a defect list and repaired as and when appropriate. The inspection challenge is best summarised by the IMO's Performance Standard for Protective Coatings (PSPC) for dedicated seawater ballast tanks[5] which requires 15 different inspection checks, of which 10 are subjective and only five are objective. The measurement of dry film thickness requires a reading for every square meter, which can reach 1,000,000 readings for a VLCC, and the creation of a coating technical file to record the work undertaken. However, in the event of a failure, the coating technical file is rarely a source of any information as to the possible cause of the failure, with the exception of the record of the original paint specification and the actual inspection records. Fifteen years after its implementation, there has been no meaningful study to compare coating performance before and after the introduction of the regulation.

The process of paint inspection and record keeping has hardly changed since the late 1970s early 1980s with the exception of the advent of electronic gauges and computers. Data is still often handled and recorded manually for subsequent transfer to computer software for reporting. The minimum required qualifications for paint inspectors comprise attendance of a two-week course to learn the basics of inspection, the use of inspection tools.

FIG 3: THE AUTHOR COMPLETING END OF DAY COATING INSPECTION RECORDS FOR A NEW BUILD SERIES OF 8 X 60,000DWT BULK CARRIERS CIRCA 1981. NOTE THE LACK OF COMPUTER AND PRESENCE OF A CALCULATOR

Coating standards referred to in specifications pose problems as they have not been developed with ships in mind but are generic and applicable to a wide range of structures from cars and trains to bridges. These need careful interpretation for application to ships. For example, one may envisage the possibility of having 100% defect-free welding on a rail car with 200m of welding in total, while on a ship there may be an excess of 60km of fillet weld. It is the author's experience that these documents are rarely read and reviewed until something goes wrong, despite good practice requiring a pre-job meeting to clarify their application.

In service and in drydock, concern has existed for many years with regards to lives lost on entry into enclosed spaces for inspections[6]. This has led to the introduction of the concept of using drones and the technology now allows for visual inspection in enclosed spaces[7]. However, this approach is limited at present because of flight time limitations. Currently, the process can be more time consuming and costly than normal inspections and does not eliminate the need for entry into enclosed spaces completely. Human inspectors can use multiple senses to assess the condition of any surface and take samples. Drones can only make a visual record. They are certainly a tool for hard-to-reach places when the vessel is in service and means of access are limited.

Drones record visual evidence and store it indefinitely for subsequent review. Should a subsequent failure arise, hours of high-definition video images can be reviewed, and issues missed by the inspector highlighted, possibly resulting in an increased level of disputes.

Future developments and conclusions

A circular economy approach is needed to improve design for coating performance to better integrate the coating process into the construction process to minimise re-work and improve coating through life performance and reduce environmental impact.

There are many ongoing areas of development across the industry aiming to satisfy future needs, many of which are being driven by regulatory and environmental concerns. One challenge the industry has is how to balance the need to meet the environmental challenge across the life cycle of the ship from iron ore extraction to scrapping, rather than focusing on local optima. For example, while speed reduction can save fuel, underwater hull cleaning can also do the same. However, these locally optimised solutions almost always ignore the impact of down time on the vessel which could result in an increased demand for the number of ships and crews, and the associated environmental impact of building, maintaining them and flying crews around the globe[8].

Current regulatory changes will place a greater pressure on formulators to develop new solutions. However, real consideration to the impact this may have on the production process, through life maintenance and repair needs of new technologies, should be carefully considered.

It is possible that this continued pressure could result in the end of 'paint' as we know it and the need emerges for alternative solutions.

The industry is actively investigating underwater hull grooming (as opposed to cleaning) using a range of automated devices. Ideas have been put forward for 'brush boats' that could tend to vessels on entry and leaving a port; even concepts that may allow ports to offer foul-free berths have been and are being investigated/researched.

The use of alternative solutions to paint, such as a matrix of UVC LEDs, could manage fouling in niche areas and potentially other larger areas[9].

Cargo tanks and holds could be 'coated' using engineered wraps, which have been used on offshore platforms and cruise ships and are increasingly popular for smaller yachts and offshore windfarms towers. One of the advantages of such solutions is that they can be manufactured in a controlled environment, limiting the health and environmental risks associated application. While they may offer improved in-service performance, such solutions pose significant challenges for new construction production processes in terms of productivity[10].

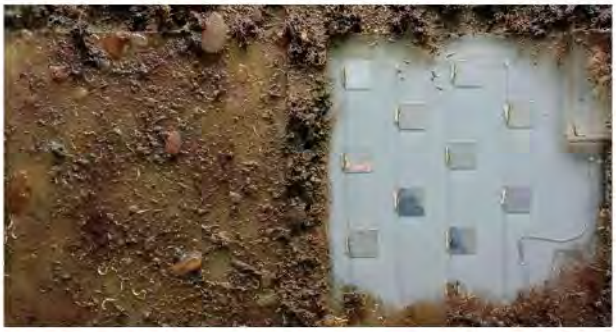


FIG 4: UVC LED ARRAY FOR FOULING PREVENTION – PHOTO COURTESY OF PHILLIPS BV

The complexity of ship design limits application of wraps in spaces, such as tanks. However, they may present a convenient and effective way for ship crews to approach onboard maintenance without the use of paint.

Some complex/difficult to access areas on land-based structures already have corrosion prevention undertaken by vapour phase inhibitors, which have also proved effective for long stretches of pipeline internals[11]. Some limited trials have been conducted on the internals of marine buoys.

There is no doubt a need for better technology to be adopted in the surface preparation and coatings activities. However, it has proven challenging to overcome the flexibility, cost and productivity of the current processes.

Inspection regimes have seen drone technologies emerge for both above water and underwater work. Underwater hull cleaning / grooming is increasingly automated. However, the

FIG 5. ANTI-FOULING WRAP BEING APPLIED TO A SHIPS HULL. PHOTO COURTESY OF FINSULATE.COM

challenges surrounding remote maintenance and repair work are still significant and this will become more critical with the move toward unmanned ships.

Performance of coatings is still very difficult to measure. Unlike other engineering systems, there are no reliable degradation curves or data that could be used to develop genuine preventative maintenance strategies for coatings. 'Hull performance monitoring systems can detect significant changes in performance in theory[13], however, best practice currently still recommends regular inspections focusing on the condition of the underwater hull, but these are again recording failure once it has occurred rather than offering a prediction tool.

Some effort[14] is now being developed to generate data to allow for objective comparison between different coating technologies leading to improved underwater hull management and these will become increasingly important.

There is therefore considerable work to be done in the next 50 years and significant challenges to be met by the coating industry. By then I hope the paint will have finally dried. ■

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[3] MEPC 75/7/15. Fourth IMO GHG Study 2020.

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