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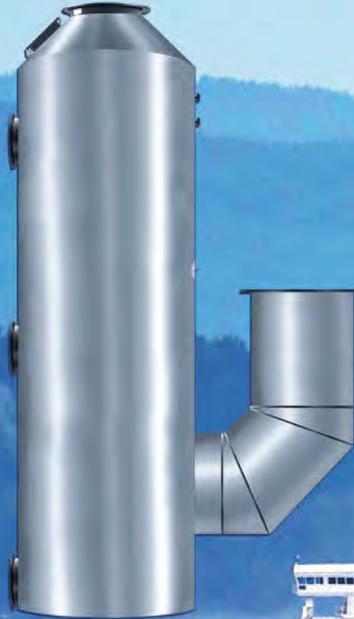
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Safety: an old problem in a new world

The safety threat posed by digitalisation and decarbonisation are the subject of a recent DNV GL white paper

No sooner had we sent *Significant Ships of 2020* (now available to order) to the printers in February than the news came through that one of the vessels featured, *CSSC Cape Town*, had suffered an accident. The 120,000dwt Capesize bulker was entering British Gibraltar Territorial Waters on 19 February when an explosion occurred, with two crew suffering serious burns and requiring evacuation for hospital treatment in Seville. The Chinese-flagged vessel sustained damage to its anchoring system but remained otherwise operational.

Inevitably, it will be some time before any official investigation report is published but some people have drawn comparison with the 2017 explosion onboard the bulker *Tamar* off the coast of Cape Cod, Massachusetts, which left two dead. The incident was subsequently attributed to methane leaking from the forward cargo hold and igniting in the windlass control room. Coincidentally (or not) both vessels were carrying shipments of coal loaded at Baltimore.

It's surprising how often a vessel relatively early in its operational life can appear more susceptible to a casualty incident. There are some infamous historical examples that scarcely need mentioning and on p.14 we reference one of the more recent, *Maersk Honam*, which was only six months into its operational life when it caught fire transiting the Arabian Sea, resulting in the death of five crew. When the Transport Safety Investigation Bureau (TSIB) of Singapore finally published its investigation report in October of last year the findings were inconclusive, although felt highly likely to have been caused by the decomposition of dangerous cargo.

Much like the problems that have arisen with VLSFO (see last month's Editorial Comment) it raises questions about whether

regulatory instruments – in this case the IMDG Code and SOLAS fire prevention provisions – failed to keep up with the pace of technical progression, or perhaps that there was insufficient scrutiny of the potential risks.

A white paper published by class society DNV GL (or, as we should be referring to them from this month, simply DNV) in February, 'Closing the Safety Gap in an Era of Transformation', looks at the challenge of developing safe practices in the face of the huge strides being made in digitalisation and decarbonisation.

For each of these megatrends the white paper identifies three 'safety hurdles' and makes recommendations. With digitalisation it suggests firstly that traditional risk-management methods may be inadequate and that there should be greater emphasis on system performance than component reliability when managing complex systems. Second, that there should be a focus on human-centred design to support staff. Thirdly, that organisations should address the tendency to become a patchwork of stakeholders by establishing digital transformation strategies.

Decarbonisation, the study suggests, is similarly characterised by an atomisation of responsibilities when it comes to safety. Stakeholders work in silos focused on subsystems when system integration would foster collaboration. A collective commitment to contributing knowledge and, in doing so, supplement the regulatory shortfall would help to address its failure to keep pace with technological progress. Thirdly, that a lack of experience among suppliers and end users alike requires a culture of continuous improvement that develops lacking competencies.

"We need to recognise how any single decision, for example the choice of fuel

or introduction of a new digital system, impacts upon other ship systems, the vessel as a whole, and even the fleet. But, if we can all work together, step out of our silos, we can develop the procedures and competencies needed to meet these challenges and enable a culture of continuous improvement," says Knut Ørbeck-Nilssen, CEO of DNV GL – Maritime.

In short, technological advancement should be complemented by a commitment to keeping people in the loop and ensuring that they have a basic holistic comprehension of the technology and processes at work, even if they can't understand the minutiae. It's a context specific approach, leaning heavily into the concept of barrier management and trying to avoid 'monkey see, monkey do' in the event of a problem. Central to that, the report concludes, is a human-centred design approach to maritime systems.

Whether these are really maritime specific problems or more of a cultural malaise that has safety repercussions in the maritime domain is perhaps in the eye of the beholder. I'm inclined to think that most human-designed systems are inherently anthropomorphic. The bigger problem is trying to build on existing foundations instead of rethinking them to reflect technological progress. Very often safety issues, whether vessel specific or more generally, can be traced back to older, known problems that have been exacerbated either by adaptation or by the passage of time.

As ever, we hope that you find something in this issue to stir your interest and I would like to remind you how much we value your feedback. Please join us again in April for a special edition in which we will celebrate 50 years since *The Naval Architect's* first publication. *NA*

Alternative fuels

Project for ammonia-fuelled tanker builds momentum

Yara International ASA and the Maritime and Port Authority of Singapore (MPA) have joined The Castor Initiative, a Joint Development Project (JDP) aiming to develop an ammonia-fuelled tanker.

Launched in January 2020 with MISC Berhad (MISC), Lloyd's Register (LR), Samsung Heavy Industries (SHI) and MAN Energy Solutions (MAN), the project is driven by a shared belief by all partners that maritime needs leadership and collaboration to meet IMO's 2050 target. According to LR, this ambition requires commercially viable deep-sea zero-emission vessels in operation by 2030, and ammonia is one such pathway towards zero carbon emission vessels.

In September 2020, the JDP reached a key milestone when LR awarded Approval in Principle to SHI for its ammonia-fuelled tanker design. Following this approval, SHI aims to continue the development of its fuel gas supply system and detailed ship design, with a view to commercialise by 2024.

At the time, Jong-Hyun Youn, SHI EVP and head of design, confirmed: "The ammonia fuel design project led by SHI brings all relevant stakeholders spanning from the fuel supplier to operator and it will result in a commercial outcome."

With the addition of Yara and MPA, the JDP has representation from all sectors of the maritime industry. While Yara, a specialist in nitrogen fertiliser, will work alongside existing partners to develop ammonia propulsion ships, MPA, a bunkering hub and flag state, brings its expertise on safety issues and ammonia bunkering procedures, as well as research capabilities in Singapore.

Quah Ley Hoon, MPA chief executive, highlights: "Decarbonisation remains a key priority for the maritime sector, not just in Singapore but globally. As a transshipment and bunkering hub, we are committed to meet IMO2030/2050 decarbonisation goals. We are also looking forward to collaborating with like-minded industry partners to support the development and trials of alternative future marine fuels such as ammonia."

Wind propulsion

UK company unveils true zero-emission ship design

Windship Technology has announced its first true zero-emission ship design, a comprehensive solution to combat CO₂, NO_x, SO_x and particulate matter emissions.



Rendering of Windship Technology's true zero vessel design

The vessel's patented triple-wing rig, tested at Wolfson Unit in Southampton, is 48m long and stored on deck via a stowage solution to assist port navigation and cargo handling. With a composite structure inspired by the wind turbine industry, Windship Technology highlights that its rig is capable of producing a driving force several times greater than existing single masted solutions of the same height.

According to the company, its design is the only viable and most economical zero-emission project for ocean-going bulk carrier and oil tanker ships. Alongside its triple-wing rig, the design incorporates solar arrays, carbon capture, optimised hull shape and specialised weather routing software. Windship Technology has also developed a new diesel electric ship drive system to eliminate CO₂, NO_x, SO_x and particulate matter to "True Zero".

The company has entered into a partnership investment with DNV GL. With the intention of classifying emission reductions, safety and operability, the classification society will conduct an outside-in and inside-out verification to assess the entire ship design.

Lars Carlsson, director of Windship Technology, notes that working with DNV GL is a major step towards proving true zero emission status. He adds: "The clock is ticking and regulation will force a new approach for an industry that is traditionally hesitant to change."

Decarbonisation

Maersk Møller Center expands strategic partners

Norden and Total are the latest companies to sign strategic partnership agreements with the Maersk Mc-Kinney Møller Center for Zero Carbon shipping.

Launched in June 2020, the Maersk Mc-Kinney Møller Center is an independent, not-for-profit R&D centre supported by the A.P. Møller Foundation, which aims to facilitate the decarbonisation of the maritime industry by collaborating with companies, academia

and authorities (see *Green Shipping 2021*, p4)

In its role as a partner, Total will share its test equipment on strategic programmes, provide R&D and shipping specialists, and will join the Center's advisory board to give strategic and technical guidance for further development of activities.

Norden will contribute to the Center's work on projects to develop and implement future fuels and zero carbon technologies. This will involve providing its 'sailing laboratories' – its owned fleet undertaking new fuel or alternative wind propulsion system trials. In addition, Norden's decarbonisation team, technical and commercial colleagues will assist the Center with their relevant expertise.

While A.P. Moller – Maersk, class society ABS, Cargill, MAN Energy Solutions, Mitsubishi Heavy Industries, NYK Line and Siemens Energy founded the Center, it continues to broaden its portfolio of partners, with the aim to create an overview of viable decarbonisation pathways and accelerate the transition to new fuel types and technologies.

Ship management

MariData project targets ship operation management

A recently launched large-scale project, MariData, aims to create a future-oriented energy management and decision support system for ship operations.

The project will develop, improve and classify simulation-based modules for energy management using a combination of maritime technologies and experience, as well as AI-based tools and methods, to produce a system for holistic ship energy and operations management.

Suitable for use both onboard and shore-side by shipping companies, the platform will combine geo-information, energy consumption data, and a decision support system (DSS) of technical, environmental and economic data. Online simulations will provide decision support for short-, medium- and long-term ship management and operations.

Project partner Hamburgische Schiffbau-Versuchsanstalt (HSVA) highlights that MariData's key innovations are precise analysis of an existing ship's drag, propulsion and fuel consumption under realistic operating conditions, which also account for wind/wave influences and hull/propeller conditions.

The platform will utilise this to perform rational analysis of the influence of individual components, improving forecast quality and the basis for navigation decisions. The system will also integrate geoservices, as well as flexible approaches to generate missing data.

Funded by the German Federal Ministry for Economic Affairs and Energy, the MariData project was formed to develop comprehensive technologies for ship energy management and reduce emissions from ship operation. It brings together major maritime players, such as HSVA, AVL Deutschland and AVL Software & Functions, Carl Büttner Shipmanagement, and more. Associate partners include Navis Carrier and Vessel Solutions and Hamburg-based ferry operator HADAG.

Classification societies

BV announces biorisk notations

Bureau Veritas (BV) has launched two new classification notations, Biorisk Managed and Biorisk Secured, which address ship safety and health requirements for all ship types.

Focusing on the creation and implementation of an outbreak management plan, the Biorisk Managed notation follows BV's Restart your Business (RYB) protocols, which check that health, safety and hygiene conditions are in place to support business resumption.

Biorisk Managed also outlines onboard responsibilities and resource management, requirements for PPE and medical equipment supplies, crew training and more. For spaces and systems, such as heating, ventilation and air conditioning, the notation covers redesign, rearrangement and modifications.

Whereas the Biorisk Secured notation comprises requirements for the installation of further systems and hardware, including a dedicated onboard area for quarantine and the provision of fixed and portable equipment. It also instructs on monitoring crew and passenger body temperatures and furnishing the ship with appropriate equipment.

MCS Cruises' *MSC Virtuosa*, delivered in February 2021, will be the first ship to receive the classification society's Biorisk notation. [NA](#)

Cruise ship *MSC Virtuosa* is the first ship to receive BV's Biorisk notation Source MSC



New fuels and propulsion systems sparking interest

Malcolm Latarche logs on for some socially distanced debate at the 'virtual' SMM

If things had gone as planned, this February would have seen the revival of the marine exhibition circuit with SMM, postponed from September 2020, taking place in Hamburg. However, travel restrictions and lockdowns finally forced the organisers to abandon plans for a socially distanced physical event in favour of a digital online series of discussions and debate.

There were some 60 hours of debate spread over four days and around 7,000 people from 80 countries joined the online programme. A success of sorts and a valiant attempt by the organisers. However, with new rules looming on EEXI and other decarbonisation measures, shipowners must be desperate to get into real conversations with innovators and equipment suppliers to discuss their options.

On the subject of innovation, projects involving new fuels are beginning to gather traction. Maersk said in mid-February that it was planning for a new carbon-neutral feeder vessel to be ordered this year and running on renewable methanol in 2023. A few days later, Maersk chief executive Soren Skou told the BBC that he expects consumers will be happy to foot the bill.

In an article on the broadcaster's website, Skou revealed that Maersk's fuel bill of US\$4 billion per year would likely double under a carbon-neutral or decarbonised scenario but "for the individual consumer, for the individual product, it will be almost nothing. It would in a container with sneakers from Vietnam, translate into something like six cents per pair of sneakers," he said.

Methanol as a fuel appears to have been dismissed by another Danish operator with DFDS head of innovation and technology, Jakob Steffensen, saying during the digital SMM conference: "I think shipping needs to be really concerned about chasing a fuel that needs carbon, because we really don't want to compete – with for instance aviation – on who is willing to pay the most for that sustainable fuel. Please look at the decarbonisation pathways of other industries in your country."

DFDS' fuel of choice is ammonia. "Hydrogen and green ammonia production is very, very scalable; the more you use them, the cheaper they get," said Steffensen, who would probably be buoyed by news released by Yara International two weeks later. The Norwegian manufacturer, along with Statkraft and Aker Horizons, are aiming to establish Europe's first large-scale green ammonia project in Norway. The partners will target green hydrogen and green ammonia opportunities within shipping, agricul-

ture and industrial applications, by electrifying Yara's existing ammonia facility in Porsgrunn.

The least carbon intense energy source – wind – has also been in the news again. German bulker specialist Oldendorff Carriers is involved in a joint development project with UK-based Anemol Marine Technologies, Lloyd's Register and Shanghai Merchant Ship Design and Research Institute to develop a wind-assisted propulsion solution for bulkers. The project, scheduled for completion in 2022, would see Anemol's tilting rotors installed on bulk carriers. The folding system allows the rotors to be lowered from vertical into a horizontal position either across the deck between hatches or along the side of the vessel.

Another project involving wind assistance was unveiled by Wallenius Wilhelmsen. Reminiscent of its 2005 concept vessel *E/S Orcelle*, the Scandinavian car carrier specialist has developed a wind-powered ro-ro carrier that may actually be built this time around.

Once completed, *Orcelle Wind* will have the capacity to carry 7,000 vehicles at speeds of 10-12knots under sail – a speed that can be increased with the help of an onboard supplemental power system.

The company said in a statement in February that plans are in place to have a design ready by mid-2022, with the finished vessel expected to set sail by 2025. To pass muster, *Orcelle Wind* has to satisfy regulatory standards relating to safety and technical performance. Operational needs must also be met, such as the suitability for deployment on multiple global trade lanes and the ability to manoeuvre in port in bad weather.

"It will take the dedicated collaboration of our world-class customers, partners and employees to make such a bold initiative as *Orcelle Wind* succeed. More than just evaluating the concept, we are committed to making this a success," said Craig Jasienski, CEO of Wallenius Wilhelmsen.

Looking away from the future to the present, scrubbers are proving their worth for tankers. According to S&P Global Platts, scrubber equipped vessels are enjoying a premium in the market as oil prices rise. Apparently, VLCCs using VLSFO have been losing anywhere between US\$2,400-\$3,200/day when chartered out for spot voyages on the Persian Gulf-North Asia routes while those with scrubbers can use the cheaper HSFO and earn close to US\$5,000/day.

If such market conditions continue, scrubber makers must be hoping for a renewed interest in retrofits. *NA*

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Coatings

Nippon announces nano antifouling technology

Nippon Paint Marine (NPM) has launched its new self-polishing antifouling paint, FASTAR, which minimises the effect of seawater temperatures, vessel speed and other external factors by utilising a nano-domain resin structure.

FASTAR's nano-domain structure is derived from the micro-domain structure used in NPM's existing biocide-free self-polishing coating (SPC), Aquaterras. The company stresses that the improved design achieves precise, controlled and effective delivery of antifouling components.

The new resin's minimum drying time required for a large container vessel at drydock is reduced by 37% compared to other coating systems, dependent upon ambient temperature during application. As Hirokazu Kaji, general manager of Nippon Paint Marine R&D, explains: "Thanks to the reduced film thickness, shipowners applying FASTAR will benefit from shortened in-dock application and drying times, resulting in further cost savings."

Cost benefits vary according to vessel size and operational profile, but the company highlights that, typically, less FASTAR paint is required for a ship's hull than existing SPCs.

The antifouling product is available in four variants: FASTAR I, FASTAR II, FASTAR XI and FASTAR XII. The latter two versions also feature Nippon's hydrogel technology, which gives an 8% reduction in fuel consumption and CO₂.

Engines

World's most efficient engine selected for *Manxman*

The Isle of Man Steam Packet Company's (IoMSPCo) new flagship, *Manxman*, will be powered by Wärtsilä 31 engines, defined by the Guinness World Records as the world's most efficient four-stroke diesel engine.

Wärtsilä will supply *Manxman* with two 8-cylinder and two 10-cylinder engines, which will be installed at Hyundai Mipo Dockyard in South Korea, where the vessel is under construction. The new ship is due to begin service in Spring 2023, replacing IoMSPCo's long-serving ferry, *Ben-my-Chree* (see TNA November 2020).

Chief executive of IoMSPCo, Mark Woodward, states that reliability, efficiency and low operating



CAD rendering of the Isle of Man Steam Packet Company's *Manxman*

costs were all key considerations in the company's selection of Wärtsilä engines. He explains: "Alongside our drive for greater efficiency and lower emissions levels, there is also an ever-increasing focus on the environmental aspects of marine transportation so we were naturally keen to select an engine that can deliver sustainable operations."

The ship's hybrid propulsion system will also include energy storage batteries and waste heat recovery, the full details of which remain unknown.

James Royston, IoMSPCo fleet operations manager, adds that the company chose Wärtsilä engines not only for its experience, but also as the engine has an average diesel consumption of 8% lower than other similar sized models on the market.

Ship safety

RightShip unveils new safety score and platform

Risk management specialist, RightShip, has launched its new Safety Score and Platform after two years of development.

Replacing RightShip's Qi platform, which went offline on 15 February 2021, the new Safety Score and Platform focuses on a ship's operational performance. Through multiple data sets and expert reviews, each vessel is benchmarked against the world fleet and given a score out of five, with full marks indicating best practise and attention to safety.

A ship's score is separated into six sub-scores and RightShip's online platform displays the influence of each sub-score on the overall results, showing rules and pathways for further improvements and ensuring ships meet minimum standards of safety.

Supporting RightShip's vetting customers, such as charters, ports and terminals, the Safety Score gives insights on a vessel or operator's performance at the first stage of their due diligence process. It also encourages shipowners to invest in processes and

technologies that better the safety of the entire supply chain. As Steen Lunch, RightShip CEO, comments: “We believe the new Safety Score is a product that will make significant changes to the way shipping operates and lead to greater safety, sustainability and welfare outcomes.

“It is an important step in our digitisation process; with all communication housed on one platform, we believe it will enhance efficiency and transparency for our customers.”

CAD/CAM

ASC’s hydrostatic and stability program gets upgrade

Autoship Systems Corporation’s (ASC) newest iteration of its Autohydro hydrostatic and stability program, Autohydro 6.10, includes tools for more efficient calculation of hydrostatic parameters, stability and longitudinal strength.

Autohydro can perform both intact and damaged analyses and produce ship stability reports that are accepted by approval bodies. Defined by the company as a ‘floating simulator’, it reports the reaction of a vessel model to various conditions. These can include loading configuration, a damage situation and outside forces such as wind or high-speed turning momentum.

The 6.10 iteration has added features for accidental oil flow performance, oil fuel tank protection, as well as second method or intermediate steps during flooding calculations and dynamic limit definitions.

ASC will supply its 6.10 update to naval architects Boksa Marine Design (BMD), a company it has worked cooperatively with to deliver engineering packages for vessels representing unique stability requirements. These include commercial ships, superyachts and more.

Nick Boksa, BMD President, explains that the company uses Autohydro to submit stability books to classification societies for a wide range of vessels

engineered by BMD. He adds: “Complicated stability issues require the Autohydro Hydrostatics and Strength software to analyse and solve. To date, all of BMD’s stability books have been approved by the designated class society, including ABS1.”

Boksa comments that AutoHydro’s Modelmaker module, used to create and edit models that will then be assessed by AutoHydro, allows BMD to easily import a hull from different 3D models. He notes: “We can get right to work defining tanks and selecting hydrostatic values critical for safe vessel operation.”

Autohydro’s next upgrade, 6.11, is due to for release in late 2021.

Navigation & performance management

Navtor expands into data analytics

Navtor, the world’s largest distributor of electronic navigation charts (ENCs), has announced the acquisition of Tres Solutions, a maritime software and analytics company.

“We considered 10 or 15 companies that look at vessel performance and Tres Solutions was the one that fitted best with what we’re doing at Navtor,” explains Tor A. Svanes, Navtor’s CEO.

Established in 2016 and headquartered in Houston, Texas, Tres Solution is said to be among the fastest-growing performance management solutions on the market. The Tres Vessel Analytics platform is currently deployed on around 300 ships worldwide, offering vessel-specific modelling based around the noon report and supplemented by expert-driven support. It is touted as a disruptive ‘savings-as-a-service’ tool offering fuel savings, as well as environmental monitoring.

The aim is to create a new unified platform that will deliver real-time operational insight, performance optimisation and enhanced decision making. The acquisition will also increase Navtor’s distribution network and means the company now has more than 7,000 customers worldwide.

Svanes says: “The main thing here is to create a fully integrated solution that’s not on the market at the moment. Of course it won’t be integrated from day one but we can now connect Tres Solutions with our onboard computer system.”

Based in Egersund on Norway’s west coast, Navtor was founded by Svanes in 2011, releasing the world’s first type-approved pay-as-you-sail ENC a year later. In 2014, it launched NavStation, a digital chart table. In 2020, it was itself acquired by software and technology investors Accel-KKR. **NA**

Michigan Trader – stability completed in Autohydro Pro



What is meant by a “shipbuilding superpower” in the 21st century?

A renaissance of British shipbuilding, once the envy of the world, is supposedly high on the government’s agenda. But is there a danger of romanticising that past? Paul Stott considers the historical facts, and what today’s maritime industry can learn from it

Last year, Boris Johnson proclaimed his government’s ambitions to develop the UK into a “shipbuilding superpower”, something which clearly has implications for professionals working in marine technology. But what precisely does it mean? It is unlikely that the UK will invest the enormous sums that would be required for us to compete in commercial shipbuilding with China and South Korea, the current “shipbuilding superpowers”, where volume and huge investment are the keys to business, and which require very significant government support.

So, what would define a “shipbuilding superpower” in the UK context in the 21st century? Such ambition appears to seek a resonance with what was once a world-beating and truly great industry. But it is useful to apply some objectivity to that notion and to be precise about when the period of greatness was and the nature of the industry at that time?

Merchant shipbuilding in the UK peaked in 1892, with a global market share at more than three quarters; a level unequalled by any nation since. The industry had developed strongly since the 1830s, based on technological leadership in iron and steam and in response to the domestic market generated by the economy of the British Empire, which needed significant numbers of ships to move goods and people around the globe.

Warship building was similarly stimulated by Empire and technological developments, as well as by various arms races. In the period up to WWI, military costs accounted for half of all UK Government expenditure, with battleship building being the single largest item in that budget. Technologies of particular note were Charles Parsons’ steam turbines and the development of armaments which led to the game-changing *Dreadnought* of 1906. The heyday of warship



British Prime Minister Boris Johnson at Appledore Shipyard, Devon, in August 2020. Image: Pippa Fowles / No 10 Downing Street

building may therefore be seen as the great days of the battleship between 1890 and WWII. Technical supremacy also led to a lucrative export market which, in the late Victorian and Edwardian eras, unlike today, primarily exported completed ships (although the export of design, equipment, systems and consultancy was also a lucrative part of that business).

Technical leadership

The first conclusion drawn from this is that supremacy is about more than just volume – it is also about technical leadership, which in the UK’s heyday lasted until the 1920s. We need to consider our industry in this light and not simply by volume. Recent export orders of design and systems to navies of significant developed nations (for example, Type 26) suggest that the UK still benchmarks well in this context in some sectors.

A further characteristic of the ‘heyday’ industry in the UK to which we might aspire was the significant employment that the shipyards generated. But what were those thousands of shipyard workers doing? In understanding this we need to look more closely at what a shipbuilder was.

One notable difference between the industry prior to WWII and that of today relates to the level of vertical integration in businesses. At least three of the shipbuilders of the time, Vickers, John Brown and Palmer, were engaged in the entire process from smelting the steel to the completed ship. In the case of John Brown & Co. Ltd, that extended to ownership of the coal and the iron ore mines.

Such capabilities weren’t the norm, but the majority of significant shipbuilders would be involved in the manufacture of machinery and systems in addition to the ships themselves. Most of the leading shipyards were also engaged in the design and manufacture of the armament and armour, the most valuable and the most profitable parts of shipbuilding at the time.

Plans of the era’s larger shipyards show a remarkably limited area involved in the construction of the ship itself. For warship builders much of their investment was dedicated to steel making, machinery manufacture, armaments and armour manufacture. Exact figures are not possible but, depending on the company, up to two thirds of workers were not directly involved in ship construction.

In viewing our current industry against its past, where vertical integration on a single site is now a less significant feature, we need to take this into account. Shipbuilding (platform fabrication and assembly) remains a relatively low margin business with the greatest value being in the systems, machinery and equipment that are assembled into that platform. Even in the boom times, profit margins for UK built ships were usually under 10% of price. Just looking at the shipyard, the final assembler, therefore, may be misleading and is not sufficient to define the industry or the UK's place in the 21st century.

We should be wary of imagining the industry of a century ago as a paragon to which we might aspire. It undoubtedly benefitted the British economy but was not without its own controversies. At the corporate level these included cartels, price fixing, profiteering and in some cases corrupt sales practices. At the shipyard level, it was an industry with a worrying health and safety record which employed workers, for example riveting gangs, on what we would now call zero-hours contracts.

Industry volatility

Another misconception of the industry in its 'heyday' is that it provided steady continuous employment of capital and labour. For at least a century we have been talking about an industry getting back to such a state, which in reality has never existed. The modern international maritime industry, both commercial and naval, is significantly 'lumpy' and contends with a level of demand volatility not faced in any other sector. But prior to WWII, the level of volatility in commercial shipbuilding was even greater than that in more recent times. For warship building, the downturn that followed WWI coincided with global economic recession and a significant downturn in demand for commercial ships, an era that is captured in images of the Jarrow March of 1936, when an estimated 80% of Tyneside's shipyard workers were unemployed. The industry was temporarily resuscitated by the demands of WWII, before continuing its decline to the 1980s.

Volatility is a feature of shipbuilding that we need to find better ways of addressing, rather than perpetually wishing it away and believing that somewhere there may exist a halcyon market with steady work. The



Romantic notions that Britain's shipbuilding past was entirely glorious are belied by darker chapters such as the Jarrow March of 1936

industry's call for a "steady drumbeat" of work from MoD is not new. In the minutes of the AGM of the Fairfield shipyard on the Clyde in 1933, the Chairman stated: "in periods of depression when merchant shipping is at a low ebb naval programmes should be anticipated in order to advance our technical skill and maintain skilled workmen in regular employment". Put another way, we have been looking for the national defence budget to support the sometimes-ailing shipbuilding sector for at least 90 years.

Improvements could undoubtedly be made in taking account of industry needs in the context of naval ordering, but this cannot be a solution to the innate volatility of the sector. Shipbuilding needs to find a better way to cope with the unpredictability of demand, not simply by wishing it away and lurching from crisis to crisis, which is the current modus operandi of virtually all shipbuilders around the globe. The key to this is, again, technological. Our prevailing shipbuilding strategy was developed during WWII and relies on volume for competitiveness.

The key to a leaner and more agile strategy lies in the capability of the digital twin and 5G technologies. The Digital Twin would permit simulation of the entire assembly process prior to construction, enabling the optimisation of that process and integration with the supply chain; but only if time is available to do that. That in turn means

having the luxury of a completed design as well as a contract and business situation that affords an extended period for planning before construction commences. There is no piece of machinery that will invest us out of the difficulties of shipbuilding: a system-wide approach is needed, including the form of contracts and finance that would permit such a strategy. But the nation that develops the new strategy may well procure itself a lead, at least until others catch up.

The question of subsidies

Finally, mention has to be made of government support. It would be a mistake to look back and to conclude that the 'heyday' industry stood purely on its own feet in terms of finances. In 1905, the American Economic Association in a report entitled 'History of Shipping Subsidies' stated: "The advocates of Government aid to shipping refer to Great Britain as the foremost example of a subsidy giving power, and ascribe the supremacy of the British merchant fleet to the policy of giving liberal subsidies to steamship companies". Good examples include government loans to enable Cunard to build *Mauritania* and *Lusitania* and scrap and build schemes that developed in the 1930s to stimulate demand.

The government of the day clearly saw the value in providing such assistance in the context of the nation's economy. Support for shipbuilding in the UK rightly got a bad

name following the difficulties of the failing industry of the 1980s, which in its dying days forever had its hand out. There can be no suggestion that we revert to such a situation, but assistance where greater value to the country can be shown (within the provisions permissible in the international context) still has its place. Recent UK procurement decisions in relation to fleet support vessels would be one example of such a positive move, others might include support for technologies that address the climate change agenda and which get freight off the UK's roads and onto ships.

In summary, a "shipbuilding superpower" in the UK context should correctly be defined by technological lead rather than by volume per se. Volume is limited by market and opportunity and to a great extent is outside the control of strategy, although opportunity would, of course, develop from a technological lead. Interesting examples

of this occurring in the commercial sector include the highly successful SD14 ships from Austin and Pickersgill in the 1960s and 1970s (see *TNA*, Jan 2018 p.40) and the development of twin-hulled fast ferries in Australia in the 1980s. Pursuit of volume for its own sake would inevitably require very significant capital investment and government support, beyond the horizon of UK ambitions. Technologies need to address the product itself and also the wide context of the business, including finance, business strategy, contract, processes and build strategy and should range much wider than just the assembling shipbuilder to adequately represent the industry. **NA**

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The challenge of firefighting onboard a container ship

Cargo misdeclaration may be a common cause of incidents, but there are a multitude of situational and design factors, according to one senior investigator

Although there's some coyness when it comes to reporting incidents, it's been estimated that a fire occurs onboard a container ship somewhere in the world at least every two weeks. Thankfully most don't reach the severity of the *MSC Flaminia* conflagration in 2012, in which three crew were killed, or *Maersk Honam* (2018) when five lives were lost, but what is it that makes firefighting onboard container ships quite so challenging?

That was the subject of a recent webinar hosted by insurers TT Club entitled 'Container ship fires: what can the ship do?'. John Gow, a former firefighter and latterly senior investigator for International Fire Investigators and Consultants (IFIC) began by highlighting

the perennial issue of undeclared and misdeclared cargo. One recent study has suggested that the reason for this problem is the high hazardous surcharge and restrictions imposed by cargo carriers, while at the same time there is heavy demand for the transit of such goods.

"If you don't know what your cargo is, it's very challenging to adopt the correct measures and deploy the right firefighting medium," cautions Gow.

Contrast with land-based response

To help comprehend the formidable threat crew are confronted with by a container ship fire, Gow highlights the example of a not untypical vessel with a keel to mast height of 72m and a stack of containers

the same height (see Figure 1). By way of comparison, Grenfell Tower, the London apartment block in which fire broke out in 2017, killing 72 people, was a fraction smaller at 67m.

Land-based firefighting has, Gow says, advanced significantly in recent years, particularly with regard to provision of PPE. The development of lightweight materials for equipment such as breathing apparatus eases the burden on the firefighters, while concrete buildings are purposely designed to offer easy access to the location of the fire and to contain it in the compartment and floor of origin. Additionally, response to a fire report in an urban area typically occurs within minutes and further resources and equipment are readily on hand.

All of which offers a stark contrast with firefighting on the open ocean. The minimum requirement is for oxygen cylinders to contain 1,200 litres, which ideally should last for 30 minutes, but with the inhalation of carbon monoxide and the anxiety of the situation this is actually far less.

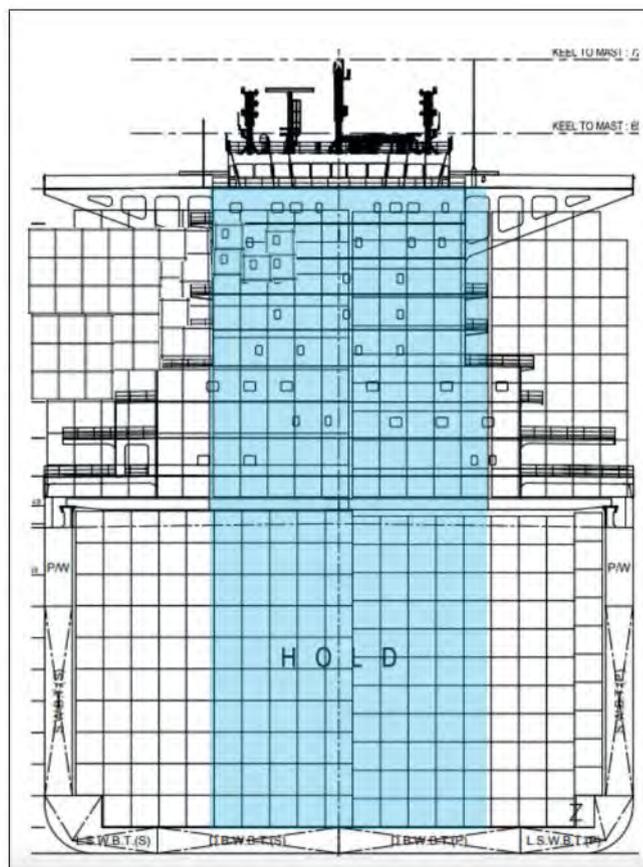
“The impact on your body is significant and by the time you get to the scene of operations you have very little air left to do anything. It’s likely you would have to be relieved in a few minutes and return back to fresh air,” says Gow.

Although a ship’s metal structure offers some advantages in preventing the spread of a fire, the close proximity of the cargo – far narrower than you might find between vehicles in a typical car park – facilitates it. These confined spaces make it almost impossible to deploy firefighting crew below deck.

Further complications arise with onboard operating procedures. As with fires on land, the fire may have had ample time to propagate before discovery, but at sea a crew member must firstly be dispatched to confirm there is a fire, and the other crew then mustered, before any action is taken. An additional consideration may be the direction of the smoke and whether the ship needs to be repositioned to improve the success of firefighting operations.

Onboard machinery and the crew accommodation are usually well protected from the threat of fire, whereas machinery spaces often have their own challenges, such as steep ladders and slippery surfaces, and accessing them may require multiple crew to assist in the operation. While equipment resources will be located at specified points onboard, the fire may mean that not all equipment is available.

Typically there is an average of 23 crew onboard a container ship, which compares favourably with the number of firefighters who might be dispatched for a land-based incident. The challenge at sea is that, in the event of a severe fire, additional resources will be hours, if not days, away from providing support. Moreover, given the basic firefighting course (as stipulated by the STCW Code for crew training) is just two and a half



A stack of containers can comfortably achieve a keel-to-mast height comparable to a tower block. Source: Jensen Hughes

days, compared to the 12 weeks required for land-based firefighting, there is an enormous difference in the crew’s experience.

Cargo hold fires

Gow draws particular attention to the systems deployed for fires in cargo holds, noting that there remains an overreliance on aspirating smoke detectors. He comments: “This is a system that’s not changed since the days of open holds. In fact, in 1946, tests in the US demonstrated that there was a significant lag time to detection and the alarm being raised due to the distance that smoke has to be drawn from the hold.”

He adds that the 1946 studies showed that the control of ventilation can and does play an important part in the management of a fire. A significant finding was that mechanical means to control ventilation would be advantageous and anything that can be done to reduce the need for someone physically present to close the hatch would assist in controlling the fire.

Presently, there is much debate about the

adequacy of different extinguishing systems. Some believe that high expansion foam offers a better solution than CO₂ as an extinguishing medium, but Gow warns that removing the foam afterwards can present a problem and also creates the danger of pockets of heat being retained and erupting after the foam has been broken away.

One further issue is the containers themselves and the role they play in fire confinement. Another study, in this case conducted by the US Coastguard in 1976, showed that there is sufficient air in a typical container to burn 12-14lbs (5-6kg) of fuel. If that container should have a timber floor with significant gaps then the fire can spread further, but an incident resulting in the ignition of cargo within a sealed, non-damaged container would not endanger adjacent containers. “The study found that if you have a fire with normal combustibles within the container then ventilation will allow fire growth to continue. But a container that’s attacked from fire from the outside will fail fairly quickly,” he notes. **NA**

EGR boosts new dual-fuel two-stroke

An EGR version of the low-pressure, dual-fuel ME-GA design from MAN promises savings in consumption and performance gains alongside high-level NOx abatement, writes David Tinsley

Applicable throughout its two-stroke engine programme, MAN Energy Solutions offers exhaust gas recirculation (EGR) in parallel to selective catalytic reduction (SCR) as an option for meeting IMO Tier III stipulations. Recent confirmation that EGR would be available for the latest addition to the portfolio, the ME-GA dual-fuel low-speed design not only ensures the requisite level of environmental compliance in all operating modes but also delivers a raft of performance benefits.

The ME-GA is the low-pressure, Otto-cycle variant of the established ME-GI high-pressure dual-fuel series. In gas mode, the ME-GA engine meets Tier III NOx emission criteria. By incorporating EGR, a vessel powered by ME-GA machinery will remain Tier III-compliant when operating on fuel oil. The technology obviates the need for additional exhaust aftertreatment.

The test campaign carried out at the company's research centre in Copenhagen covered evaluation of EGR on the ME-GA engine running in both diesel and gas modes. While effectiveness in NOx abatement was verified, it was additionally found that EGR improved engine performance with either fuel.

Thus, compared to a 'standard' ME-GA without EGR, it was demonstrated that application of EGR would reduce both specific gas consumption (SGC) and specific fuel oil consumption (SFOC). When operating in gas mode, SGC is lowered by approximately 3% across the complete load range, and SFOC is brought down by some 5% in diesel mode.

Methane slip

The technology also holds out the prospect of reducing methane slip relative to an ME-GA engine not equipped with EGR, although the company is holding back from exact quantification until further research has established to what extent unburnt methane release can be abated



Image of the nascent, 700mm-bore ME-GA dual-fuel engine incorporating an EGR solution

while maintaining a good equilibrium for recirculation. However, significant reduction levels of 30-50% are foreseen. A further benefit is that the introduction of the EGR solution to the ME-GA suppresses pre-ignition, or knocking, a phenomenon associated in certain circumstances with Otto-cycle engines.

The variant of the ME-GA will employ a high-pressure EGR system, facilitating integration into existing engine room designs. The EGR unit itself does not change the engine footprint.

The company has nearly a decade of experience with the emission reduction technology, having sealed the first order for an EGR system in 2011, duly incorporated on a container ship's ME-C propulsion engine. By December 2020, contracts had been secured for over 240 engines equipped with EGR, of which at least 33 were in service. The design similarity of the latest solution to the EGR systems used for the ME-C series will, according to MAN, "lower the price point, since the supply chain and components are already matured".

The EGR system functions by drawing some 30-50% of the exhaust gas stream into the EGR receiver, where it passes through a pre-spray to lower the temperature, before passage through the main cooler spray and water-mist catcher. A blower raises the pressure for scavenging purposes, and the gas is then fed back into the compressor and the engine. The solution developed for ME-GA installations requires less pipework than that for low-pressure EGR systems.

MAN plans to make the high-pressure EGR option available on the same timescale as the projected delivery of the debut ME-GA production engine by the end of 2021.

Two models

The ME-GA generation will be launched with five- and six-cylinder models in the 700mm-bore size, at a nominal maximum continuous rating (MCR) of 2,830kW per cylinder. Designated the G70ME-C10.5-GA type, maximum power output will thereby be 14,150kW and 16,980kW respectively.

The ME-GA two-stroke is a pre-mixed, dual-fuel engine, wherein methane is admitted during the compression stroke. This allows for a low gas supply pressure, which is advantageous for vessels producing large amounts of boil-off gas that can be used as fuel, notably LNG carriers. Much of the concept derives from the ME-GI high-pressure, gas-injected, low-speed platform. The new design will supplement, not supersede, the successful ME-GI family.

The latter will remain as one of the pillars of the portfolio, as underscored by the 2019 launch of the ME-GI Mark II version.

Strong interest from the LNG carrier sector in a low-pressure dual-fuel design has been a key driver for the ME-GA project.

Twin-engine LNGCs represent the biggest market segment for ME-GI engines. The ME-GA alternative obviates the relatively high cost of the fuel gas supply arrangements, including the high-pressure compressor for

boosting the pressure of boil-off gas to the 300bar injection pressure needed for the ME-GI engine in LNGC applications. The commercial case for the design is thereby founded on the lower capital expenditure involved for the shipowner.

MAN's move has no doubt also been influenced by arch-rival Winterthur Gas & Diesel's success with the low-pressure X-DF family in the dual-fuel two-stroke propulsion market. *NA*

WinGD expands X72DF range with four new options

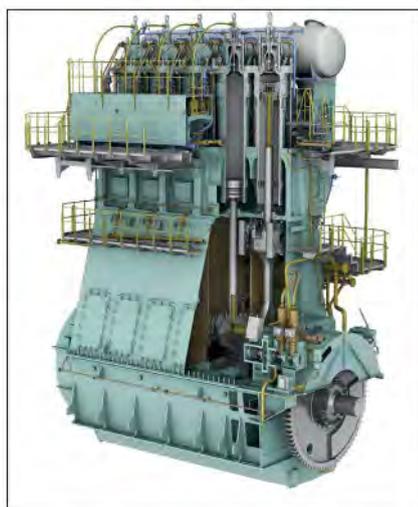
The Swiss-based engine manufacturer's bestselling model is now available in four configurations

First launched in 2015, when the company was still jointly owned by Wärtsilä, WinGD's X72DF dual-fuel engine platform was widely considered to be a game changer. Consolidating on the success of the X-DF low-pressure engine technology that had been unveiled two years earlier, the X72DF took the lean-burn (Otto cycle) principle and applied it to a 72cm bore, enabling it to switch smoothly and cleanly from diesel to natural gas.

Not only did it offer a route to current and future emissions compliance, but was smaller, lighter and offered improved running stability than its high-pressure counterparts. Such has been the platform's success that WinGD highlights the fact that the X72DF accounted for every low-speed engine ordered for a newbuild LNG carrier during 2020. The platform is also suitable for Suezmax tankers, Panamax and sub-Panamax container ships and Capesize bulks.

In February, following what are described as "baseline design improvements", WinGD unveiled four different versions of the X72DF, in what it says will offer greater ship flexibility while continuing to help owners reduce their installed power and emissions.

Volkmar Galke, WinGD's global director of sales, comments: "These options reflect the varied demands on shipowners to design vessels more efficiently, reduce installed power and cut emissions dramatically.



The X72DF

Whatever route shipowners choose to meet these demands, there is now an X72DF that will work for them."

The base version, X72DF-1.1, incorporates an upgraded version of WinGD Integrated Control Electronics (WiCE) engine control architecture, along with simplified production and installation and a modular scavenging concept. Meanwhile, five and six-cylinder engines can utilise the selected power/speed range, with lower specific fuel consumption, of the X72DF-1.2. The company says this option has been designed for those owners seeking to limit installed power in line with IMO's EEDI and (pending) EEXI requirements.

Both of the above will also be available with X-DF2.0 upgrades, featuring the iCER (intelligent control by exhaust recycling) technology that WinGD launched last year and is said to offer a 50% reduction in methane emissions compared to the first generation engines (see *TNA* September 2020). *NA*

X72DF engine particulars

	X72DF-1.1	X72DF-1.2	X72DF-2.1	X72DF-2.2
No. of cylinders	5-8	5-6	5-7	5-6
Cylinder bore (mm)	720	720	720	720
Piston stroke (mm)	3,086	3,086	3,086	3,086
Speed (rpm)	69-89	69-79	69-89	69-79
MCR (kW)	25,800	15,600	22,575	15,600

Commitment to a hydrogen future

Decarbonisation of sea transport will be assisted by a Belgian pairing's determined focus on hydrogen-based propulsion

A new pathway towards a low-emission and ultimately a zero-emission future in shipping has recently been opened up through the market introduction of a series of hydrogen dual-fuel (DF) propulsion engines under the BeHydro brand. The powering solution offers the opportunity to reduce CO₂ emissions by up to 85% from reciprocating engine machinery.

Four models of the medium-speed, four-stroke design, spanning a maximum rating band from 1,000kW to about 2,700kW, have been released by the BeHydro joint venture of Antwerp-based deep-sea operator Compagnie Maritime Belge (CMB) and Ghent manufacturer ABC Engines.

The introductory DF offering, designated the DZD series, encompasses six- and eight-cylinder in-line models, and 12- and 16-cylinder vee-form types, each delivering some 166kW per cylinder at a crankshaft speed of 1,000rpm. A companion range of 100% hydrogen, spark-ignited (SI) versions is set to follow, promising wholesale elimination of CO₂.

ABC's DZC proven medium-speed family has provided the technical platform for the initial BeHydro hydrogen DF engines and the nascent hydrogen monofuel (spark-ignited) engines.

For the DF types, the CO₂ emission abatement achieved by burning hydrogen will be complemented by NO_x and particulate matter (PM) minimisation in diesel mode through the specification of, respectively, a catalytic converter and particle filter, using proprietary ABC aftertreatment systems. While selective catalytic reduction (SCR) ensures IMO Tier III compliance in all modes, the inclusion of a diesel particle filter (DPF) also brings the engines within the ambit of the EU Stage V requirements.

Emissions compliance

The SI models will still need SCR and DPF for EU Stage V accreditation, but will meet Tier III criteria without exhaust



Hydrogen dual-fuel medium-speed engines have been released under the BeHydro brand

aftertreatment, and offer the further benefit of compliance with Germany's TA Luft comprehensive air pollution standards and the Flemish VLAREM regulation.

Although the immediate priority is the successful launch and operational performance of the hydrogen-capable DF DZD generation, the BeHydro partners are already looking to the next step in the decarbonisation journey by extending the new engine marque to a power level of 10,000kW. This would be equivalent to the highest output obtainable in the current ABC portfolio. CMB advised TNA that: "Once there are applications which can supply 700kg per hour to each engine, we are ready to build the 10MW (hydrogen) version of the DL series".

The DL platform developed by ABC was announced in September 2012, in the shape of the DL36 in-line engine. First released in six- and eight-cylinder configurations, the follow-on launch of DV36 vee-type 12- and 16-cylinder versions signified a major hike in unit powers obtainable from the Belgian manufacturer, taking its scope to unit applications of 10,400kW.

The company added LNG dual-fuel models to its production programme some years ago and subsequently investigated new dual-fuel solutions using methanol and hydrogen, which included recourse to a single-cylinder test engine at WTZ Rosslau in Germany. Methanol and hydrogen have specific characteristics and differ from

methane in many respects, resulting in varying engine thermodynamics, injection strategies and safety concepts. Burning pure hydrogen produces no CO₂ in the exhaust.

In the hydrogen DF engine, a diesel pilot is used as the ignition source. To address the issue of potential pre-ignition with hydrogen fuel, ABC's strategy included measures to reduce the temperature of the hydrogen-air mixture below the auto ignition limit at the point of pilot diesel injection, preventing hot spots on pistons and cylinder tops, and boosting the air flow so as to dilute the hydrogen/air mixture, which also cuts NO_x emissions.

Diesel fallback

DF engines are a pragmatic way of integrating new fuels into the market because users can always return to diesel operation should there be any issues relating to fuel availability or price, giving the owner more leverage as well as flexibility and better safeguarding service dependability.

The debut contract for BeHydro entails two 12DZD dual-fuel engines of 2,000kW apiece in a tractor tug ordered by the Port of Antwerp. The installation has been specified with SCR and DPF, and storage for 400kg of hydrogen is arranged right aft.

Through ABC, a wealth of reciprocating engine experience has been assimilated into BeHydro, which affords a solid basis and market credibility for the new brand while expanding the market reach of the Ghent manufacturing plant. It also provides CMB with a point of realisation and prospective supply of hydrogen power solutions for its extensive deep-sea fleet of bulk carriers, chemical tankers and container ships.

As an owner committed to a 'green' future, CMB's developmental path gravitating to hydrogen reciprocating engines hinges on factors such as the costs of the alternative course of 'electrification', reliability, and operational concerns

regarding the further powering alternative whereby hydrogen is used in fuel cells. An additional consideration is the perceived scope of hydrogen dual-fuel power as a retrofit solution, which would help facilitate the energy transition of the existing fleet.

From CMB's perspective, storing hydrogen aboard ship is a more technically and commercially challenging issue than burning the fuel. Hydrogen has to be kept at minus 253°C to maintain a liquefied state and has a low volumetric energy content. It is a low flashpoint fuel, which will ignite from the smallest spark.

Demonstration project

CMB had shown its intent in pursuing 'greener' possibilities in 2017 when it commissioned a 14m passenger catamaran powered by two hydrogen dual-fuel Volvo Penta engines. Built in the UK by BW Seacat of Fareham, the craft was put into service on the River Scheldt partly

	6DZD	8DZD	12DZD	16DZD
Cylinders	6 in-line	8 in-line	12 vee	16 vee
Power, kW	1,000	1,335	2,000	2,670
Rpm	1,000	1,000	1,000	1,000
Swept vol, litres	95.71	127.61	191.51	255.21
Dry weight, kg	10,620	13,905	18,000	21,750

BeHydro dual-fuel (DF) hydrogen/diesel engine range – main propulsion

to ferry CMB personnel but mainly as a technology demonstrator. The hydrogen system was supplied and installed by another UK firm, Revolve Technologies, a pioneer in the development of hydrogen internal combustion engines, subsequently purchased by CMB and renamed CMB Tech.

Towards the end of 2020, CMB made a further UK acquisition, that of Lowestoft- and IJmuiden-based offshore crew transfer

and windfarm support vessel operator Windcat Workboats. As well as diversifying CMB's business portfolio into the fast growing renewables sector, the rationale behind the deal is also to scale up the deployment of hydrogen-powered vessels. CMB said in December that the first hydrogen-powered crew transfer craft, the *Hydrocat*, was expected to be operational as early as June 2021, powered by hydrogen-diesel DF machinery. [NA](#)

US shipbuilding project endorses homegrown machinery

Indigenous four-stroke diesel technology is central to the integrated electric propulsion plant chosen for the nascent generation of US training ships

US medium-speed diesel machinery that meets exacting IMO Tier III and EPA Tier 4 standards, without the need for an emissions aftertreatment plant, has been endorsed in a prestigious, domestic shipbuilding project.

The programme for a new generation of multi-mission vessels, combining a primary role in merchant navy officer training with disaster support capabilities, was set in motion last April when the US Maritime Administration (MARAD) authorised a two-ship order at Philly Shipyard. The subsequent award of the diesel-electric system's prime movers to Wabtec Corporation acted on a commitment to the US industrial chain and also signified state sector endorsement of an engine design that has attracted contracts from commercial operators worldwide.

Powering specification for each newbuild is based on four main generating sets driven by 16-cylinder vee-form models of the 250-series four-stroke engine, brought into the Wabtec portfolio after the company's 2019 merger with GE Transportation. The eight-engine contract will be fulfilled at the Grove City production plant in western Pennsylvania.

This deal hoisted Wabtec's sales tally with the L250/V250 series in marine applications beyond the 100 mark. Philly Shipyard went on to announce in January 2021 that it had been awarded two additional vessels under the National Security Multi-Mission Vessel (NSMV) programme, raising the prospect of a further deal spanning eight engines. An option is retained on a fifth such newbuild, which would take the overall propulsion engine requirement to 20 units.

The 16-cylinder V250MDC model for shipboard duty has a nominal maximum continuous rating (MCR) of 4,200kW at 900rpm crankshaft speed, rising to 4,700kW in the 1,000rpm version. In each case, the recommended match points for fixed pitch propeller installations are lower than those for controllable pitch propeller applications. The gensets will be fitted in dual engine rooms, delivering electrical energy to two 4,500kW propulsion motors and all other shipboard consumers.

Technical breakthrough

The 250 series is a rugged class of four-stroke machinery, proven across rail, stationary power generation and shipping sectors. The introduction of the latest iteration for the marine market denoted a technical breakthrough by virtue of its ability to meet Tier III and US EPA Tier 4

Seen here in its 16-cylinder configuration, the 250-series engine provides an in-cylinder solution to the toughest emission limits

emission criteria through purely engine-internal measures. Moreover, the Tier 4 version yields a higher power output than its EPA Tier 3 predecessor, and improved load response.

Obviating the requirement for selective catalytic reduction (SCR) technology yields savings in space, costs and maintenance related not only to the catalytic reactor unit, but also the dosing system and associated requirements for a storage tank and ongoing urea replenishment. Furthermore, as the original developer, GE had asserted that the Tier 4 engine avoids the need for the tight control of the exhaust gas temperature that has to be ensured with SCR systems, preventing clogging from ammonium hydrogen sulphate issuing at lower temperatures.

Overall, an emissions-compliant powering arrangement based on the latest 250-type engines entails less complexity as regards both installation and operation.

Emissions abatement to the required stipulations is achieved through a raft of measures including cooled exhaust gas recirculation (EGR), high-pressure common-rail fuel injection, increased peak cylinder pressure enabled by two-stage turbocharging, and an advanced Miller timing cycle. The new marine offering is said to have benefited significantly from the development and validation of the EPA 4 locomotive engine, and Wabtec claims that the tighter enviro limits have been achieved without compromising fuel efficiency.

More than US\$20 million has been expended at the Grove City works specifically to test and validate non-urea (non-SCR) marine and locomotive engines to the latest US and international emission regulations.

The US\$630 million initial shipbuilding contract for two 160m NSMVs was entrusted to Philly Shipyard by TOTE Services of Jacksonville, acting as



programme construction manager on behalf of MARAD. A similar figure is commanded by the recent repeat order covering third and fourth sisters, and confirmation of a fifth ship would hoist the total contract value of the programme to between US\$1.5 billion-1.6 billion.

The primary mission of the ships will be training future merchant navy officers, to which end the layout provides accommodation and facilities for 600 cadets. Parallel capabilities in disaster response and humanitarian assistance are reflected in a diversified freight and equipment handling capacity, and logistical and medical resources.

Electric propulsion

The NSMV driveline culminates in a single fixed pitch propeller, with pairs of main gensets arranged in two engine rooms, and two electric propulsion motors acting on the single shaft and located in separate watertight compartments right aft. The requirement is for ships to be able to make 18knots with a 15% sea margin when 'full and down', and to maintain a 12knot cruising speed on two engines.

Featured in the design is a stern thruster of approximately 900kW and a retractable, combi-type bow thruster sized to confer a take-home propulsion capability in the event of the loss of the main propulsion system, up to and including the shaft and propeller.

The adoption of two separate main machinery spaces, in distinct fire zones with a dividing watertight bulkhead, also affords good training opportunities for cadets, since the vessels will typically operate at no more than 12knots on training cruises, necessitating only two main aggregates in one engine room to be online. With machinery shut down in the 'idled' space, training can be conducted under better circumstances for the students, potentially to include the opening up of engines for training purposes.

The decision to use an integrated electric drive propulsion system incorporating medium-speed diesel engines, rather than a direct-drive, low-speed diesel or dual-fuel two-stroke solution, was influenced by considerations of capital cost, size of power units, overall fuel efficiency and operating flexibility.

While the first two vessels are scheduled to be handed over in the spring and winter of 2023 respectively, 2024 delivery slots have been allocated for the second pair.

The lead ship will be allocated to the State University of New York (SUNY) Maritime College, to supersede the steam turbine-powered *Empire State VI*. The latter is the oldest in the fleet of MARAD-owned training ships assigned to the six maritime academies in California, Maine, Massachusetts, Michigan, New York and Texas. **NA**

Challenging times, but Finland has eyes on the future

The Finnish shipbuilding industry and maritime cluster experienced a tough 2020, with many uncertainties, but there are reasons for confidence. Kari Reinikainen reports

Finland's economy and its maritime industry have not been as badly hit by Covid-19 as those of many other European countries, but the outlook remains uncertain, says Elina Andersson, secretary general at Finnish Marine Industries.

Larger companies in the country's maritime cluster have fared rather well, but for many businesses that are involved in maintenance and servicing of cruise ships in particular, the outbreak of the pandemic meant a sudden stop.

"Some companies will face a liquidity crisis as a result. The ability of shipping companies has decreased due to the pandemic and when deliveries of many ships have been postponed, companies in the supply chain are finding it difficult to find other projects to fill the gaps in demand. Expectations have been lowered as a consequence," she explains.

It is important that the entire supply chain of the cluster can survive the present situation, because it is difficult to build it back up if competence has been lost. "Although it's not easy to list all sectors of the cluster that are likely to suffer most, turn key contractors probably are among the worst hit," Andersson notes.

Postponed deliveries of ships will lead to delays in payments to companies in the supply chain, but luckily the large cruise shipping groups were able to secure funding and have not been forced to cancel orders. Given the present crisis in the sector, this is of vital importance.

Driving R&D investment

Reduced cash flow means that many companies have been compelled to look at all their expenditure, including research and development (R&D). A few have adopted a counter-cyclical approach and they continue investing in R&D despite the present challenges.



Elina Andersson, Finnish Marine Industries

Andersson says: "Digitalisation and clean technologies are obvious sectors to receive funding. A crisis is always also an opportunity: it forces people to think along new lines and to innovate".

At the moment, there is no clear visibility regarding when the situation might start to improve. "The ability of shipowners to invest holds the key. In many sectors of freight shipping, this has been low for quite some time. It will take time before we will see a resumption of cruise ship orders," Andersson concludes.

Tapio Karvonen, senior researcher of maritime studies at the University of Turku tells *The Naval Architect* that Covid-19 has presented cruise shipbuilding with a new situation but not an untenable one. For example, Meyer Turku shipyard now intends to build just one large cruise liner per year instead of the earlier pace of 1.5 ships.

"The main point here is that no orders have been cancelled, rather deliveries have been pushed further into the future."

He adds: "The ability to design and build icebreakers and ships that operate in ice conditions remain a key area of competence for the cluster, which has been confirmed by [the ongoing] Finnish-Swedish icebreaker project."



Pentti Kujala, Aalto University

Uniting academia and the maritime cluster

Meanwhile, Aalto University and Pentti Kujala, its professor of marine technology, are leading an R&D project called MarineX, which brings together various companies in the maritime cluster and a number of universities. Focusing on passenger ships and shipping, it was launched before the Covid-19 pandemic broke out and the project participants have applied a €10 million grant from Business Finland, which would cover 50% of the project's budget.

As work has progressed, MarineX has expanded from design and engineering aspects to include health onboard. Digitalisation and IT are also a major part of the project, Kujala points out.

"The cluster wants to position itself at the top in a global context. It wants to drive development forward by working together – the entire cluster, not just companies," he continues.

The EU has funded several projects in the same area as MarineX, but these have been without visible input from universities. The MarineX initiative will help the Finnish maritime cluster to adopt a more active approach to European co-operation in the future, Kujala believes. *NA*

Developing business, retaining skills

To retain its skills, the Finnish shipbuilding industry and the cluster that supports it must build on existing strengths while also looking at potential new markets

Helsinki Shipyard was one of the very few Finnish shipbuilders to win an order for a cruise ship in 2020. The vessel in question, a 12,500gt luxury expedition vessel to be delivered in 2022, will be operated by Swan Hellenic, itself acquired by Cyprus-based Russian investors last year.

The same yard has two slightly smaller ships on order that will also be operated by Swan Hellenic. It means that employment at the yard has remained unaffected by Covid-19 and the outlook for the near future is encouraging, says Carl-Gustaf Rotkirch, board member and until recently CEO of the company.

Citing sales director Markku Kajosaari, Rotkirch notes that enquiries for expedition cruise ships have started to emerge again after a sudden silence in the spring, when the pandemic hit – small and medium sized cruise ships are one of the sectors the yard is interested in.

The management has also decided to explore the megayacht segment, which has remained buoyant. Expansion of the yard's business in that direction would be a natural development given its cruise shipbuilding activities.

Good prospects in icebreaking tonnage

Icebreaking tonnage is another area that Helsinki Shipyard specialises in; over the decades and under different owners it has built a large part of the world's icebreaker fleet. As the North East and North West Passages are becoming increasingly attractive due to climate change, the demand for icebreakers, icebreaking supply vessels and tankers capable of breaking ice is expected to remain strong. In the past 10 years, the yard has delivered 10 such ships.

Rotkirch comments that the company is also interested in a Swedish-Finnish joint project to replace the five Urho class icebreakers that Helsinki built in



Carl-Gustaf Rotkirch stepped down as Helsinki Shipyard's CEO at the end of January

the mid-1970s with a new generation of vessels. In 2016, Helsinki delivered the LNG-powered icebreaker *Polaris* to Arctia Ice-breaking Oy, the Finnish state-owned company that controls the country's icebreaker fleet. The planned Urho class successors are expected to capitalise on the green credentials that *Polaris* introduced, Rotkirch notes.

The yard has close links with Aalto University and other academia, which Rotkirch says has helped ensure that it has the right people with the right skills. The situation is more challenging when it comes to the blue collar part of its workforce, as many of these are aged 55 and over.

To tackle the situation, the management has decided to hire young people who are trained for their jobs by senior colleagues, so that the skills and competences can be transferred from one generation to another.

Rapid development in the use of the North West and North East Passages by commercial shipping has kept Aker Arctic, the Finnish company that specialises on ice-class technology, very busy and the

outlook remains encouraging as well, says Reko-Antti Suojanen, the company's CEO.

Global customer base to support business

"Russia is quite dynamic as it continues to develop shipping of LNG via the North East Passage," he explains, adding that the company is involved in the development of the next series of LNG carriers marking an evolution from the Christophe de Margerie Class that initiated the shipments in 2017.

A Finnish-Swedish project to build five icebreakers replacing the same number of vessels – again built in the mid-1970s – is another major project that the company is currently working on.

The new ships must be at least 32m in beam in order to be able to support the Panamax sized bulk carriers that serve Lulea, a Swedish port on the Gulf of Bothnia that is used for iron ore exports. Ro-ro vessels that serve the northern and eastern parts of the Baltic are also much larger now than they were five decades ago, which calls for larger ice-breakers.

Shipping and shipbuilding are both cyclical industries and Suojanen believes Aker Arctic is able to retain its position as a leader in its field by having a global customer base. As a result, the company is involved in all icebreaker projects currently underway.

Continuous flow of work is vital, he adds, because it allows the company to fund R&D and to offer new solutions to its customers. Sometimes, as in the case of the LNG carriers, the question is about fine tuning a concept that has proven to work well, but which can be improved further. In other cases, like the Finnish-Swedish icebreaker project, the company works from a largely blank sheet to develop a new design concept.

As icebreakers are vital to the trade of the countries they serve, they are often regarded as strategic assets. "Russia wants to give the work on nuclear-powered icebreakers to domestic companies and in the case of non-nuclear ones, domestic technology plays a major role," Suojanen says. Icebreakers are also government owned, which means that constructing them becomes part of the industrial policy of the nation in question, which means favouring domestic companies.

To maintain its position, Aker Arctic is investing significant amounts of its

own R&D funds and also participates in national projects, such as MarineX (see p21), and others funded by the EU. This requires close cooperation with various companies that are involved in the design and manufacture of shipbuilding equipment. "New fuels, battlers, digitalisation and e.g. monitoring various shipboard systems remotely means that ships are becoming increasingly complex," Suojanen comments.

Cruise ship building may not see pre-Covid ordering in this decade

When it comes to large cruise ships, the industry has been fortunate to have several strong years before 2020. Meyer Turku had to reduce its head count by 250 as a result of the Covid-19 pandemic's effects on the cruise industry. However, the figure was much lower than the 450 foreseen in April.

The delivery of the 185,000gt *Mardi Gras* to Carnival Cruise Line shortly before Christmas meant that the yard itself, plus companies in its supply chain, received a boost to their liquidity, says Tapio Karvonen, senior researcher of maritime studies at the University of Turku.

Furthermore, the fact that the major cruise shipping groups have been able

to raise funds to help them weather the pandemic has enabled them to keep their orderbooks intact, at least so far.

There is no way to forecast with any accuracy the pace of recovery of the cruise industry. Passenger volumes may take three years to reach the levels of 2019, but as the industry has an orderbook of more than 100 ships, new orders for large vessels could take years to materialise. "There will be no return to the hectic pace of construction of these ships in the present decade," Karvonen forecasts.

This suggests that the situation may continue to pose challenges for years to come. However, for as long as orders are not cancelled to trigger gaps in the production flow, Meyer Turku and companies in its supply chain are not dealing with a worst case scenario.

Fewer but larger ferries

Rarely do shipyards that have gone out of business reopen, but this happened in the previous decade with what is now Rauma Marine Constructions (RMC). Once part of STX Finland – as were the other two newbuilding yards – the company has re-established itself as a builder of ferries.

For several years, RMC received orders for an average of about 12 large ferries annually, of which five to eight were for



Meyer Turku delivered *Mardi Gras* late last year. Credit: Carnival Cruise Line

owners in northern Europe. More recently the pace has slowed down and RMC has just two large ferries on order (in addition to several ships for the Finnish navy). This is partly because the size of newbuildings has increased over the years, says Hakan Enlund, sales director at RMC.

Shipbuilding is cyclical by nature and the industry in Finland has experienced several deep crises over the decades. In the past, the importance of the yards and the wider maritime cluster had not always been understood by politicians, but fortunately this situation has improved significantly over recent years.

Many of the companies in the cluster have a global customer base rather than just the domestic shipbuilding industry. As shipping and shipbuilding become increasingly complex due to factors such as digitalisation, developing skills on a wide base has become vital for the success of the cluster.

This again means that it must attract bright young people not just from the home country, but also from all over the world. In a cyclical industry, this may not always be easy.

Collective bargaining in spotlight

Pay and other terms of work are obviously an important factor when it comes to the career choices of young people. Traditionally, employer organisations and trade unions in Finland have negotiated these on national level.

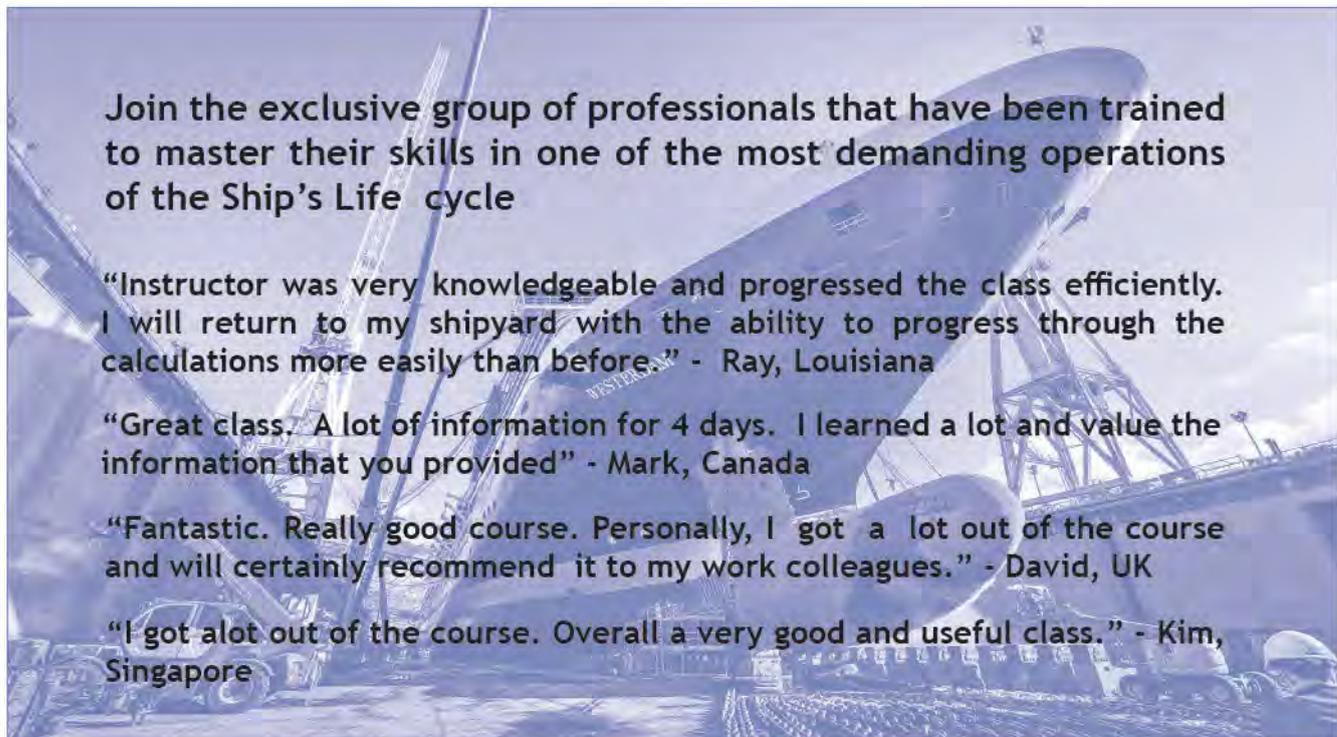
But in the past couple of years, cracks have started to appear in this decades-old system, with employer organisations in the powerful forest and technology industries in particular calling for more flexibility, such as company specific agreements on hours of work and, increasingly, pay.

The question is politically charged: defenders of the existing system say why should two people doing the same job in two separate companies be paid different wages.

Its critics say that the two companies might experience, for example, different cycles of business: while one might have no problems paying the agreed wage, a company in a downturn could be struggling.

Export industries have traditionally been able to offer better pay than ones serving just the domestic market and the matter has significant relevance to the maritime cluster as well.

In lean times, flexibility would probably help the cluster as a cushion against the challenges it faces. On the other hand, securing the people with the right skills requires competitive earnings. Should the nationally agreed bargaining system end, people might shop for jobs more than today. *NA*



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Simulating flood recovery manoeuvres using a free-running submarine model.

Authors: P Crossland and P Marchant.

(IJME 624) "The authors make a valuable contribution to the sparse literature on submarine dynamics and control. Although security considerations preclude the publication of actual data, the paper is able to provide a clear description of how an important safety problem has been modelled mathematically and at model scale, accounting for the contributions of hydroplanes, the ballast and trim system, and human factors to create a Safe Operating Envelope."

Assessing the determinants of safety culture in the maritime industry.

Authors: Daniela Andrei, Michelle R Grech, Mark Griffin, Andrew Neal.

(IJME 620) The Publications Committee wishes to commend the authors for a well presented paper tackling an important subject. The information gleaned by the study provides a valuable insight into safety culture and the difficulty of determining real-life data to ensure safety improvement is correctly focussed.

A study into the coating thickness of ship ballast tanks.

Authors: Remke Willemen, D Luyckx, R Meskens, S Lenaerts and Kris De Baere.

(IJME 618) The paper addresses a comprehensive study into the scatter of paint film thicknesses within 84 ballast tanks across a range of vessels types and ages. Data presented illustrated the spread and skew found in specific vessels and how well this aligns to IMO recommendations.

Understanding the Challenges of Major Tank Coating Refurbishment Projects for Operational On-Station Floating Assets.

Author: Adam Westwell.

(IJME 564) The paper addresses the array of issues to be addressed whilst recoating ballast and cargo tanks at sea whilst maintain operational availability of FPSO platforms. Much of the discussion and considerations are however applicable to a much wider range of vessels, with similar tanks, even when refurbishing activities are undertaken in dock.

Why Sailing yacht rudders break.

Author: Dr Kim Klaka.

(IJSCT234) This paper provides an accessible consideration of a tangible aspect of safety. The paper is practical in recognising a design basis behind many of these failures, offers both a clear discussion & analysis and a change to the design criteria.

Non-uniform rational B-spline based iso-geometric analysis for a class of hydrodynamic problems.

Authors: M. Goel, R. Sharma, S. K. Bhattacharyya and Tae-wan Kim.

(IJME 591) Both the editor of the IJME and the Pubs Committee wish to commend the authors on an interesting and well presented paper.

A future foretaste. Shipbuilding industrial tendencies.

Authors: Rodrigo Pérez Fernandez and Ernő Péter Cosma.

(IJME 649) This paper is very insightful, especially if you have an interest in CAD and future developments in this area. Effective synchronization between what we design and what we build. The paper presents several scenarios with improvements likely to occur the next few years.

Future proofing tanker designs

With shipowners worried that decarbonisation risks today's newbuildings becoming tomorrow's stranded assets, a Joint Industry Project between Hyundai Heavy Industries and DNV GL has attempted to combine sound advice with practical solutions

The maritime industry is getting greener, and while that might once have seemed like vague speculations of a better tomorrow for today's shipowner it represents a quandary. With IMO's oft-repeated decarbonisation targets – a 40% reduction in average carbon intensity by 2030 and a 50% reduction in total greenhouse gas (GHG) emissions by 2050 – looming large, is it better to invest in current proven solutions knowing that a costly retrofit of greener technologies may be necessary in the vessel's lifetime? Or is it more prudent to squeeze further life out of existing tonnage in the hope that the picture will become clearer in the next few years?

With the news in January that the global orderbook has dropped to its lowest level in 31 years – and notwithstanding other factors such as Covid-19 – the evidence would appear to suggest that many owners are leaning towards the second option, at least until the precise regulatory requirements become clearer. Needless to say that represents a problem for shipbuilders.

During 2020, following a Memorandum of Understanding signed at the Gastech trade fair in Houston in 2019, shipyard Hyundai Heavy Industries (HHI) Group and classification society DNV GL set themselves the task of developing low- and zero-carbon solutions for shipping. The results of that project were presented in a webinar, entitled 'Green Tankers towards 2050', at the end of last year.

MEPC 75

While it was certainly open to criticism of insufficient decisive action, the 75th meeting of IMO's Marine Environment Protection Committee (MEPC) in November last year was notable for the agreement of two key measures. Effective from the start of 2023, the introduction of the Energy Efficiency Existing Ship Index (EEXI) will see existing ships subject to

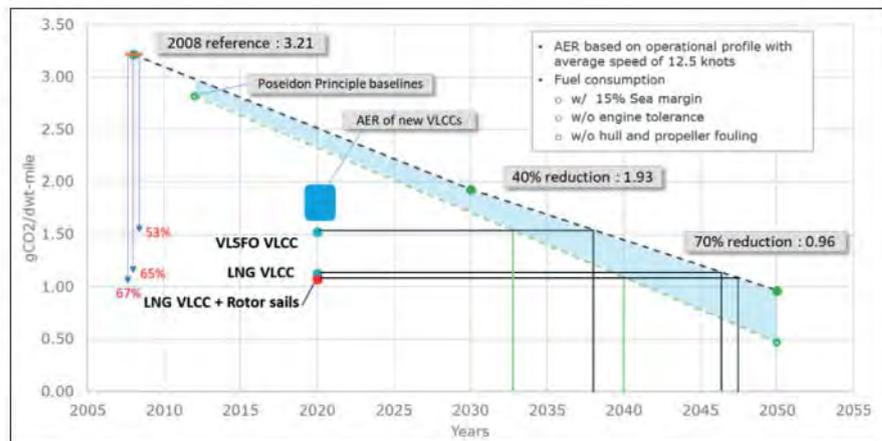


Fig 1. VLCC - Environmental performance. Source DNV GL

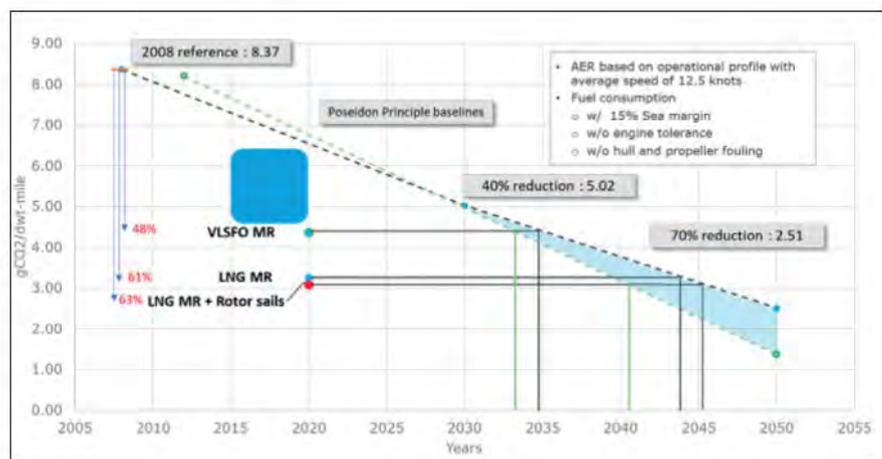
technical performance standards roughly equivalent to EEDI Phase 2 or 3. EEXI will be a goal-based standard, meaning that shipowners are free to decide for themselves whether they reach the targets by changing to lower emission fuels, installing energy-saving devices (ESDs) or, what is expected to be the most popular option, through implementing engine power limits.

Parallel to that, all ships over 400gt will also be subject to an enhanced version of the Ship Energy Efficiency Management

Plan (SEEMP), with mandatory reduction targets for operational emissions and rated according to a Carbon Intensity Indicator (CII).

Christos Chryssakis, DNV GL's head of business development, says it's probable ships will be assigned a rating from A to E: "We don't know what the targets will be but we can make some reasonable assumptions. If a vessel is in A, B or C there is no problem. If a ship has a rating D for three consecutive years or, if a vessel is in E, then it has to improve within one year."

Fig 2: MR Tanker environmental performance. Source: DNV GL



Ship type	Required EEXI (Reduction from EEDI reference Line)
Bulk carrier	Δ15~20% by size
Tanker	Δ15~20% by size (VLCC : 15% / MR 20%)
Container	Δ20~50% by size
General cargo	Δ30%
Gas carrier	Δ20~30% by size
LNG carrier	Δ30%
Reefer	Δ15%
Combo	Δ20%
Ro-ro/ro-pax	Δ5%
Cruise ship	Δ30%

Fig 3. In accordance with EEXI different ship types will need to improve their efficiency compared to 2008 baseline levels. Source: HHI

Running the ship on very low sulphur fuel oil (VLSFO), which gives a vessel an AER 53% of the 2008 baseline levels, may keep it below targets until the mid 2030s, yet would still require some form of further remedial action within the vessel's operational lifetime.

But a VLCC built today that's equipped to run on LNG has an AER of 65% compared to 2008 levels which, assuming the vessel continued to operate until the mid 2040s, would be sufficient to stay within acceptable levels. If that ship was also equipped with rotor sails its efficiency could be improved slightly further to 67%.

In the case of MR tankers, these vessels spend around 56% of their time at sea, with a typical operating speed of 12-13knots. This translates into an AER of 48%, meaning even current vessels will start exceeding IMO's efficiency requirements before 2030 (Figure 2), although opting for VLSFO buys a couple more years. Once again, the real benefits are predicted to come by opting for LNG, which could keep carbon emissions within acceptable levels until around 2044.

In 2018, DNV GL launched its Carbon-Robust Model, a methodology for allowing shipowners and investors to calculate the total cost of ownership of future designs. These designs are tested against different regulatory, technology and market scenarios to assess their viability. Using this approach, different permutations were considered for both the VLCC and MR tanker, such as the use of either VLSFO or LNG, the application

So, given that alternative low- or zero-carbon fuels are not realistically expected to be a viable option until at least 2030, what choices can shipowners make to ensure the vessels they order today are as 'future proof' as possible? To begin answering this question, DNV GL focused on two ship types, very large crude carriers (VLCC) and medium range (MR) tankers, using AIS data to develop an understanding of their operational profile.

It was found that typically a VLCC spends around 70% of its time sailing

and the rest either waiting or loading/unloading. Modern vessels (those built between 2015 and 2019), as denoted by the blue rectangle in Figure 1, were found to be achieving an Annual Efficiency Ratio (AER) within current IMO efficiency requirements. They were also below the stricter baselines for the Poseidon Principles, the 2019 agreement reached by the shipping finance sector to promote greener investment. However, by 2030 such vessels will be operating at around the permissible level of efficiency.

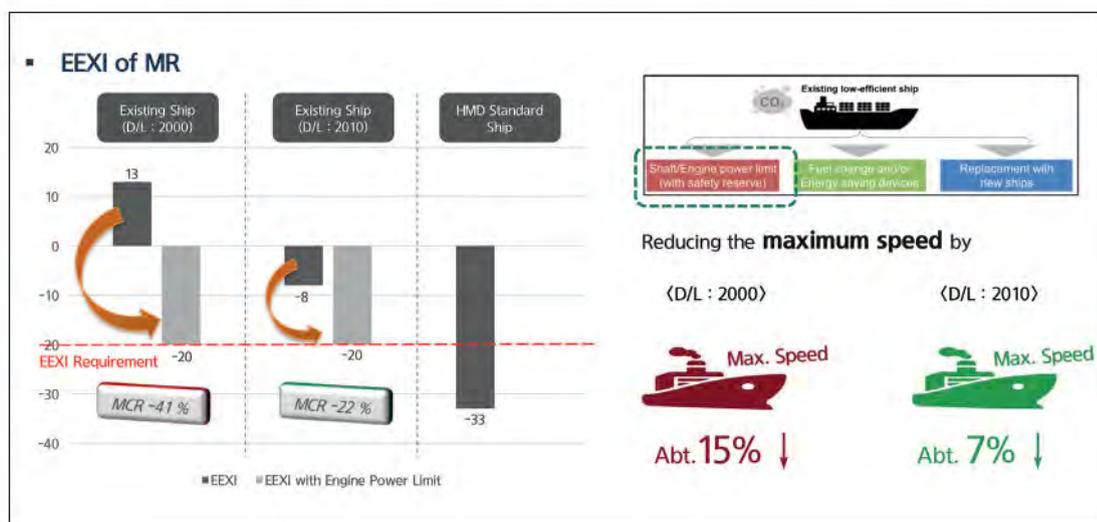
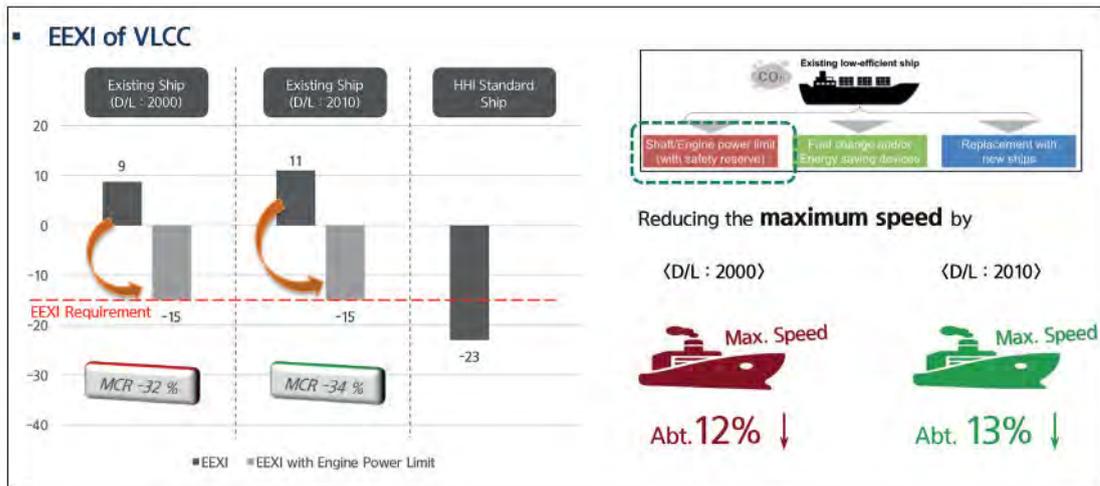


Fig 4: EEXI of MR tanker. Source: HHI

Fig 5: EEXI of VLCC. Source: HHI



of ESDs and the use of rotor sails. The study concluded:

- LNG combined with ESDs results in designs that perform significantly lower than IMO's GHG ambitions during their lifetime.
- Large vessels, such as the VLCC, are less sensitive to price variations when it comes to selection of LNG as fuel.
- When more expensive fuels are used, energy-efficiency designs will likely have a higher commercial impact, because the efficiency measures balance against the higher fuel cost.
- The probable introduction of carbon taxes makes such designs even more attractive.

HHI case studies

"To achieve zero emissions this century people say that carbon zero or carbon

neutral fuels should be applied. However it is also true that they could not be applied for large-scale commercial ships in the short to medium terms, because there are many commercial and technical barriers which won't be tackled in 10, maybe even 20 years," says Yi-Hyo Chung, Hyundai Mipo Dockyard's (HMD) head of initial design, as he explains HHI's contribution to the project.

The Korean shipbuilder also undertook studies for both VLCCs and MR tankers, but focusing on how existing designs compared to the EEXI requirements that will be imposed in the next few years (see Figure 3), taking designs it had built in 2000, 2010 and the current day. In the case of MR tankers, given that shaft power limitation is the most expedient way of achieving EEXI requirements, it was found that the engine would need

to be derated by 41% (a 15% drop in its maximum speed) to be compliant, while a 2010 MR tanker would need a 22% reduction in its MCR (7% speed decrease) to do so (see Figure 4). A current standard MR design by HMD is 33% below the reference line.

Chung notes: "The case study shows that even a 20-year-old MR could have a possible solution to maintain her operation with less flexibility and service speed. However, limited speed and comparatively poor fuel consumption could be disadvantageous in the chartering and resale markets."

The corresponding study for VLCCs threw up an anomaly, in that the 2000 vessel was actually closer to the reference line than the equivalent in 2010, translating into MCR reductions of 32% and 34% respectively (see Figure 5).

Fig 6. EEDI summary with different fuel, ESD and wind propulsion permutations. Source: HHI

Ship Type	Description	MCR (kW)	Design Speed(kts)	Fuel	EEDI (%)	Remark
HHI VLCC	Standard + ESDs	22,000	14.8	MDO(MGO)	-23	ESDs : Hi-PSD, Hi-Fin, Hi-Rudder & Bulb
	Standard (De-rated MCR) + ESDs	18,400	14.8	MDO(MGO)	-31	Decreased MCR down to Minimum Propulsion Power
	Standard + ESDs + LNG DF	22,000	14.8	LNG	-42	LNG : Primary Fuel
	Standard + ESDs + LNG DF + Wind Propulsion	22,000	14.8	LNG	-46	
	Standard (De-rated MCR) + ESDs + LNG DF + Wind Propulsion	19,320	14.8	LNG	-51	Decreased MCR down to Minimum Propulsion Power
HMD MR	Standard + ESDs	7,180	14.5	MDO(MGO)	-33	ESDs : Hi-PSD, Hi-Fin, Hi-Rudder & Bulb
	Standard + ESDs + LNG DF	7,180	14.5	LNG	-49	
	Standard + ESDs + LNG DF + Wind Propulsion	7,180	14.5	LNG	-54	LNG : Primary Fuel

Chung says this was due to a unique engine situation. “Twenty years ago, the [MAN B&W] S90MC-C engine was applied and its maximum available power was about 29,000kW. There was no choice for higher power for VLCC engines. As time went on, the [Wärtsilä] RT-Flex82 engine was introduced for the VLCC with higher power as its competitor, therefore VLCCs could apply more powerful engines by 2010, meeting market demand at the time for higher speeds.”

HHI shares DNV GL’s conviction that LNG is the only viable solution that can ensure long-term efficiency compliance, cut carbon emissions and serve as a bridging fuel to zero-carbon shipping in the future. To date, it has either built or has under construction 40 dual-fuelled vessels, including such successes as the Gagarin Prospect. Moreover, the company has developed thousands of hullforms and a vast array of ESDs, such as the Hi-Rudder and Hi-Fin, and HHI has extensive experience in developing optimum propulsion tanker types with the introduction of rotor sails. A standard design MR fitted with ESDs could drop from 33% below the EEDI requirement to as much as 54%, depending on its trade patterns (Figure 6).

Future technologies

Hyunjoon Shin, head of the future research dept at HHI subsidiary Korea Shipbuilding & Offshore Engineering (KSOE), presented additional research into the current state of alternative fuels and technologies, noting that while ammonia, hydrogen and batteries may be long-term solutions, their lower fuel density would mean a trade-off with cargo capacity. Moreover, ‘blue’ and ‘green’ hydrogen and ammonia will remain cost prohibitive until production can be scaled up and carbon taxation introduced.

But there is no reason, Shins explains, why ships built today can’t be prepared for that eventual transition to alternative fuels. Although still only at the conceptual stage, KSOE has started researching the necessary technology for ‘an ammonia ready’ LNG-fuelled ship (Figure 7).

He comments: “LNG fuel tanks made of stainless steel or 9% nickel steel cannot be used for ammonia fuel storage,

	Ammonia Ready LNG Fueled Ship	Ammonia Fuel System Retrofit
Fuel tank 	LNG tank (High manganese steel) → is usable for ammonia fuel also	LNG tank (High manganese steel) is used as ammonia tank + Additional ammonia fuel tank can use the LT steel.
Engine  	HP LNG DF engine	HP Ammonia DF engine
	Multi-fuel engine (under development by HHI group)	Ammonia fuel burning to be available with minor retrofit
Fuel supply system 	FGSS (Fuel gas supply system)	To be replaced by LFSS (Liquid fuel supply system) (some equipment of FGSS such as glycol system, submerged pump in tank, etc. can be utilized for LFSS also)

Fig 7. Ammonia ready LNG-fuelled ship. Source: HHI

however, high manganese steel can be used for both LNG and ammonia. Later, additional ammonia fuel tanks due to the lower energy density can be installed with low-temperature steel and engines can be easily converted to ammonia fuel. Engine makers, including HHI Group, are developing LNG engines which can be converted to ammonia with minor retrofits.

“The fuel gas supply system (FGSS) would need to be replaced with LFSS (liquid fuel supply system), because LNG fuel is gas but ammonia is liquid. However, some equipment such as a glycol system and submerged fuel pump can be designed for use on both systems to reduce the retrofit costs.”

Beyond that, there are true zero-carbon vessel concepts in development, such as the electric propulsion 20,000dwt hydrogen carrier concept announced by HHI in October last year, and a 50,000dwt MR tanker to be powered by a MAN ME-LGI ammonia engine that HHI hopes to commercialise by 2025.

LNG doubts

Despite the endorsement of the world’s biggest shipbuilding group and the largest classification society, many shipowners remain perturbed by the capex of gas-powered newbuilding, which is roughly 15-20% that of a conventionally fuelled ship. Another perennial problem is methane slip, particularly with regard to low-pressure engines, and Chung comments that HHI is starting

development of an aftertreatment system but it may take some time.

Chryssakis adds: “We know that there is [also] a lot of work in the direction of developing methane oxidation catalysts, while some technology suppliers are developing other types of aftertreatment devices that should be able to reduce methane emissions from the exhaust gases. In particular for engine makers, MAN announced in a publication last August that they are testing a methane oxidation catalyst that can reduce methane emissions by up to 70%. This development is mainly relevant for four-stroke engines, since they are suffering from higher methane emissions than two-stroke engines.”

In addition, he says that DNV GL itself has been conducting research into LNG tanks; the types of tank used, their size, materials and whether they are optimised for the required sailing range and bunkering locations of the vessel, which can impact upon the EEDI rating.

“The design pressure is essentially a trade-off between the filling limit and boil-off gas handling (holding time in the tank). Tank materials can be decisive on whether a tank is flexible for another fuel, such as ammonia. All these choices also have an impact on cost and operation of the vessel and have to be examined for each vessel separately. By optimising selection of these parameters it is possible to identify the most suitable LNG tank technology for each vessel, and therefore the most cost effective as well.” *NA*

'Malaccamax' tanker pays tribute to Iino Lines' heritage

As a further taster of *Significant Ships of 2020*, now available to order, we take a look at one of the notable tankers featured

The name *Fujisan Maru* is an important one in Japanese maritime history. In 1931, the original 13,500dwt 'oiler' *Fujisan Maru*, built at the Harima Sanbashi shipyard for Iino Shoji Kaisha, became the nation's first oceangoing tanker, originally transporting crude from North Sakhalin, in present-day Russia, to Tokuyama, Japan, until being requisitioned by the Japanese navy for wartime service and sunk in 1944.

Yet its years of merchant service came at a time of growth for the shipowner, now known as Iino Kaiun Kaisa (Iino Lines), which became one of Japan's biggest tanker operators. Today, Iino Lines has a wet tonnage fleet mainly comprised of very large crude carriers (VLCCs) that are still helping to meet Japan's demand for oil imports.

In March 2020, the owner took delivery of the 312,499dwt fifth-generation *Fujisan Maru*, one of two VLCCs designed and built by Namura Shipbuilding at its Imari shipyard on the island of Kyushu.

Malaccamax design

The latest *Fujisan Maru*, which will primarily ship crude between the Persian Gulf and Far East, is a fourth-generation Malaccamax, which means to say it has been built to the largest dimensions currently capable of passing through the Strait of Malacca. Notwithstanding the 25m average depth in the Strait, Namura Shipbuilding tells *The Naval Architect* that one of the main differences from a conventional Capesize or VLCC is that a Malaccamax isn't fitted with a bulbous bow, allowing it to be several extra metres longer. The latest design has a length overall (LOA) a fraction under 339m, 6m more than the previous Malaccamax generation and 24m more than the original iteration of these vessels. Namura Shipbuilding explains these further gains, and with it further increase in cargo



Fujisan Maru

volume, were made possible through a relaxation of Japanese port restrictions.

The additional length allows for a more efficient vessel due to the slightly increased cargo capacity of 351,296m³. In total, there are 15 cargo tanks arranged in five sets of port, starboard and centre tanks, as well as two slop tanks. This arrangement allows for simultaneous carriage of three grades. Three Shinko steam turbine driven cargo pumps and two stripping eductors comprise the cargo handling equipment.

Efficiency measures

The ship's propulsion performance is improved by adoption of energy saving devices developed by Namura Shipbuilding. These include the long-established Namura flow Control Fin and the Rudder Fin attached to the stern, together with the aerodynamic narrow superstructure, hub vortex reduction type propeller boss cap, and low-friction

type antifouling coatings. Power comes from the single ultra-long stroke MAN B&W 7G80ME-C9.5 two-stroke diesel main engine built by Mitsui, rated with a 24,700kW output at 67rpm.

The vessel has been built for compliance with IACS' Harmonised Common Structural Rules for bulk carriers and oil tankers (CSR-BC&OT), as well as anti-corrosion regulations such as IMO's Performance Standard for Protective Coatings for oil and water ballast tanks (IMO PSPC-COT and PSPC-WBT). *Fujisan Maru* is also notable for being the first vessel in Iino Lines' fleet to have a scrubber installed, being equipped with an Alfa Laval U-type open loop system. **NA**

The original *Fujisan Maru*, built in 1931

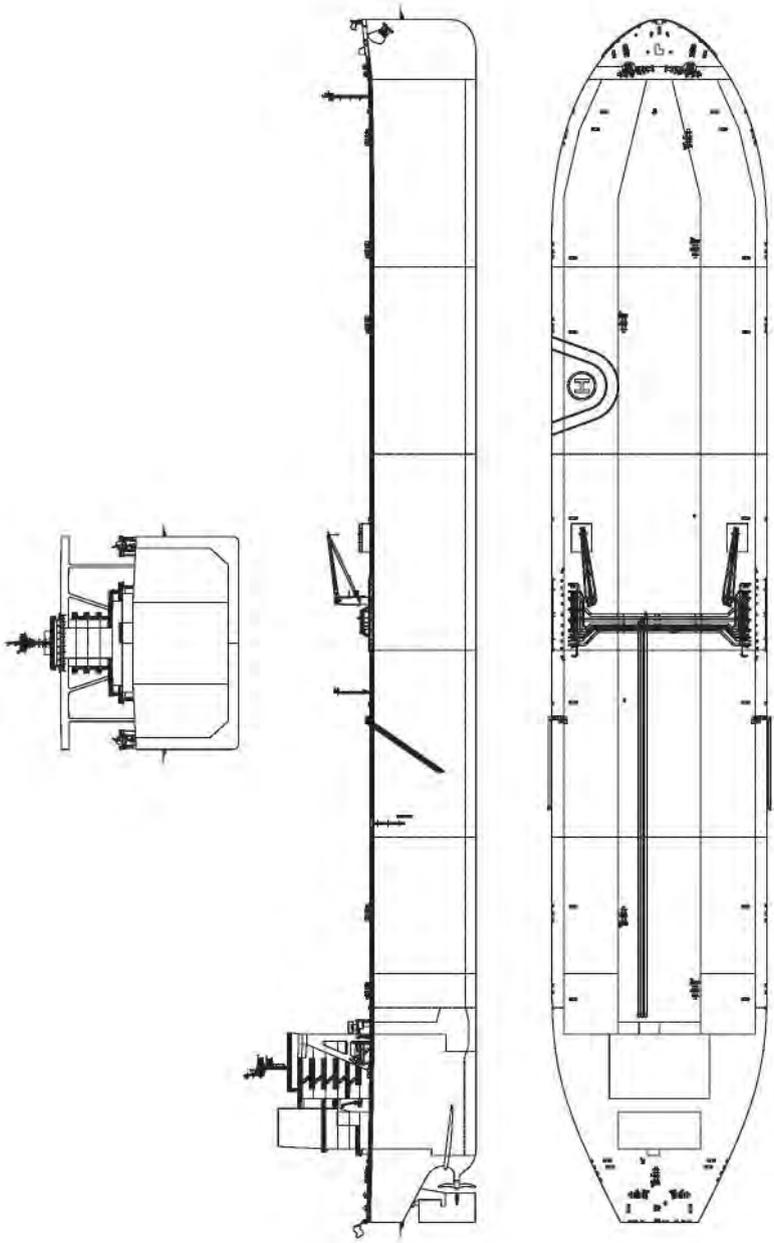


TECHNICAL PARTICULARS

Fujisan Maru

Vessel type:	Crude oil tanker
Length (oa):	338.92m
Breadth moulded:	60m
Cargo capacity:	351,296m ³
Deadweight, design:	312,499t
Gross tonnage:	160,106t
Main engine output:	24,700kW
Classification society:	ClassNK
Flag:	Japan

General arrangement of *Fujisan Maru*



Composite materials offer commercial shipbuilders an enticing mix of benefits

Tom James, sales business development manager, Hexcel, examines the key issues with increased composite adoption and its current state in shipping

Composites have been used in recreational boats and yachts since the 1950s with both materials and production processes developing steadily since. They can massively reduce vessel weight, though these gains and the associated reduction in fuel costs and emissions are not the only advantage of composites. Increased cargo capacity, extended maintenance cycles, smoother hull surfaces, and in-built vessel health monitoring are all identifiable benefits versus metallic constructions.

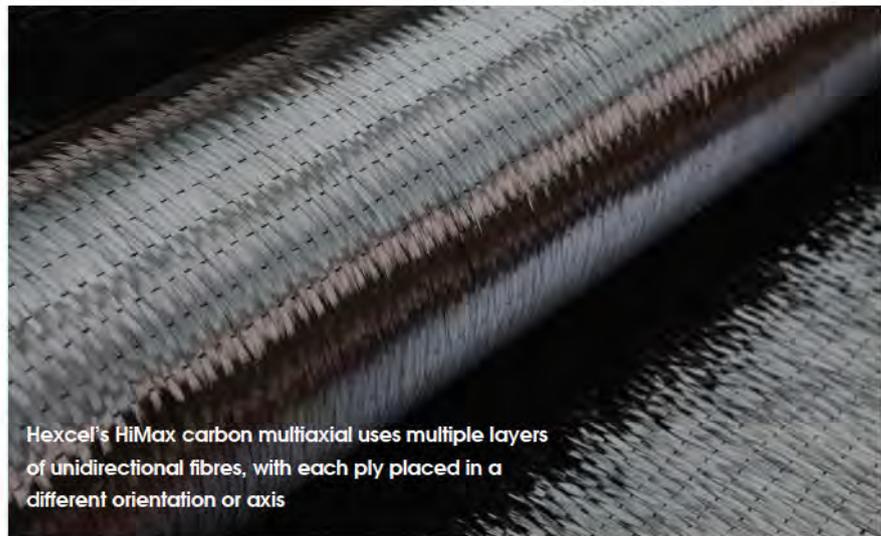
While larger military craft have sought to exploit the benefits of these lightweight, non-magnetic and corrosion-resistant materials, composites are not yet commonly used in large-scale shipbuilding.

Steel construction for commercial vessels is not just the industry standard, it was effectively the only option allowed by the IMO's SOLAS regulations until 2002. More recent amendments relating to composites offer guidelines for their applications and some concessions to the previous mandate on non-combustible materials, though regulatory hurdles remain.

State-of-the-art materials

Hexcel has supplied advanced composite materials to the marine industry for almost 50 years, manufacturing a comprehensive range of DNV GL-certified products for high-performance craft as well as commercial marine vessels. When we use the term composites, we are typically describing a material in which reinforcing fibres (carbon, glass, aramid or, plant-based) are used to strengthen a resin matrix, combined to produce a stronger yet light-weight composite material with improved properties.

Composites can be used to form monolithic laminates simply composed of resins and fibres, or complex sandwich structures where a foam or honeycomb core separates two thinner laminate skins, providing a higher stiffness to weight ratio than a monolithic layer.



Hexcel's HiMax carbon multifaxial uses multiple layers of unidirectional fibres, with each ply placed in a different orientation or axis

These materials can be supplied and used in several different formats and while they apply to large percentages of ship hull, deck and superstructure components, as well as ancillary parts such as communication masts, hatches, and even propulsion components, the optimum material solution depends heavily on the application and its unique requirements.

In terms of composite material formats, large composite shipbuilding demonstrator projects have often used dry fabric reinforcements, typically in the form of multi-layered textile products, where machine-laid fibres are orientated at different angles then stitched together to stabilise the fabric. These fabrics can then be combined with liquid resins (typically epoxy or vinyl ester) via moulding techniques such as resin infusion, where vacuum pumps are used to draw resins through fabric plies pre-positioned in a mold tool.

Prepreg composites use similar fibres, however, the catalysed epoxy resin systems are combined with the reinforcements on a production line before the materials are used, hence the name prepreg or pre-impregnated. After impregnation, the prepregs are chilled and stored.

When required in production, the prepreg materials are defrosted and cut to size before being laid up in the mould, consolidated under vacuum, and cured in an oven or autoclave. Prepregs enable the highest structural performance for the lightest weight and are heavily used in aerospace, wind turbine blades, and performance yachts and boats.

At Hexcel, we usually advise that composite material, format, and process selection is decided on a case-by-case basis, and it is at this stage that our skilled composite engineers and material development teams add the most value, balancing cost and performance and guiding vessel owners and builders toward the most appropriate solution.

It is without a doubt that current state-of-the-art materials and processing technology are ready for composite integration into shipbuilding at the component level. Applications such as tween decks, hatches, wing sails, rudder flaps, and propellers have all been developed, approved for use and, in some cases, deployed onboard. The full composite >100m hull is still a development for the future, but the building blocks and technology to deliver it already exist today.

Large composite structures afloat today

In 2016, Croatian shipbuilder Uljanic completed the *Siem Cicero*, a 200m car carrier with a capacity of 7,000 vehicles. The vessel has 13 vehicle decks, with the topmost three decks featuring a fibreglass and foam sandwich construction that reduces deck mass by 25% compared to steel. In addition to stability benefits, a fuel savings of 4% has also been reported.

Japanese propeller specialist Nakashima has also developed a range of carbon fibre bladed propellers and thrusters. First deployed on the 64m chemical tanker *Taiku Maru*, Nakashima has since also equipped ferries and fishing boats with similar propellers.

Rotary and fixed sails for propulsion assistance are another interesting composite application onboard. Norsepower rotary sails have been fitted to several vessels since 2014, with the largest units to date being a pair of 35m tilting sails fitted to the 155m ro-ro *SC Connector*. Anemoui, Becker Marine Systems, and Wallenius with their *Oceanbird* sail-powered 7,000-vehicle transatlantic range transporter concept are all expanding rapidly in this space. Composites are well suited to such sails where lightweight (and strong) structures are required for stability considerations.

Industrialising composites production

With material solutions and production processes available, one might think that shipowners' desire to capitalise on the benefits of composites would be already driving the increased adoption of lightweight composites into new builds. As well as the regulatory complexities regarding fire performance mentioned earlier, there are some challenges associated with large merchant vessels that have not had the same impact in smaller vessels and other large-scale composite applications.

One such challenge is the adjustment required by yards to introduce composites at scale. Steel production environments are not always suitable for composite processing where controlled conditions are needed to ensure production consistency. Additional skills related to composite design, engineering, and manufacture also need to be fed into the mix.



Announced last year, the *Oceanbird* vessel under development by Wallenius Marine to build a 200m wind-powered ro-ro, with wingsails made from composites and steel

Fortunately, other industries have successfully industrialised composite production for very large structures. Composites are completely established in both aerospace (previously dominated by metallic constructions) and wind energy, with raw material supply chains, process automation, inspection, and MRO parameters all clearly defined. Shipbuilders will certainly adapt to new techniques, and with the current disruptions to the commercial aerospace sector, major composite industry players' opportunities may be well placed to support rapid growth in new high-volume composite applications.

Collaborative research projects such as FIBRESHIP and RAMSSES have been hugely important in generating industry focus on composite applications as well as providing the shipbuilders with design methodologies, validated production techniques, and a potential adoption pathway. Both of these multinational EU projects have defined specific demonstration cases that use composite construction throughout the vessel. Of particular interest for large vessels are the three composite vessel structural concepts detailed by FIBRESHIP. By presenting composite options for an 85m fishery research vessel, a 200m ro-pax, and a 250m containership, the project has illustrated how a staged approach could bring composites to full scale in commercial shipping.

Designing for composites with the full life cycle in mind

The FIBRESHIP and RAMSSES projects also included significant work on life cycle analysis (LCA) tools specific to composite vessels. Experience from other composite sectors provides valuable data, such as analysis including end-of-life considerations. Thermoset composites, such as the epoxy and vinylester structures previously described, are traditionally challenging to recycle. With millions of tonnes of composites in use globally in aerospace and wind, and with the first generations of composite aircraft and wind turbines approaching their end-of-life, the requirement for recycling options is paramount.

Fortunately, the composite recycling industry is accelerating in line with this need with several converters now able to recover glass and carbon fibres from manufacturing and end-of-life waste with remarkably close (90+%) properties to original virgin fibres. These recovered materials are not yet available in the same long length continuous fibres as in their original composite application but can still be used, either in non-woven mats or in new short fibre molding applications such as sporting goods.

Carbon Conversions Inc., Hexcel's strategic partner in carbon fibre composite recycling, has successfully recycled some of the largest marine composite structures processed so far when they worked with

Team Oracle to reclaim carbon fibres from the hulls and masts of two of the team's America's Cup yachts.

Dispelling the myths about composites

Often perceived as high-performance lightweight materials from Formula 1 racing or aerospace, we do come across misconceptions concerning the suitability of composites for merchant shipping.

One common misperception is that composites can be fragile and fail suddenly in use. While it is true that modeling of composite structures is often more complex than for a metallic part, well-proven tools and simulations do exist from aerospace and other industries. Validation and test programs, coupled with tightly controlled composite material and component production, can provide extremely accurate predictions of failure mechanisms and operating limits.

Composites can also nearly always be repaired, even after suffering severe damage. Both the aerospace and wind energy markets have developed well-defined inspection and repair protocols to maintain composite structures throughout their life. Specific

maintenance and repair strategies may even reduce the workload required to keep marine structures operational in an environment that is hostile to steel.

As with all complex engineered structures, it is important to look deeper than raw material cost when evaluating the worth of new construction technology. Composite materials can sometimes cost more than steel, but a full life cycle analysis considering fuel savings and payload gains makes a strong positive case for composites in the vessels of the future.

Navigating a smooth path through the regulatory hurdles

Regulatory consensus and an approval pathway are key requirements to the wider adoption of composites, with FIBRESHIP and RAMSSES focusing heavily on this issue. The industry recognises the massive potential of composites and, with targets such as the IMO's desire to cut CO₂ emissions by 40% by 2030, the drivers to implement are present too. While these issues have not been completely resolved, considerable momentum has been created recently.

RAMSSES utilised a shorter-term fast track approval concept in its work with

Bureau Veritas, based on the definition of an approved material solutions database, fire risk cases, and a package of analysis and simulation tools. The FIBRESHIP approach was comparably longer term in that the project sought to develop an entirely new rule set covering fire performance, structural requirements and production alongside partners RINA, BV, and Lloyd's Register. Challenges remain, but by considering application areas across the vessel and overall fire systems present, a global safety equivalent with steel construction appears eminently achievable.

Hexcel expects to see a considerable increase in composites deployment aboard large vessels in the next decade.

With the correct design, engineering, materials, and production parameters in place, advanced composite materials such as those manufactured by Hexcel create lighter, cleaner, and more efficient ships. At Hexcel, we believe that it is a case of when – rather than if – the step-by-step adoption of full composite structures in vessels >100m in length goes ahead. *NA*

For more information, visit: www.hexcel.com

Action to decarbonise the shipping industry needs to happen now

Fuel agnostic clean technologies will play a vital role in getting to net zero emissions, argues Noah Silberschmidt, CEO, Silverstream Technologies

The decarbonisation debate is heating up: for progressive ship owners and operators, meeting the IMO's target of at least a 50% reduction in total GHG emissions by 2050, compared to 2008 levels, while maintaining economic viability in a competitive market, is rightly at the top of their agendas.

Much of the debate in shipping has, to-date, focused on the importance of establishing a clear range of alternative, low- and zero-carbon fuels to meet IMO targets. It is right that much of the attention is being placed here, because of the significant carbon reduction

potential of alternative fuels. However, to solely focus on these future solutions ignores measures for efficiency that are currently on the market and places emphasis on fuels that need considerable development, when action to decarbonise needs to happen now. This approach fails to consider the symbiotic relationship between future fuels and fuel efficiency.

In fact, industry leaders have already started to champion a change of mindset, with Maritime UK chair Sarah Kenny, stating in a recent webinar that “the conversation around tech should be more than just clean fuels, and using tech to get to net zero

emissions could help ships' productivity and efficiency as well as the environment.”

To illustrate the scale of the fuels challenge, UCL estimates that US\$1.4 trillion of investment in R&D and infrastructure is needed to successfully commercialise a range of future fuels for shipping.

While no one can argue against the importance of future fuels in the decarbonisation of the shipping industry, the sector must also retain focus on efficiencies that can be delivered now, regardless of fuel or operational patterns.

Proven, available, fuel agnostic clean technologies, which can be retrofitted

on the existing fleet, are vital to ensure we not only reduce emissions today but enable shipowners and operators to retain a competitive advantage. This is especially important when looking to the future. With low- and zero-carbon fuels set to be far more expensive than shipping's commodity fossil-based fuels, clean technologies that significantly increase fuel efficiency will be vital as long-term solutions that underpin the economic viability of the global fleet in the coming decades. To install them today is to therefore get ahead of the game.

The impending influence of EEXI

The case for clean technology now is further highlighted by impending regulations, such as the IMO's approved amendments to MARPOL Annex VI to introduce an Energy Efficiency Design Index for all existing ships (EEXI). Although subject to adoption at MEPC 76 later in 2021, the requirements aim to address the technical aspects and operational measures of a vessel in relation to carbon intensity and, if approved, will come into force in 2023. These requirements will act as a further catalyst to drive uptake of clean technologies.

On much of the global fleet, clean technologies present one of the only currently available pathways to comply with the new rules, allowing owners and operators to remain profitable as they tackle the wider decarbonisation challenge. Likewise, while slow steaming may be viewed as the easiest route for some owners to attain EEXI compliance, it is an ineffective short-term solution to a long-term problem and risks us undermining the objective of the regulation, increasing the material efficiency of vessels in the global fleet.

The power of air lubrication

The existing fleet therefore requires readily available and retrofittable proven clean technologies to effectively increase fuel efficiency and remain in operation in light of new requirements. Few technologies are currently recognised to meet the current Energy Efficiency Design Index (EEDI) Phase III requirements, but air lubrication is one of them. This is significant because the methodology for EEXI is likely to match very closely with the current methodology



Noah Silberschmidt

used to calculate EEDI.

Air lubrication is increasingly being acknowledged by regulatory bodies and influential industry players as a credible, effective, and easily implementable clean technology. For example, the International Transport Forum's 'Decarbonising Maritime Transport – Pathways to zero-carbon shipping by 2035' cited air lubrication as one of the 'known clean technologies' that, if deployed across the global fleet, could make it possible to reach almost complete decarbonisation by 2035. Shell also referenced air lubrication as a valid solution in its 'Decarbonising Shipping: All Hands-on Deck' report as did the IMO in its 'Fourth GHG study'.

The Silverstream System

Our air lubrication technology, the Silverstream System, increases fuel efficiency, and associated emissions by 5-10% (depending on vessel factors) no matter the fuel being used onboard.

Milestone orders such as the installation of the Silverstream System on 12 Hyundai Heavy Industries-built, Shell-chartered newbuild LNG carriers, among further notable orders with Grimaldi, is reflective of the increasing recognition of the viability and value of clean technologies to truly cement emissions' reduction.

Regulatory, shareholder, and public demand has made it a commercial necessity to demonstrate progress on decarbonisation – and therefore to invest in clean technologies alongside future fuels. No matter the fuel, clean technologies have the power to reduce fuel bills and emissions, provide operational flexibility to vessels, and increase profitability for ship owners and fuel payers.

With several industry leaders implementing and placing higher value specifically on air lubrication, and new regulation set to drive further change, we believe solutions such as the Silverstream System are set to play a vital role in reducing emissions on the existing fleet and will become a standard on newbuild vessels in the coming years.

The unavoidable truth of low-carbon fuels is that they will require higher operational expenditure on a per voyage basis. Clean technologies that increase fuel efficiency and reduce associated costs will become a vital strategy for maintaining profitability. Taken together as part of intelligent retrofits and new vessel designs – and with the scale of the challenge ahead – an ecosystem of clean technologies that drive cumulative savings is the path that our industry must take if it is to reach its decarbonisation goals. *NA*



Silverstream System, the company's air lubrication system for increased fuel efficiency

Corvus confident hydrogen will prove no hard sell

A partnership between battery specialists Corvus Energy and Toyota hopes to achieve mass production of hydrogen fuel cells for maritime use by 2024

Most attempts to forecast the maritime industry's future energy requirements anticipate that electric propulsion will take on greater prominence with the shift towards carbon-free solutions, and in particular fuel cells that convert liquid fuels such as hydrogen and ammonia into electric power. Hitherto, despite a handful of pilot projects, that speculation has failed to translate into commercially viable technology.

So the announcement that marine energy storage specialist Corvus Energy has signed a Memorandum of Understanding (MoU) with Toyota, the world's largest supplier of fuel cells for the automotive industry, for the development and production of sustainable, large-scale energy maritime-certified hydrogen fuel cell systems, could prove a decisive moment.

"We need to bring scalable, complete solutions to the market. So far we have only initiated pilots but, by selecting Toyota as a partner, and building on what we have done with the battery, we are looking at going straight on to the industry and we think we can scale up," said Corvus CEO Geir Bjørkeli during an online press conference to officially launch the partnership at the start of February.

The announcement is related to a research project led by Corvus and involving several other significant players in Norwegian maritime: Equinor, shipowners Norled and Wilhelmsen, ship designers LMG Marin, the NCE Maritime CleanTech cluster, and R&D institution the University of South-Eastern Norway (USN). The partners have received a €5.2 million grant from government agency Innovation Norway to develop and produce modularised and cost-effective PEM (Proton Exchange Membrane) fuel cell systems for the international marine market. These projects are also related to other Norwegian initiatives such as Wilhelmsen's Topeka project,



Figure 1. Corvus anticipates the next 30 years will be marked by large-scale utilisation of energy carriers, in particular hydrogen

which aims to construct and operate two liquid hydrogen-fuelled short-sea ferries. Equinor, which is majority owned by the Norwegian government, is also part of a separate project building a liquid hydrogen production plant at the Mongstad Industrial Park, near Bergen.

"At Corvus, with our project consortium partners, we will design the fuel cell module with all systems, design packaging and software and we will explain a little bit later how we can combine the use of fuel cell and battery. We're going to have exactly the same interface towards the electrical integrator," explains Bjørkeli.

As part of the plans, Corvus intends to build a brand-new fuel cell factory in Bergen, where the company also opened a battery plant in 2019. Like that facility, and its equivalent in Vancouver, Canada, where the company is headquartered, Bjørkeli says it will deploy robotic technology on the shopfloor.

By adding fuel cells to its product portfolio, Bjørkeli believes his company can become a more complete provider of zero-emission solutions. But it's also an acknowledgement that battery technology will be unable, for the foreseeable future, to meet all the energy demands of deep-sea commercial vessels.

That's not to say batteries haven't advanced considerably since Corvus was launched 12 years ago; when it was sourcing the 10tonne lithium-ion core battery cells used onboard the battery electric car ferry *Ampere* (delivered 2015) the cost was typically US\$1,200-1,400 per kW/h of stored energy. Today, that cost has been significantly driven down as much by the company's ability to purchase cells in large volumes. The partnership with Toyota is intended to utilise the same economy of scale; allowing Corvus to get a quality product at the most competitive prices.

Building on battery experience

The aim is to offer batteries and fuel cells in unison as a single package. Kristian Holmefjord, Corvus EVP and project director, explains: "[Whereas] the ICE is a very robust unit that you can do almost anything with in terms of loading and stress, when it comes to fuel cells we need to use them slightly more cautiously. We need to ensure they're much more stable in production and the way they're used to get the most value out of your power system.

"One of the important parts is that we're keeping the same interface through our customers today. We have the exact same

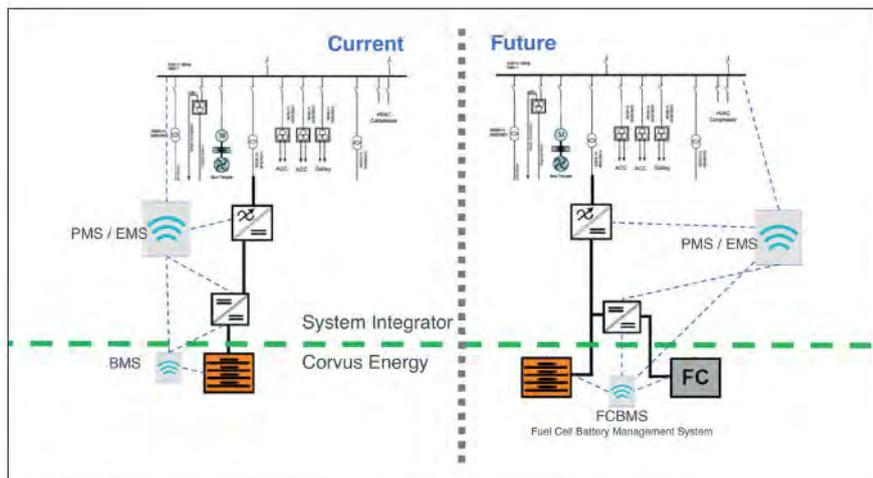


Figure 2. Corvus' current and future value propositions

value chain when we're delivering to our end customer, the system integrator."

Presently (see Figure 2), Corvus supplies its customers with a maritime battery and complementary battery management system (BMS), which interfaces with a system provided by the system integrator, services typically provided by companies such as Wärtsilä and ABB. Under the plans, the fuel cells will join the batteries under a combined management that optimises the lifetime performance of both.

"The integrator we use today for the battery is the same we will use for the fuel cell", says Halvard Hauso, Corvus' CCO. "All the partners in the supply chain are the same as we use today. Working with these partners is what has brought us to where we are."

He adds that, just as batteries have moved away from the 'one size fits all' model (Corvus itself now offers a choice of seven different batteries, according to needs), so too will the same philosophy be applied to fuel cells. "We are now starting with the ideal PEM fuel cell with

hydrogen and then we're going to build up what we need to cover the full maritime industry. There is no silver bullet for the fuel cell, and there are so many different vessel types and operational profiles that it's not possible."

The permutation of fuel cell and battery size is expected to vary according to the scale and operational profile of the vessel (Figure 3). A short-sea ferry that operates close to shore, charging on a regular basis, would logically have a larger battery. In this instance, the fuel cell serves as a range extender on occasions when the ship might be required to travel longer distances with zero emissions. Conversely, a long-distance vessel would have a small battery and large fuel cell; the battery functions more as a stabiliser for extensive periods. The majority of ships would fall somewhere in between, requiring careful calibration considering the high cost of the fuel cell. However, Corvus believes the environmental benefits would be considerable, with a

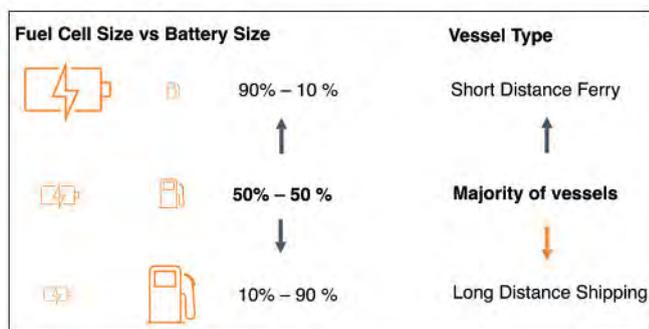


Figure 3. The battery/fuel cell configuration will change according to the vessel's operational profile

90-minute voyage saving some 10,350 litres of diesel, corresponding to 27tonnes of CO₂.

Decarbonisation is inevitable

Freddy Bergsma of Toyota Europe's Fuel Cell Business Group says his company is convinced that decarbonisation "needs to happen" and is committed to achieving this by the middle of the century. He adds: "In that context, we work on our own products but we also make our technology available to third parties. We make all the patents for our hydrogen fuel cell technology available for free, at present, and also that the products themselves are made available so other people can reap the benefits."

"Passenger cars are not necessarily directly applicable to other applications, [but] starting with the base technology that we have today we've repackaged that in what we call a standard modular approach. This basically produces a complex module that can be used for a variety of applications."

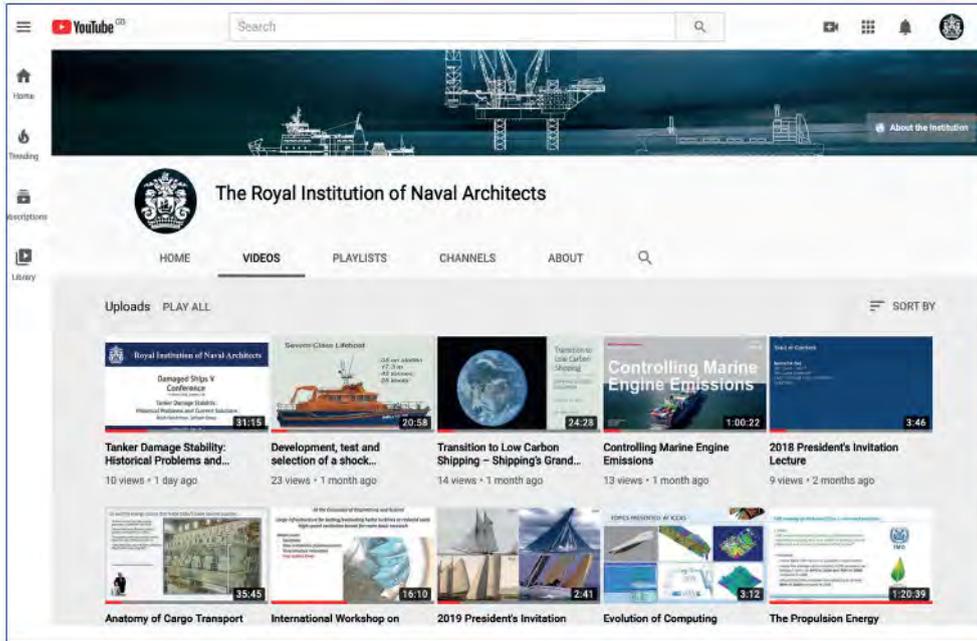
In other words, technology can be repackaged to suit installation on a ship, with each generation of the technology becoming lighter, more compact and with higher power density. As a company with a background in mass production, Bergsma is confident that by adopting a modular approach to production Toyota can realise benefits in quality and cost efficiency.

"The passenger cars create the economies of scale for us for the fuel cell systems, of which other applications can then benefit in turn. In reverse we need other applications - whether marine, buses or trucks - because those are the big consumers of the hydrogen. That's important because a large consumption attracts supply and makes the economies of scale for hydrogen production in turn. So there's a nice synergy from our perspective."

Although it has yet to announce any formal collaboration with a classification society, the project is targeting achieving type approval for the first PEM Corvus Fuel Cell System by 2023-24, with scaled-up automated factory production beginning shortly afterwards. A second-generation solution, featuring solid oxide fuel cells (SOFC), is anticipated by around 2025. *NA*



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CYBERSECURITY



A clearer vision is needed for bridge design

The demands of digitalisation are re-shaping the bridge space around flexible workflows, enhanced functionality and cyber security, writes Pascal Goellnitz, product line manager, IBS, Sperry Marine

Shipowners have considerable choice when it comes to integrated bridge systems (IBS) but in reality, some of the options available to them in terms of integration and functionality may be limited, with a narrow scope for innovation beyond the addition of some extra features.

Achieving a greater degree of digitalisation in vessel operations requires not just proven hardware and software but the ability to respond to client needs and develop completely new solutions when required. In fact, we believe end users should be encouraged to challenge their OEMs to come up with new ideas and incorporate them into newbuilding projects.

To fulfil the needs for a recent series of ultra large container vessels, with capacity over 20,000TEUs, our approach was to re-define the bridge layout and interfaces, with a focus on human-centric design.

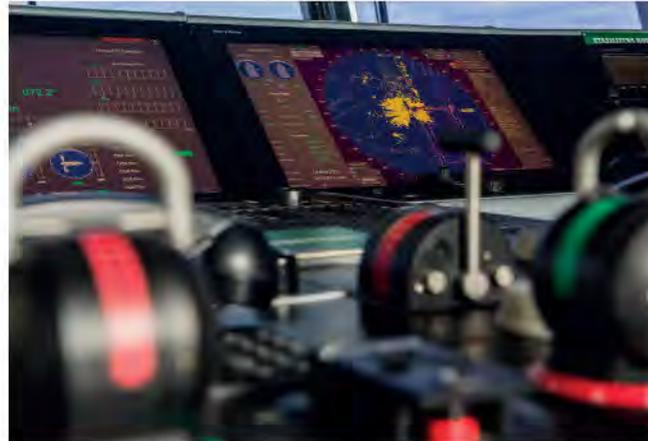
Sperry Marine considered how to make the space more functional for navigators, providing greater connectivity between critical components to support flexible working and secure access between front and back of bridge.

The approach was to introduce a new navigation system, VisionMaster Net, allowing the integration of panel PCs and specifically designed bridge consoles to accommodate a re-designed bridge workflow and enable the workstations to function as an assistant to the navigator rather than defining their working position.

The decision to use panel PCs contributed to a more spacious layout bridge, allowing the team easier access to the bridge windows for better watch/vision capability.

Among the challenges to consider for this new type of ultra large vessels was the size of the ships. Some 400m long and more than 60m wide, the bridge team would require additional visibility around the vessel in order to manage operational risk when manoeuvring and berthing.

As a solution, Sperry Marine installed a navigation radar with four radar sensors



Sperry Marine's integrated bridge system

around the ship as close to the waterline as possible and merged the video into a single 360-degree view that was not impeded by the superstructure. This system, known as Total Command, reduces the minimum viewing distance and provides an enhanced 360deg view around the vessel. Because the sensors are lower power than traditional navigation radars, their lower emissions do not create health hazards for the crew working in close proximity.

As the ship was so long, it was exceedingly hard for a navigator on the bridge wing to tell if the vessel was truly parallel to the quayside when berthing. To resolve this, Sperry devised a camera system known as SmartEye. This consists of two cameras mounted in the forward and aft blind spots and one each on port and starboard, providing a 180-degree view. The video from all four is merged to give the view from the bridge wings without the need to run between them, providing visibility on mooring lines and tug positions.

To complete the augmentation, Sperry Marine installed two further high-precision positioning antennas fore and aft to provide highly accurate vessel positioning which enables safer, faster and more efficient berthing. This data is added to the SmartEye system as a separate overlay to the ECDIS system, showing distance to berthing

position in meters and approach speed.

At the back of the bridge, Sperry Marine installed the SperrySphere data management platform to simplify passage planning and facilitate the transfer of ENC updates to the navigation system without using a flash drive.

SperrySphere features a 55inch touch screen 'tactical table' hosting passage planning software, chart tools, sailing directions and safety documents from where passage plans can be transferred to VM Net for loading and validation. To reduce process risk and improve cyber security, the SperrySphere features the Secure Maritime Gateway, with a 'dematerialised zone' that indirectly connects the ship's administration network with front of bridge. The SMG controls traffic by allowing only the export of permitted data files into the DMZ from where they can be transferred to VM Net.

Bridge technology literally drives the shipping industry. As a regulated space, it has not always kept pace with innovations elsewhere, but the technology created for this series of cutting-edge ships represent completely new concepts.

With maritime digitalisation gaining speed, suppliers must be capable of acting increasingly as a preferred strategic partner; because the solutions the industry needs cannot be bought off the shelf. *NA*

Bridging the technical divide

Two extremes remain a reality on the bridge: traditional versus fully integrated, says Anders Bergh, technical sales manager at Lean Marine

The shipping industry is very traditional, and some would even say that as an industry, compared to some other transportation sectors, it is often a late adopter of new technologies. This is true for the industry's approach to digitalisation and integrated bridge systems. Even though it took a long time to start to emerge, during last decade shipping has taken big steps forward towards data-driven digital transformation.

Shipowners and operators are now comprehending the value of gaining a deeper understanding of their ship operations through big data and interest in developments of AI-powered technologies that enable more energy efficient voyage planning and execution is therefore increasing.

However, when looking at the setup of the bridge on ships a split between the old traditional era and new digital era remains. In today's bridge systems, we see two extremes: traditional bridges with minimum tools versus fully integrated bridge systems. Moving from one extreme to the other may not be possible for every vessel, but a decent level of digitalisation is possible for all, and further improvements can be made over time.

If you are wondering where to start your vessel's digital transformation as a shipowner or operator, you should consider how far you would like to go on a short and long-term basis, then choose technology that would be able to follow your expectations in time.

Understanding vessel performance

The first step is to build up knowledge on a vessel's performance. In this way, you can start to improve the ship's operational efficiency, which will result in saving fuel, reducing emissions, and lowering operational costs. To do this, having a good level of data on weather, voyage, navigation, and your vessel's operational performance is essential. This prerequisite is the key to enabling performance monitoring,



Anders Bergh, technical sales manager at Lean Marine

analysis, creating best practices, and then, improving vessel/fleet performance.

A ship operator might require an automated data collection system to facilitate data gathering which obtains more reliable data and consolidates it as big data in one central platform. Even though it may not be possible to connect all vessel data available within the confines of the system from the beginning, starting from the vital data sources and completing the rest over time is possible.

However, without performance management software in place, a ship operator would be just looking at hectic big data, which would require a great deal of analysis by the fleet performance team to determine the outcomes. This would be quite complicated and very time consuming.

With a performance management solution in place, a fleet performance team can easily turn complex volumes of big data into meaningful information. They can also visualise data as easy-to-understand graphs/indicators and transform data into useful reports. Therefore, this allows the fleet manager to quickly find out how the vessel is doing, where there are performance improvement opportunities, how the crew can adapt the best practices, and so on. In this way, ship operators can easily take fact-based decisions for improving a vessel's operational efficiency

and hence, lower the operational cost.

Additionally, having a central data platform that collects, transforms, and communicates the data with other systems means that workload onboard and onshore is greatly reduced.

Once the vessel performance improvement opportunities are defined, it is time to take action to make the required efficiency a reality. But this is much more complicated than it sounds, especially when it comes to fuel efficiency. Let us go back to the bridge of the ship and see how the systems there can help acting on the gained knowledge.

Although advanced tools can help reduce time spent on monitoring vessel performance and changing conditions, or setting speed and tracking fuel consumption, depending on the experience of the crew and individual judgements, intended improvements may differ. Also, manual speed and/or power setpoints adjustment frequency can remain relatively low because of bridge team high workloads. It is not uncommon for lever adjustments to be several hours apart, sometimes by even more than one day. Adjustment frequency and human factors can cause costly variations in speed and power, notably during fast changing weather or sea conditions.

To support the work of the crew and ensure optimal fuel efficiency, automation could be the answer for significantly decreasing human intervention and avoiding any unwelcome surprises.

At Lean Marine, we provide two solutions that enable automation and digitalisation: an 'on top' propulsion automation system – FuelOpt – and a smart performance management and reporting software – Fleet Analytics. We are confident our solutions offer operational efficiency benefits as soon as installation is complete.

Automated and direct fuel savings from the bridge

FuelOpt provides a direct interface between the machinery and vessel crew on the bridge that controls the parameters

which matter most on operational efficiency: speed, fuel consumption, engine power or a combination of these. Notably, the consumption setpoints empowers them on avoiding overconsumption of fuel in harsh conditions, such as high swells and winds.

Once it is activated with the push of a button from its intuitive panel on bridge, FuelOpt achieves real-time fuel savings and emissions reductions. The system dynamically controls vessel propulsion based on the commands set, adapting the propulsive power to the changing environmental conditions. In this way, steady and predictable shaft power can be achieved, removing costly variations in speed and power caused by human operational factors.

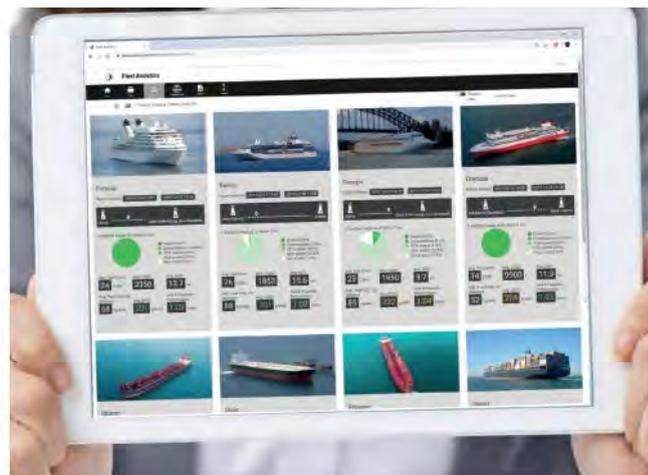
On vessels with a controllable pitch propeller, FuelOpt acts as a dynamic tuning system for the propulsion machinery. The system regulates the propeller's pitch and RPM separately to operate the engine and propeller at optimal conditions. In this way, the system ensures to produce maximum amount of propeller thrust with minimum amount of power, hence wasting significantly less energy. In addition, automatically and continuously following the signals from the engine and propulsion line enables FuelOpt to avoid risk of overload on the systems, adding an extra layer of operational safety.

To operate as a propulsion control system, FuelOpt gathers vast volumes of vessel data in real-time from sensors onboard (e.g. fuel flow meters, alarm systems, GPS, speed-log, etc.), particularly from the propulsion line and engine. Consequently, FuelOpt leverages the power of digitalisation for fleet performance management without any additional cost to the shipowners.

Turning data into knowledge

The cloud-based performance management and reporting software Fleet Analytics sits as the centrepiece for data collection and transmission. FuelOpt-generated data and data gathered from multiple sources, including satellite, wind, and logbooks are integrated into Fleet Analytics. The system turns this big data into knowledge presented in an easy-to-understand way and feeds data not

Fleet Analytics is a performance management and reporting tool



only to its own features, but also into existing business intelligence solutions. As a data platform that communicates with other systems, Fleet Analytics removes the need for multi-data entry by allowing the use of data gathered/received from different systems.

Fleet Analytics can be used for both daily vessel follow-ups and for analysing long-term performance. It provides aggregated fleet views and status insights for onboard and ashore personnel. In this way the shipowner and operator can learn from their past voyages and improve the next ones, improving operational efficiency and reducing operating costs and emissions.

Additionally, through the automatic generation of environmental and voyage reports, Fleet Analytics helps to reduce reporting workload onboard and ashore.

When these technologies are used together, ship operators can easily exploit the

win-win scenario of gaining a unique combination of data analysis over time and direct fuel optimisation in real-time for greatest achievable ship optimisation. The use of tools such as these will help the industry to bridge the gap between traditional and fully integrated bridge systems. [NA](#)

About Lean Marine Sweden AB

Lean Marine offers innovative solutions for fuel saving and increased operational efficiency for the marine industry, with the aim of reducing the environmental impact of operating a vessel.

Headquartered in Gothenburg, Sweden, the company's vision is to become a globally recognised player synonymous with direct and effective solutions.

Lean Marine's automated and direct fuel-saving system FuelOpt and smart performance management and reporting tools Fleet Analytics have been contracted to over 50 different shipowners.

FuelOpt draws together onboard sensor data to automate fuel consumption



Evolutes of the metacentre

The possible inclinations of a floating object's transverse metacentre is as important as its centre of buoyancy and widely misunderstood. Yevhen Oberemok offers some guidance for better understanding the geometry

Calculation of stability is not particularly difficult for a specialist. However, when teaching future navigators, it has been observed that students sometimes have issues in individual assignments, when they turn to various sources on the Internet, and, in particular, when they study the topic of "transverse metacentre". In addition, there is also confusion in terminology, since in some sources the metacentre is considered as the intersection point of buoyancy force with the centre-line plane (CL). This often confuses those who begin studying ships stability.

The trajectory of metacentre depends on the breadth B and depth of hull D , hull shape, waterline parameters and heel angle Θ . It makes sense to consider this topic in the absence of trim ($\Psi=0$) using the example of one of the simplest objects considered by many authors: a parallelepiped pontoon.

Fig. 1 shows evolutes – the trajectories of the transverse metacentre M_T of the pontoon for various relative draughts ($0.25 \leq d/D \leq 0.75$), heel angles 0° - 90° and $B/D=2$. The curves $M_T=f(d/D, \Theta)$ function have very complex shapes. The metacentre moves along its evolute in different areas (depending on the draught) at different speeds.

The change of $BWL=f(\Theta)$ function (waterline width from heel angle) is of essential importance for the metacentre trajectory.

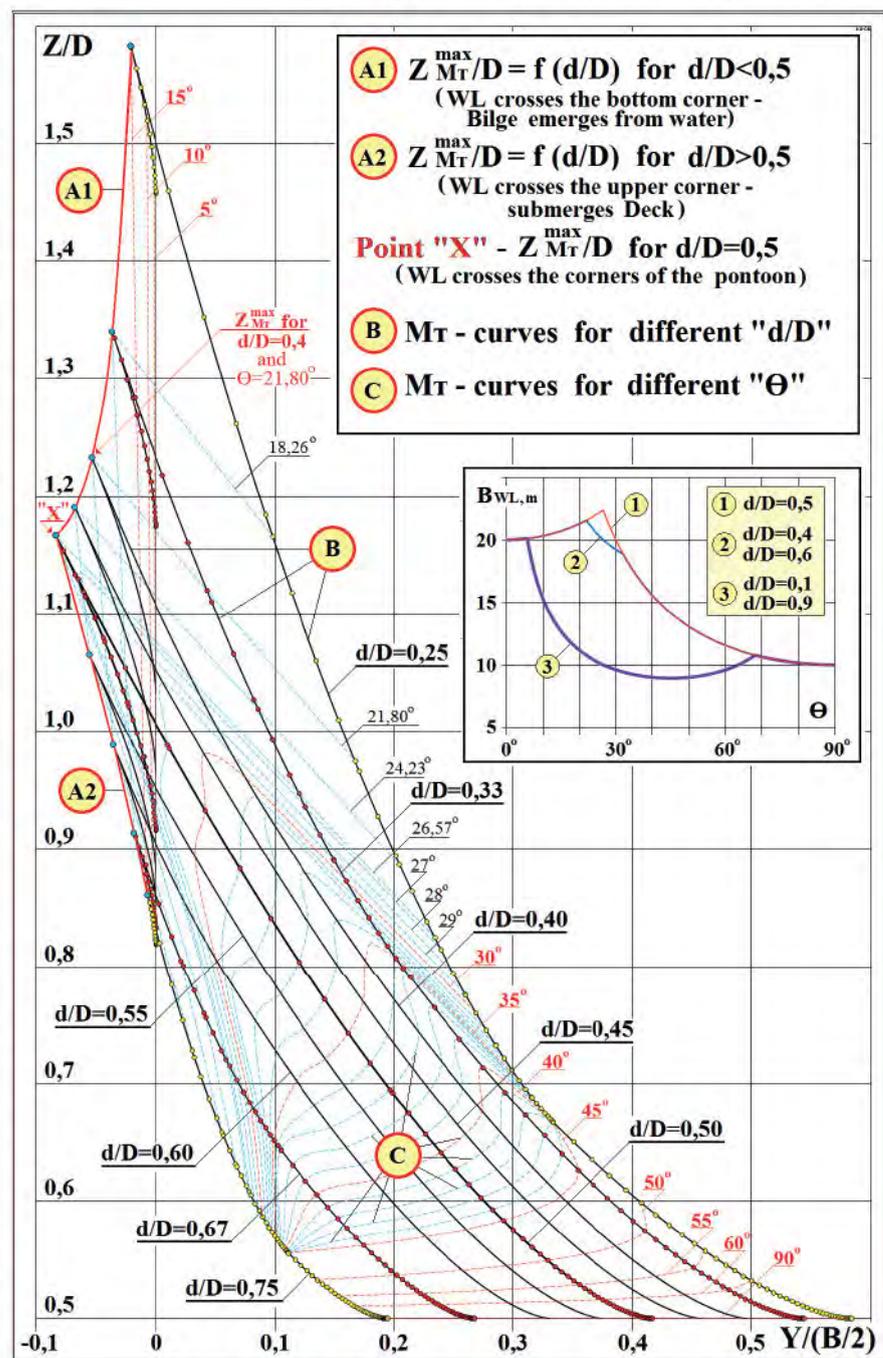
The metacentre of the pontoon with a heel of 0° to 90° for considered values of d/D can be located in the CL only at a specific angle of heel. The lever arm of form in this case reaches its maximum value.

At draught close to limiting, the trajectory of the metacentre can cross the CL twice, and in special cases – three times. And this is due to a change in the parameters of the waterline, since the function $BWL=f(\Theta)$ when the condition

$(B/D) \cdot (d/D) \geq 0.5$ is true has only one extremum, and when $(B/D) \cdot (d/D) < 0.5$ it has three extrema (fig. 1).

Fig. 2 shows the trajectories of the centre of buoyancy (involute) and the evolute of metacentre M_T for $B/D=1.5$ and

Fig. 1 Evolutions of metacenters $M_T=f(d/D)$ for $0^\circ \leq \Theta \leq 90^\circ$



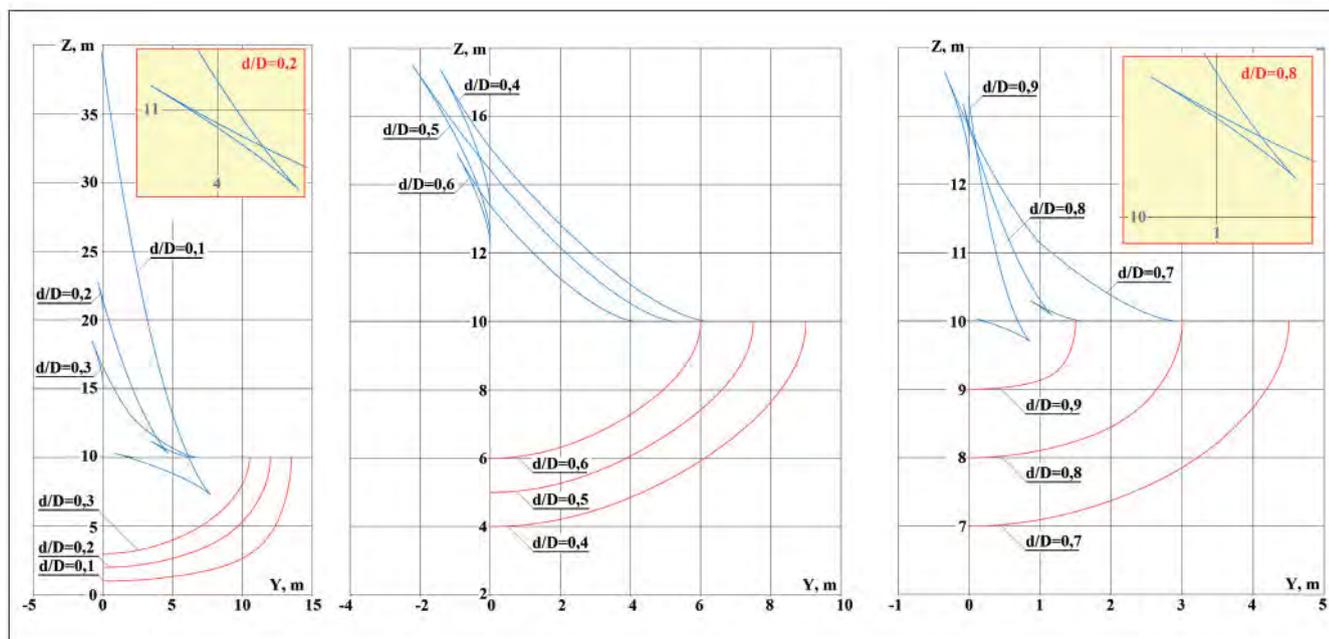


Fig.2 Evolutions (Mr) and involutes (C.B.) for B/D=1,5 and $0,1 \leq d/D \leq 0,9$

a variable parameter d/D . Evolute forms are very complex, while involutes keep their traditional harmonious properties.

In spite of having the simplest hull shape, when heeling the pontoon changes its main parameters following nonlinear dependencies. Therefore, the function

of change for the angle of deck's entry into water or bottom exposure $\Theta' = f(d/D, B/D)$ for an object with a rectangular cross-section has a nonlinear character in the entire range of values in review (Fig. 3).

At draughts close to extreme ($d/D \leq 0.25$, $d/D \geq 0.75$), in hulls with a

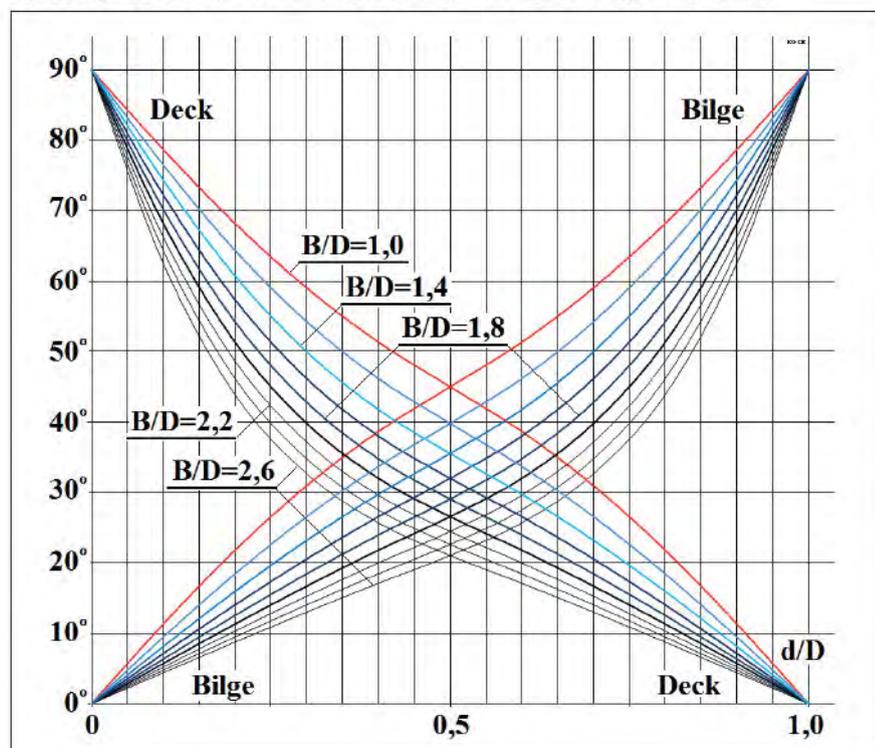
traditional B/D ratio, the shape of the evolute becomes much more complicated. This is due to the fact that the waterline, as noted above, has three extrema and, therefore, the evolutes already have three sharp bends. This is especially pronounced for the transverse section of hull, which is close to a square ($B/D \approx 1$). Fig. 4 shows the evolute of Mr (black curve) and the involute of the centre of buoyancy (C.B.; red curve) for a pontoon with $B=20$, $D=20$ at the draught $d=15$ ($d/D=0.75$); the dotted lines mark the metacentric radii at 15° , 30° , 45° , 60° and 75° (red colour), as well as at angles of 26.57° and 63.43° (blue colour when the waterline crossing the deck or the bilge).

In addition, Fig. 4 also shows the evolutes with three sharp bends for draughts, at which the metacentre intersects the CL only at one point that lies on the longitudinal axis of pontoon's symmetry. A similar situation is possible with draughts of 5.625m and 14.375m. These diagrams illustrate that objects with rectangular and circular cross sections have fundamentally different understandings and explanations of the metacentre.

Obviously, the B/D ratio also affects the shape of the evolute (Fig. 5, 6).

The evolute of the metacentre during its transformation from Cartesian coordinate system into polar coordinates is easily

Fig. 3 Angles of heel (deck submerges into water or bilge emerges from water)



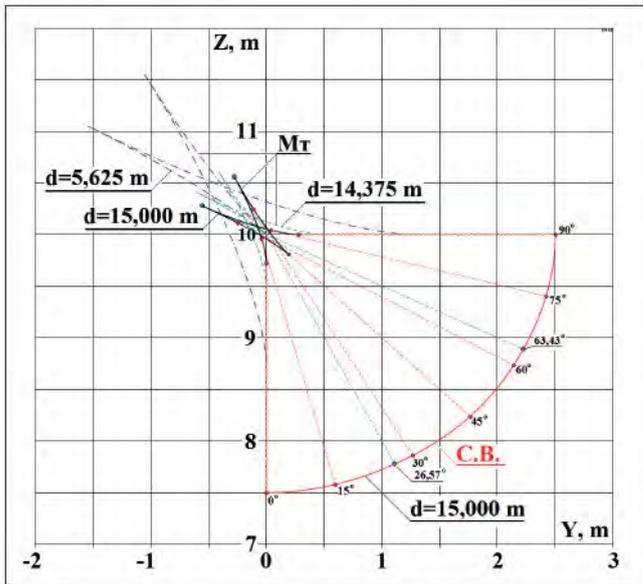


Fig. 4 Square pontoon ($B=H=20$ m, C.B. for $d = 15$ m and M_T at three draughts)

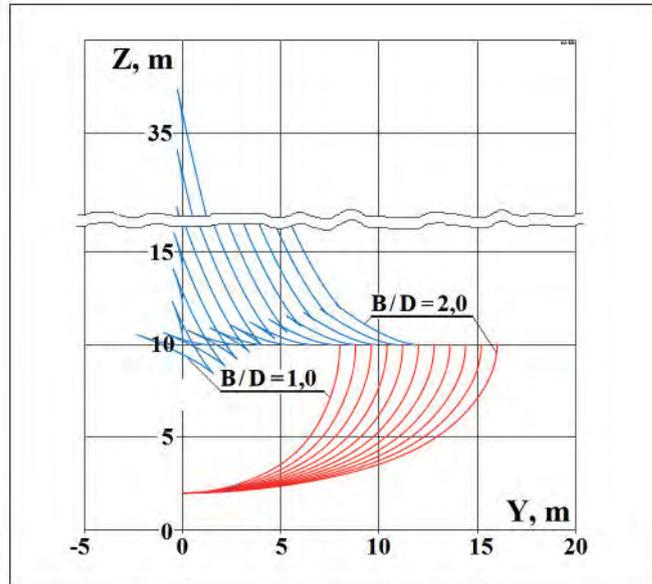


Fig. 5 C.B.- and M_T - curves for $d/D=0.2$ and $1 \leq B/D \leq 2$

transformed into cross-curves of stability at any draught.

For the range of real pontoon draughts ($0.25 \leq d/D \leq 0.75$, see Fig. 1), in which only one sharp bend is observed in the evolute, the main coordinate points are the bending point (when deck submerges into water or bilge emerges from water) and the point of intersection with the CL (maximum lever arm of form). These two points, in combination with the centre of gravity, explain the wavy shape of the diagram of static stability, because they determine its main parameters: the point of its inflection and maximum value of its lever.

Therefore, the following points can be made:

- the division of stability into initial stability and stability at large heel angles is conditional and is due to the existing methodology;
- the transverse metacenter for the stability of any floating object is as important a conditional point in the entire range of possible inclinations as is its centre of gravity or centre of buoyancy;
- consideration of the position of metacenter only at $\Theta=0$ narrows the understanding of its functions;
- with the appearance of the heel, it does not disappear anywhere and continues to be an integral and important part of any floating system, because the

metacenter performs its functions at any position of the system on the water;

- if there is data on the centre of gravity, then the use of the evolute (by analogy with the centre of buoyancy) makes it easy to draw the diagram of static stability, since the metacenter and the centre of buoyancy in the equilibrium position are on the same vertical.

These materials complement the existing methodology, allowing a more

complete view and explanation when teaching all processes that occur when tilting any system. *NA*

Yevhen Oberemok,
Naval Architect, PhD,
www.onma.ed.ua

The author would be delighted to share more detailed materials on this topic with interested readers.

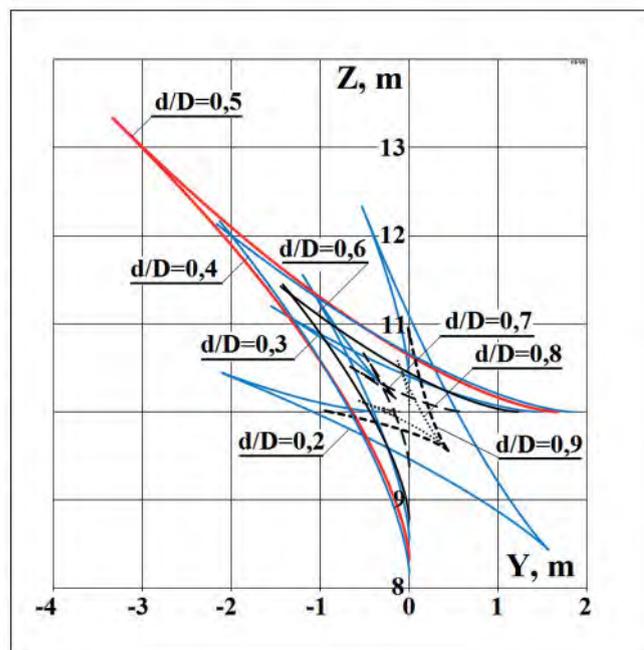


Fig. 6 Evolutions of a square pontoon ($B=H=20$) for different draughts



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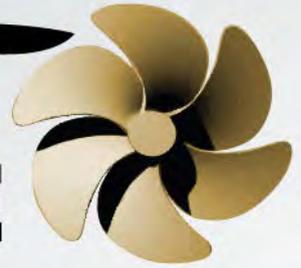
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