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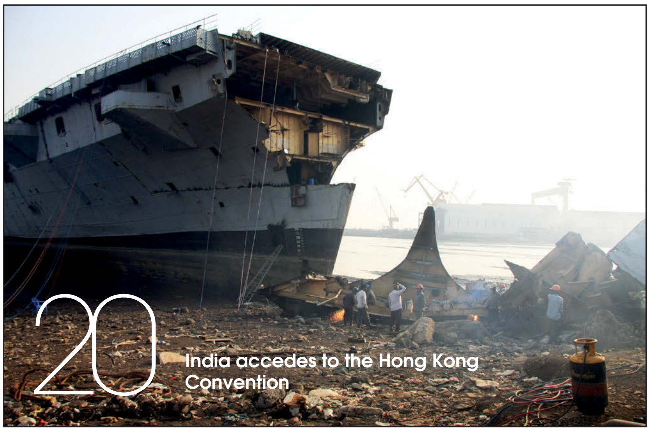

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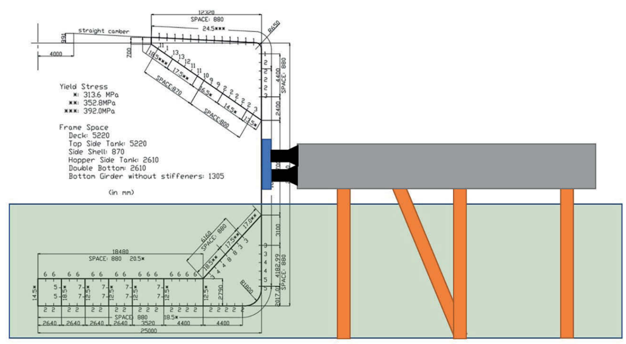

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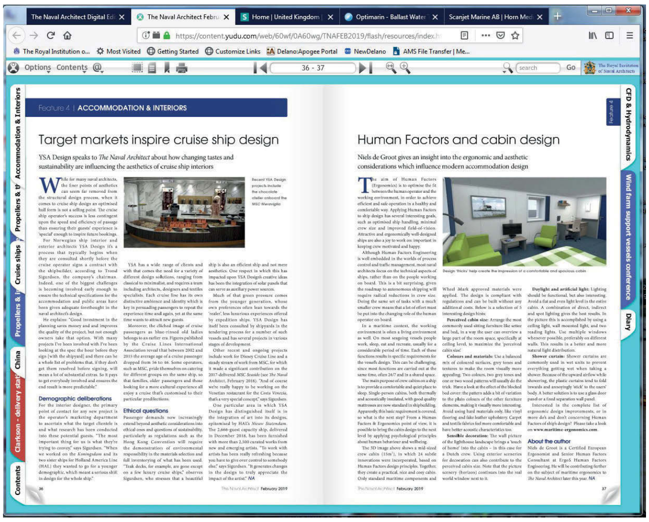

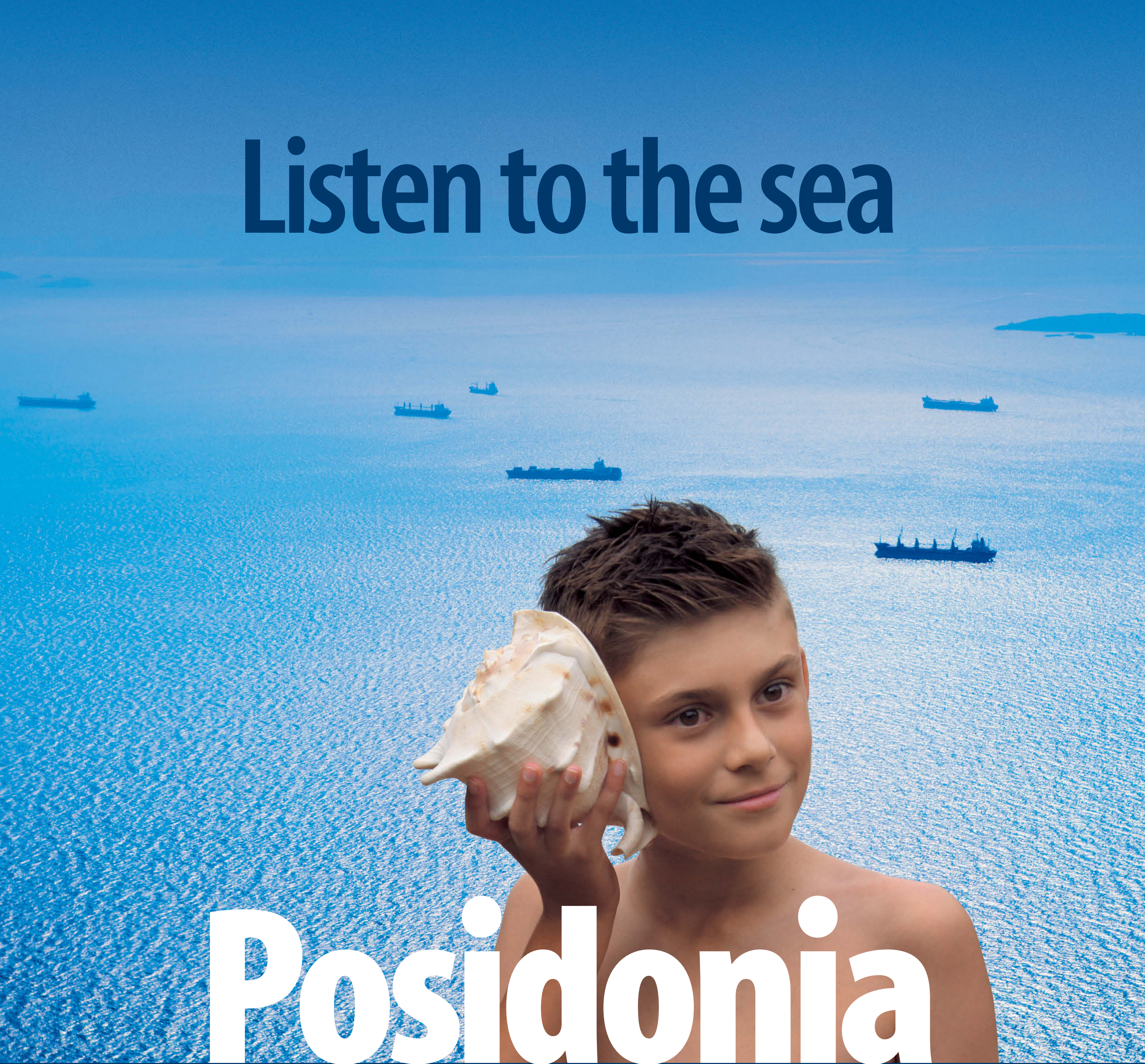
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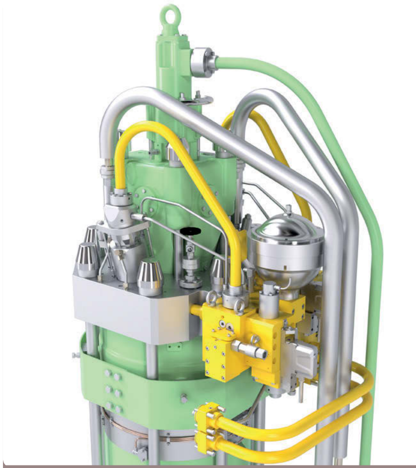


MAN's ammonia ambitions

MAN is working with Japan's Kyushu University in adapting its ME-LGIP engine for ammonia capability

Regular readers will know that *The Naval Architect* has followed with interest the ongoing research into ammonia as a green alternative fuel, with several leading classification societies highlighting it as one of the most credible options on the table. In the most recent edition of its Maritime Forecast to 2050, DNV GL went so far as to call it "the most promising carbon-neutral option for newbuildings".

So the announcement, at Shanghai's Marintec trade show in early December, of two ammonia-fuelled ship projects is an encouraging indication that industry players are starting to think seriously about zero-carbon shipping.

First came Dalian Shipbuilding Industry Co (DSIC) with its announcement of a 23,000 TEU ultra-large container ship concept, which has been awarded an AiP by Lloyd's Register (LR). The 'C-Future' solution is proclaimed by DSIC as a pioneering initiative in green shipping development and clean energy applications. LR were particularly involved in the facilitation of hazard identification (HAZID) workshops to determine potential hazards throughout the design phase.

Later in the week, the Shanghai Merchant Ship Design & Research Institute (SDARI) revealed it was working with ABS on the compliance and design considerations for a 2,700 TEU ammonia-fuelled 'Chittagong-max' container feeder ship.

Significantly, MAN Energy Solutions are attached to both projects as it seeks to promote its ammonia ambitions.The manufacturer announced last January that, in partnership with Japan's Kyushu University, it was developing its LPG-burning ME-LGIP engine to run on NH_3.

These plans were further elaborated upon in a white paper published in November, entitled '*Engineering the future two-stroke green-ammonia engine*', which anticipates an ammonia-combusting engine will be commercially available in two to four years. Such engines, it suggests, might be installed (whether newbuilding or retrofit) as a dual fuel 'ammonia ready' solution with LPG carriers, which occasionally transport ammonia as cargo, suggested as "first movers".

Given the growing demands for fuel flexibility, MAN is also looking at onboard power generation, with the MAN B&W engine two-stroke engine said to be capable of fulfilling both roles. Such a solution would require changes to the ship design to accomodate the gensets (and hence the alacrity with which it has teamed up with SDARI and DSIC) and the paper states that MAN is currently evaluating the feasibility of directly coupled generators with either fixed or variable rpms, the latter of which might require the safeguard of additional battery power.

Predictably, MAN is keen to downplay the potential of electrical engines (whether batteries or fuel cells) for long-haul shipping. "Low-speed marine engines are already the most efficient propulsion system for transoceanic shipping, making them the de facto, standard powertrain for commercial vessels," argues Bjarne Foldager, senior vice president for MAN's two-stroke business, in relation to both projects. "In this respect developing ships by ammonia makes perfect sense as it has the potential in the future to be created from renewable, primary-energy sources such as wind, hydro or solar."

Converting surplus renewable energy into a storable form, or Power-to-X (PtoX), is increasingly mooted as the solution to achieving carbon-free shipping, but it remains largely conceptual. In the June 2019 edition of *The Naval Architect* we looked at a feasibility study conducted by Environmental Defense Fund Europe that considered the potential of Morocco and estimated that if its wind and solar power potential were fully exploited it could produce around 48,000GWh/day, a figure that would comfortably fulfill all the ammonia needs for the international fleet by 2050, even in a 'high case' scenario.

However, to achieve such abundant energy production would require investment in the scale of US$100 billion. Ammonia's advocates point to the existing infrastructure for the chemical's use in industrial processes as an agricultural fertiliser, which would negate to some extent the problems that hindered the rollout of LNG, but widespread implementation of ammonia as an alternative fuel would inevitably require some upscaling of these facilities, even assuming they are favourably located.

In that regard, the SDARI feeder ship project is probably better positioned to become a reality, in that developing bunkering facilities for short-sea routes will be easier to achieve. But it will be interesting to see whether the eventual designs pique the interests of shipowners, given that these are the scale of vessel for which batteries and fuel cell solutions will probably be suited for in the coming years.

Equally, the DSIC announcement has nothing to say about the lower fuel density of ammonia, which would require larger fuel tanks and presumably other energy-saving technologies. Or is there an implication this might be mitigated by slow steaming? All in all, one gets the feeling MAN have scored an ammonia publicity coup while the more difficult questions remain unanswered. *NA*

Hydrogen carriers

KHI scores hydrogen first

Japan's Kawasaki Heavy Industries (KHI) launched *Susio Frontier*, the world's first liquified hydrogen carrier, at its Kobe shipyard on 11 December, although the vessel's completion isn't expected for a further year.

The *Susio Frontier* represents the first stage in a Shell-backed project in which hydrogen derived from brown coal in Australia will be shipped to Kobe in Japan. Vacuum-insulated storage tanks, currently being constructed by Japan's Harima Works, capable of holding 1,250m^3 of liquid hydrogen at a temperature of -253°C, will be installed onboard the vessel in the latter part of 2020.

KHI was the first Asian yard to construct an LNG carrier, *Bishu Maru*, in 1983, and the *Susio Frontier* draws heavily upon that expertise. However, to achieve the additional insulation new technologies were required, such as the glass-fibre reinforced polymers that will be used for the tank support structures.

Motohiko Nishimura, the head of KHI's hydrogen development centre said: "At present, this is the only ship in the world to apply the International Maritime Organization's interim safety standard for carrying liquid hydrogen, and when it completes its trials in 2020, we hope its approach to safety will become a de facto standard."

Japan is investing heavily in the development of hydrogen as a carbon-free alternative fuel. In September, at its annual Hydrogen Ministerial Meeting in Tokyo, it received support from more than 30 countries for a plan to set up over 10,000 'hydrogen refuelling stations' worldwide within the next decade. It also set non-binding goals to produce more than 10 million hydrogen-powered mobility systems for different modes of transportation worldwide during the same period.

However, the country's topography and population density makes it unsuitable for large-scale implementation of renewable energy projects, meaning that the importing is the most viable method of sourcing fuel.

The launch of *Susio Frontier*

Ship recycling

Indian government ratifies Hong Kong Convention

The Indian government has agreed to a proposal for the accession to the Hong Kong Convention for Safe and Environmentally Sound Recycling of Ships, 2009 (HKC) and enactment of a new ship recycling bill.

As the world's largest ship recycling nation, handling around 5million gross tonnes annually or approximately 30% of the worlds ship recycling market, the decision marks a significant step forward for the IMO convention.

India is the 14th nation to join but the first South Asian country to do so, even though 90% of vessels are scrapped in the region. The HKC is set to enter into force 24 months after ratification by at least 15 states representing 40% of the world merchant shipping by gross tonnage, and a combined maximum annual ship recycling volume not less than 3% of their combined tonnage.

The country's new Recycling of Ships Bill, 2019 outlines that ship recycling facilities must be authorised and only such yards will be permitted to import ships for recycling; that Ship-specific Ship Recycling Plans (SRPs) must be prepared for incoming vessels; and the installation and use of hazardous materials is prohibited. Additionally, it states that when the Hong Kong Convention 2009 finally comes into force, its provisions will also be implemented under the authorities of the bill.

The government, which has been considering the decision since August 2019, hopes that by conforming to international standards, its ship recycling industry will be boosted even further. It aims to nearly double the gross tonnage currently recycled to nine billion by 2024 (see also p.20-21).

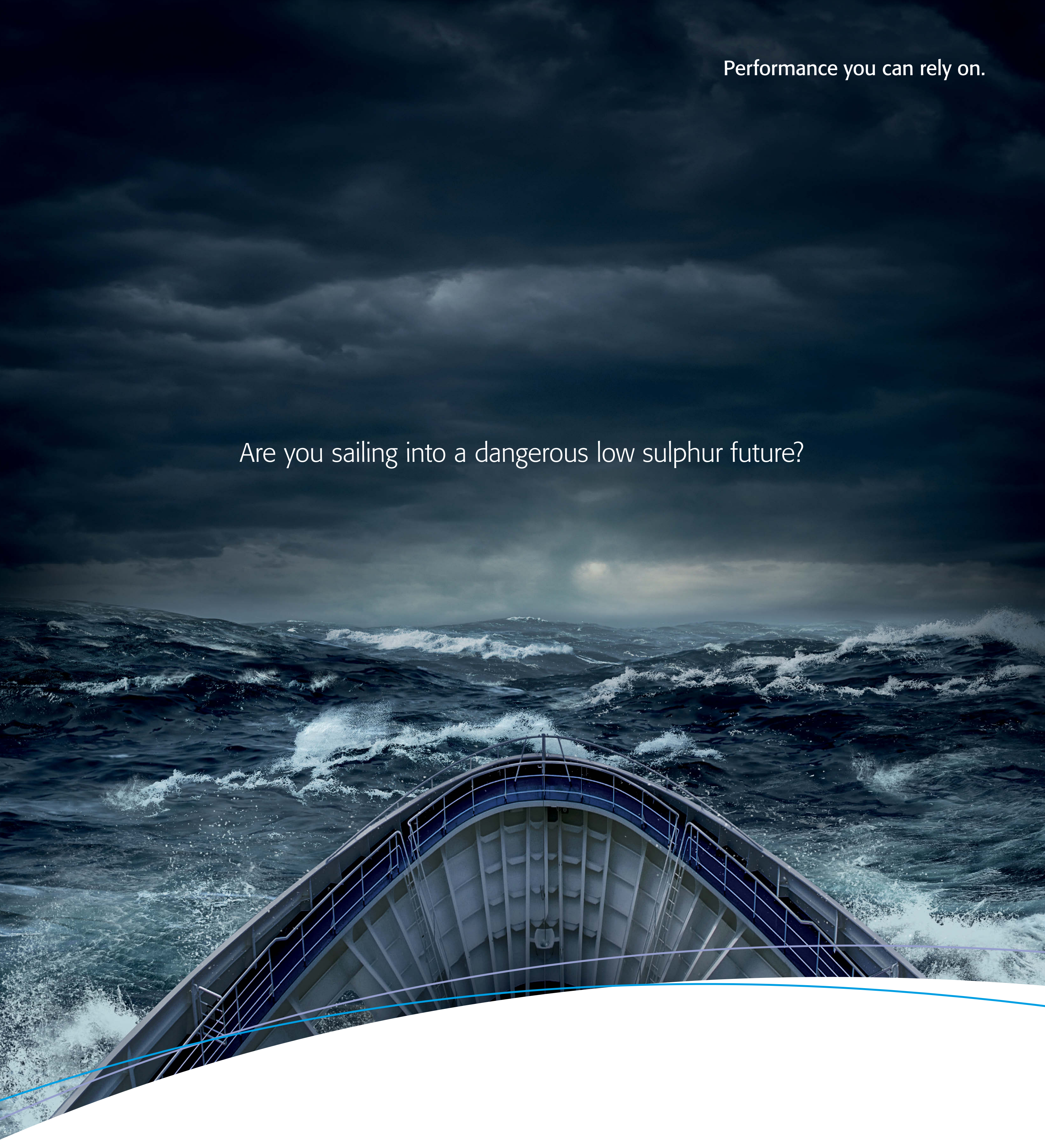
Emissions control

CSA 2020 frustrated by Malaysian scrubber decision

The Clean Shipping Alliance 2020 (CSA 2020), the pro-scrubber shipowner lobby group, says it is disappointed by the Malaysian government's decision to ban the use of open-loop exhaust gas cleaning systems in its coastal waters ahead of the 1 January global sulphur cap.

A Malaysia Shipping Notice (MSN 07/2019), issued 12 November, advises ships calling at Malaysian Ports that they must either switch to compliant fuel oil or change over to closed-loop/hybrid systems before entering Malaysian coastal waters and ports.

"The decision will impact not only our member shipping companies, but over 200 other international shipping companies that have announced their intent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to install scrubbers as an accepted means of compliance under MARPOL Annex VI," warned CSA 2020 Chairman Capt. Mike Kaczmarek.

Malaysia's ban follows that of the Panama Canal, announced in October. China, Singapore and the Port of Fujairah have previously announced bans, as have a number of European countries.

At a CSA 2020 technical conference held in Brussels in November, Dr. Elizabeth Lindstad, chief scientist at SINTEF Ocean, presented evidence that the use of scrubbers with HFO not only produces lower emissions than compliant fuel, but may also reduce greenhouse gas emissions.

However, despite a number of studies many still believe that additional research is required. In December, the Canadian branch of the World Wildlife Fund said it supported the ban of open-loop scrubbers in Canadian waters, suggesting that the 35 million tonnes of washwater effluent discharged off the British Columbia coastline in 2017 may be having a detrimental impact on the resident killer whale population.

LNG

LNG-fuelled car carriers to lower VW's carbon footprint

Siem Car Carriers has launched its latest newbuilds, claimed to be the first trans-Atlantic car freighters in the world to be powered by LNG, at Xiamen Shipyard in China.

The new pair of Pure Car Truck Carriers (PCTCs) – *Siem Confucius* and *Siem Aristotle* – will transport cars for Volkswagen, replacing two of the company's nine HFO ships currently used on route between North America and Europe.

Each 200m long, 38m wide ship is fitted with twin tanks capable of holding 1,800m^3 of LNG each. They can carry cars on 13 decks with a capacity of 7,000 revenue tonnes – a similar vehicle capacity compared to traditional diesel-fuelled ocean carriers.

The transporters are powered by MAN Energy Solutions' MAN B&W ME-GI dual-fuel marine engine with direct injection and exhaust gas treatment. Delivering 12,600kW, the ships are capable of running at 16.5knots in eco-speed mode. Additionally, the ships are equipped to run on biogas.

Up to this point, only a few smaller ships for rolling cargo have been constructed with LNG propulsion for short-haul traffic.

Siem Confucius begins service this month (January 2020) while *Siem Aristotle* will start operations in the spring.

Siem Confucius

Performance monitoring

Japanese companies to enhance CBM through collaboration

Japan Engine Corporation (J-Eng), Nippon Yusen Kabushiki Kaisha (NYK), Monohakobi Technology Institute (MTI) and ClassNK have partnered together to research and develop condition-based maintenance (CBM).

The collaboration aims to improve main engine safety and optimisation of maintenance timing for its UE low-speed engine platform. To do this, sensors will be installed onboard an in-service vessel's main engines and steam turbines. The collected data will be analysed to determine the engine's reliability and predict the machinery's remaining useful life.

By examining the vessel's performance data, the programme is seeking to enhance engine condition diagnosis accuracy, which in turn could be used to optimise management of CBM.

Unlike time-based maintenance (TBM) – typically practiced within the shipping industry – CBM does not require a vessel to pause operations for at least a week every two or three years. Instead, real-time continuous monitoring could help make earlier failure predictions and avoid unexpected delays.

Following testing and analysis, research results will be shared with ClassNK, so the classification society may schedule their vessel inspections based on CBM with greater accuracy and upgrade CBM guidelines.

J-Eng is also undertaking a digital twin study in efforts to reproduce the main engine's running condition virtually based on actual operational data. Meanwhile, NYK plans to adopt artificial intelligence technologies to advance CBM, which it views as a step towards the creation of more automated vessels. *NA*

Shipping leading on emission reduction

Malcolm Latarche reflects on some of the announcements at Marintec and the shipping related discussion at the COP 25 climate conference

Just weeks before the 2020 sulphur cap came into effect as the latest in a long list of environmental regulations, the shipping industry was been demonstrating its environmental commitment and credential at events as far apart as China and Madrid.

As maritime exhibitions go, Marintec China is seen less as presenting the latest developments to potential shipowners as being an opportunity for equipment makers to sell goods and ideas to the Chinese shipbuilding sector. However, in recent years it has also been used to promote new ship designs and concepts.

Two years ago, it was smart and autonomous ships making the news but in 2019 the environmental impact of shipping was the major talking point. Almost certainly that is because since the IMO's MEPC adopted its decarbonisation roadmap in April 2018, finding a means of reaching the ambitious targets set has become something akin to the quest for the Holy Grail. Until a truly carbon-free form of propulsion becomes available, shipping must either look to ways to reduce CO_2 emissions rather than eliminate them altogether.

At Marintec, numerous new emission-reducing ship designs were given Approval in Principal (AiP) by one classification society or another. Two of these which are truly carbon free and being fuelled by ammonia are covered elsewhere in this issue, most of the others were dual-fuel ships. As LNG does have a lower carbon content than oil fuels, it can be seen as being in line with the IMO's 2050 reduction target if not complete decarbonisation.

Lloyd's Register handed out at least nine AiPs including to China Merchants Energy Shipping, and Dalian Shipbuilding Industry (DSIC) for the development of the first efficient LNG-fuelled VLCC; DSIC got another for a 175,000m^3 LNG carrier and COSCO Zhousan for a dual-fuel Aframax. Marine Design and Research Institute of China received a trio of AiPs for dual-fuel tankers: a 113,000dwt Aframax, a 158,000dwt Suezmax and a 300,000dwt VLCC.

Three more went to SWS, Anemoi Marine Technologies. and Silverstream Technologies for an energy efficient 180,000dwt dual-fuel Capesize bulk carrier design. A second bulk carrier AiP was given to Penglai Zhoushan Jinglu Ship Industry, China Ship Scientific Research Centre and CSIC Shanghai Marine Energy Saving Technology Development for their energy efficient 88,000dwt design.

Bureau Veritas also handed out an AiP for an innovative 19,000m^3 LNG bunkering vessel called the Quadelprop, which features an azimuth thruster fitted at each corner of the hull and controlled by a redundant dynamic positioning (DP) system.

Showcasing advances to other players within the industry is one thing but persuading outsiders of shipping's progress is more difficult. Yet that is what the ICS attempted to do at the COP 25 Climate conference in Madrid.

From an environmentalist point of view, it was generally accepted that the COP talks were far from successful. However, Simon Bennett, ICS Deputy Secretary General, speaking at a side event, updated the audience on what was happening within the shipping industry saying, "There are already mandatory CO_2 reduction regulations in force globally that will require all new ships to be at least 30% more carbon-efficient by 2025, with a 50% improvement by large containerships by 2022... IMO will adopt a new package of regulations in 2020 with a focus on operational fuel efficiency and speed optimisation. This should ensure further CO_2 reductions by 2023 and that the sector is on track to exceed the IMO target of a 40% efficiency improvement across the entire world fleet by 2030".

"The industry's greatest priority is to help the IMO make rapid progress with implementing its very ambitious 2050 target, cutting the sector's total CO_2 emissions, regardless of trade growth, by at least 50%, with full decarbonisation soon after".

Following the ICS's presentation, Martin Dorsman, Secretary-General of the European Community Shipowners' Association, commented on the European front. Following the announcement of the European Green Deal two days previously he said the industry fully supports the new European Commission's ambitions to be the first climate-neutral continent but called for action on a global basis.

He added: "We urgently need new technologies and alternative fuels. The EU can support R&D by making EU funds suitable for use by the shipping industry and the broader maritime cluster. Europe must support pilot projects and the deployment of bunkering infrastructure in EU ports for new fuels."

Whether or not the comments at the ICS event get reported, it is evident that shipping is taking its role more seriously than many nation states. *NA*

Digitisation

nauticAi joins ranks as Fleet Data application provider

The Finland-based start-up nauticAi has become the latest tech company to sign on as a certificed application provider for Inmarsat's Fleet Data service.

Made commercially available last year, Fleet Data collects data from onboard sensors, pre-processes that data and uploads it to a cloud-based database, which is equipped with a dashboard and Application Programming Interface (API). It was developed by Inmarsat alongside Danelec Marine.

Founded in 2018, nauticAi specialises in intelligent maritime awareness solutions for shipping operators. The start-up will use the Fleet Data API to provide their Bridge Operations Quality Assurance (BOQA)-solution, a methodology that was inspired by the aerospace industry and originally introduced to maritime by Royal Caribbean and Carnival cruise lines.

BOQA was developed for shipping in response to a growing need for safety solutions with 24/7 monitoring of sensors and way of standardising operational quality assurance across ship fleets. It uses artificial intelligence to function as an automated event tracker that can instantly raise alerts when it detects anomalies and operational deviations, such as excessive rudder movements, sudden stops, under keel clearance and black-outs.

nauticAi has said that the move will remove the hassle of having to visit ships and build expensive interfaces for the Voyage Data Recorder (VDR) and other ship systems that feed into their BOQA.

The start-up joins NAPA and IB Influencing Business, which partnered with Inmarsat in April and October 2019 respectively, as a Fleet Data provider.

Artificial Intelligence

Stena Line trims fuel consumption with AI

Ferry operator Stena Line has successfully employed artificial intelligence (AI) to predict the most fuel-efficient way to operate a vessel, claiming a reduction in fuel consumption of up to 3% per trip.

A pilot project to test an AI-assisted vessel began in 2018, after the software was installed onboard the *Stena Scandinavia*, which operates between Gothenburg to Kiel. According to the company, the results showed that a saving of 2-3% of fuel per trip could be achieved with AI assistance.

The technology works by simulating different scenarios before suggesting the most optimal route and performance setup during a trip. Variables including currents, weather conditions, shallow water and speed through water are taken into consideration.

Fuel for a ferry line such as Stena can make up around 20% of its total operation costs, meaning a reduction in fuel consumption is highly desirable. Minimising environmental impact is also a key target that the AI may help attain.

The software, dubbed Stena Fuel Pilot, is to be installed on several other vessels with operating routes around Sweden, Germany and Denmark. There are plans for a fleet wide roll-out on all 37 vessels in Europe during 2020, aligning the company with its goal to become "the world's first cognitive ferry company; assisted by AI in all areas by 2021."

Eco-technology

Havyard secures partners for largest fuel cell system

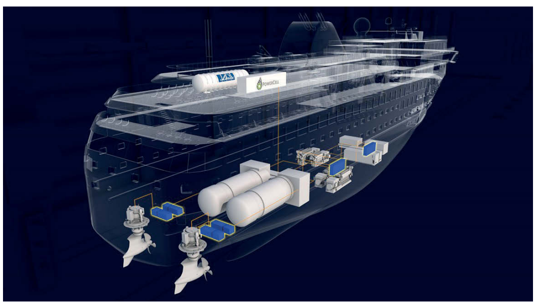
Norwegian shipbuilder Havyard Group has signed contracts with Sweden's PowerCell and German-headquartered Linde Engineering for the development of a hydrogen fuel cell system for large ships.

Havyard will work with PowerCell to design a zero-emission fuel cell system while Linde will supply cryogenic tanks able to store and transport liquid hydrogen, which will be used to fuel the cells.

The plan is to connect several 200kW modules in parallel, resulting in a total output of 3.2MW, thereby creating an emission free system utilising fuel cells that meet the IMO's safety requirements.

As part of the project, the system is to be installed and tested by the shipping company Havila Kystruten on route between Bergen and Kirkenes in northern Norway. "These vessels have the space available for storage of hydrogen and can easily be refuelled during one of their many stops," said Per Wassén, CEO of PowerCell.

In order to meet Norway's strict shipping regulations, Havila Kystruten will build four new ships equipped with zero-emission solutions, with the first expected for delivery in 2021. The system will also be designed so that it may be retrofitted on existing ships.



Havyard, PowerCell and Linde are working together to create the most powerful maritime fuel cell system

The agreement is part of the Pilot-E project – a funding scheme for the Norwegian business sector – which Hyvard won a Nkr104 million (US$11.4 million) grant through in 2018.

Aerodynamics

AiP secured for ULCC wind screen design

Class society DNV GL has granted an Approval in Principle to Mitsui O.S.K Lines, Ltd. (MOL) for its bow-mounted emissions-reducing windshield design for ultra-large containerships.

Developed by the Japanese shipping company and Samsung Heavy Industries, the wind screen streamlines a vessel by lowering wind resistance on its hull.

According to MOL, the technology is capable of reducing emissions by an average of 2% thanks to its optimal design for ultra-large containerships. The horseshoe-shaped form encloses the front line of stacked containers to maximise the wind resistance-reducing effect while minimising the weight of the main unit.

In 2015, the windshield was installed and tested on the mid-sized containership *MOL Marvel* as it operated between Asia and North America. The data collected was compared with that gathered from a sister ship not fitted with the windshield, and in 2017, the tests confirmed a reduction of 2% with the ship travelling at 17knots.

The shield was developed with the intention of addressing the need for greater wind resistance on ever-larger containerships, which carry container loads of increasingly tall heights on their desks.

MOL's windshield may lessen wind resistance for ultra-large containerships

Safety

Ecochlor brings gas-freeing tech to market

Texas-based NanoVapor has paired up with ballast water treatment system manufacturer Ecochlor to introduce its gas-freeing technology to the maritime industry.

Launched at Marintec China in December, NanoVapor technology seeks to improve the health and safety of seafarers working in confined spaces by suppressing toxic vapour emissions, or volatile organic compounds (VOCs). A single application can suppress VOCs for days, according to the company. It also reduces time and environmental pollution related to degassing bunker and cargo tanks.

The NanoVapor units are made up of two components: a nano-suppressant liquid, TankSafe, and a portable delivery unit, Model ST-1000. They use a compressed air source to a create a high-flow air stream in order to inject the suppressant molecules into the tank. The molecular suppressant is claimed to work up to 90% faster than current enclosed space procedures to quickly suppress VOC evaporation.

As TankSafe is created from renewable materials and is biodegradable, it leaves no residue or hazardous waste product behind. Additionally, Echochlor reports that NanoVapor technology is more cost effective than traditional methods of cleaning such tanks. It is expected that the technology will help owners comply with IMO 2020 regulations and the increased need for bunker tank cleaning, due to the change of fuel grades.

At the time of writing, NanoVapor was finalising tests with Lloyd's Register, which was expected to grant type approval imminently.

Artificial Intelligence

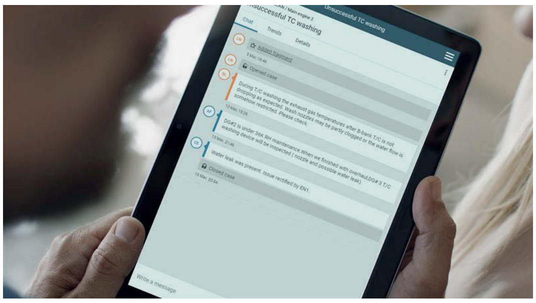
Wärtsilä introduces AI-base predictive maintenance

Finnish tech giant Wärtsilä has debuted its predictive maintenance tool, Expert Insight.

The digital product is to provide predictive maintenance service that detects and advises solutions to anomalous behaviour using Artificial Intelligence (AI) and machine learning techniques. According to the company, support can be delivered proactively through the tool to customers and offer long-term accurate insight for maintenance strategies.

Expert Insight takes predictive maintenance to a new level, Wärtsilä claims, by identifying issues ahead of any serious damage occurring and enhancing machine availability. Through AI and advanced diagnostics, equipment can be monitored in real-time.

Wärtsilä Expert Insight utilises AI and advanced diagnostics to relay data to the customer



"[The product] greatly improves the reliability of equipment and systems, and it gives us added ability to respond far more proactively throughout the lifecycle of the customer's asset," said Frank Velthuis, director digital product development at Wärtsilä. In addition, it is expected to foster closer collaboration between Wärtsilä and its customer's technical personnel.

Stabilisers

Gyro Marine completes world's largest gyroscopic stabiliser

Italian manufacturer Gyro Marine Srl has announced it has completed what it says is the largest, most powerful gyroscopic stabiliser to be built since the 1930's, weighing in at 22tonnes and with a stabilising capacity to 1,100kNm.

With no contact to the water and an ability to place anywhere on the ship with equal effect, large-scale gyroscopes are gaining considerable interest. Gyro Marine, which designs and manufactures gyroscopic stabilisers for mega yachts, military and offshore sectors, offers a range of machines to 50tonnes, with stabilising capacities to circa 2,000kNm, and multiple machines for larger applications. Despite the massive scale of the machines, the company says its solution represents only a few percent of vessel displacement.

Gyro Marine's gyroscopic stabilisers utilise its patented Active Drive technology, said to be unique among stabilisation technologies. Because large ships are typified by longer roll periods an undriven gyroscope has limited effectiveness, meaning the best solution is to actively induce the gyroscope to move and behave more like an actuator, rather than damper. The Active Drive ensures that maximum work is continuously extracted from each machine and opens possibilities for inducing roll for application such as ice clearing.

The company states that rolls reductions in excess of 90% have been realised and residual roll amplitude of only a fraction of a degree. The capability to offer a high level of stabilisation in all weather conditions, and all types of navigation, means the technology has an obvious attraction to vessels operating in Arctic routes or engaged in scientific pursuits. *NA*

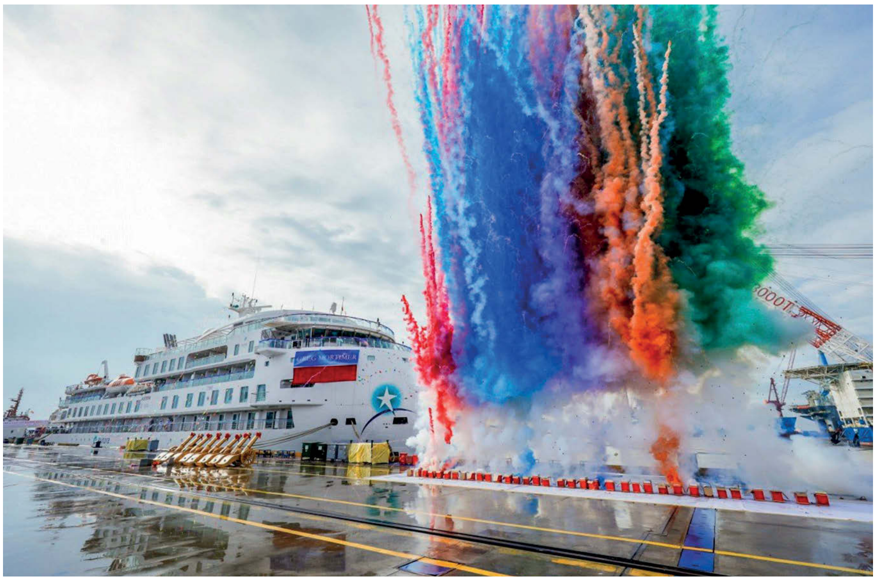
Gyro Marine's 22-tonne gyroscope under construction

China breaks into luxury cruise market

China Merchants Group delivers *Greg Mortimer,* the first made in China polar cruise ship, and prepares to expand its operations with a new building site

Last September, China Merchants Heavy Industry – a subsidiary of China Merchants Industrial Group Co., Ltd – delivered its first polar expedition cruise ship, *Greg Mortimer*, to US-based SunStone Ship. The handover marked a breakthrough for China in the cruise industry, a goal which the country has long sought since rising in the ranks as a shipbuilding mega-power.

Designed by Ulstein, in partnership with SunStone and Aurora Expeditions, whom the ship will be contracted to, the *Greg Mortimer* is outfitted with 135 cabins, more than 80 luxury rooms and a capacity for around 250 passengers. The vessel can travel at a maximum speed of 16.3knots and measures a total length of 104.4m, a width of 18.4m, a designed draft of 5.1m, and a total tonnage of 8,035tonnes.



Greg Mortimer was delivered in September 2019

Safety first

In contrast to the design of many common ship noses, this cruise ship is designed with Ulstein's innovative X-BOW. The inverted bow concept maintains a more even displacement versus traditional bows, ensuring a faster, smoother and more comfortable sail during navigation in relatively harsh sea conditions. X-BOW's unique shape and deck shielding also minimises wave splashes, preventing decks from freezing and increasing the safety of passengers onboard.

Greg Mortimer is the first ship in China Merchants' polar expedition cruise series and the first new polar cruise ship built by China with safe return-to-port. The technology guarantees that if the ship cab encounters a loss due to fire or water, the crew can control the return-to-port console and rely on the cruise ship's own backup power supply to safely return to the nearest port. As such, the ship is equipped with four generator sets within two independent cabins to provide full-ship power, meeting the safe return requirements of passenger ships outlined by SOLAS. Even in bad sea conditions, the return-to-port equipment can reach 1,500nm. Overall, the technology has greatly improved the survival rate of the cruise ship and safety of all passengers onboard.

Construction challenges

During the ship's one-and-a-half-year construction period, which began in March 2018, the shipyard's technical team had to find solutions for more than 100 technical problems. Technical challenges included: a safe return to Hong Kong, thin-plate welding deformation, vibration and noise control, and complex collaborative operations. Despite this, *Greg Mortimer* was successfully launched, tested and delivered two months earlier than the stated contract period.

Compared to the construction of a 400,000tonne super large ore ship (VLOC), it is not easy to carry out cable design and system installation on this polar expedition cruise ship with a volume of only 8,000tonnes. The ship is installed with more than 30km of pipelines and 340km of cables.

The safe return-to-port system also proved to be complicated, given that this design has only been applied to large and medium-sized cruise ships in the past. Additionally, as there are almost no technical personnel with relevant experience in China, most of the ship's design team had never worked with the technology before. In response to this challenge, China Merchants Group created a team of experts to help overcome the technical difficulties associated with the safe return equipment and at the same time speed up the training of its own technical personnel.

Thin plate cutting and heat deformation problems caused by welding have always been a major problem during the construction of cruise ships. Through joint research and development at Haimen base and steel manufacturing enterprises, the steel plates of *Greg Mortimer*'s hull structure are only 5mm thick. However, whether the heat deformation of such a thin steel plate exceeds the standard will have a decisive influence on the subsequent construction of the dressing, which will have an important impact on the weight measurement results of the cruise ship. If the calculation result does not meet the relevant requirements of the technical specification, the shipowner may face steep fines.

Hu Xianyu, general manager of China Merchants Industry, said that the China Merchants Haimen base has created a segmented production line that meets the requirements for cutting and assembly of cruise ships. Furthermore, the welding experts and technical workers inside the organisation formed a special thin-plate team to research and upgrade the existing process procedures and tooling equipment, and successfully solved the problem of thin plate deformation control during the construction stage. "Through cooperation with domestic manufacturers, the error will be controlled within 0.2mm and the matching rate of the whole ship will be nearly 40%," said Wang Cuijun, deputy general manager of China Merchants Group.

Market breakthrough

As early as 2016, China Merchants Industry focused on market demand and actively sought to enter the cruise manufacturing market. After several rounds of negotiations, on 27 April 2017, the company officially signed a contract for four polar expedition cruise ships, plus options for an additional six, with the Miami-based SunStone Ships. At present, the two sides have signed agreements for seven Infinity-class newbuilds, with work on the second vessel already underway and the steel cut for the third ship.

"In terms of the construction of luxury cruise ships, China Merchants has steadily and progressively promoted the localisation of cruise ships in accordance with the principle of 'from small to large, from easy to difficult'," said Wang Cuijun. "Although the polar expedition cruise ship delivered this time is not large, it is high-end. China Merchants will use this as an opportunity to build a fully automated luxury cruise manufacturing plant at Haimenbase, supporting industrial park, and introduce well-known luxury cruise ship manufacturers at home and abroad."

In 2018, China Merchants Group began planning a world-class cruise ship manufacturing base and supporting industrial park covering an area of 650,000m^2. The group will introduce automated and intelligent European advanced thin-plate production lines, leading upstream and downstream cruise-related businesses from home and abroad, and combine the operational experience of China Merchants Shekou to create a world-class luxury cruise ship package.

The envisioned manufacturing base is estimated to cost a total of 5 billion yuan (US$703 million). It is expected to officially start operation in 2022 and will be able to construct two 135,000tonne cruise ships at the same time. The shipyard will be divided into four public service platforms: a national-level materials and technology test center, a research and development service platform, a supporting industrial bonded warehouse, and an industrial display center.

According to Wang Cuijun, China Merchants will also build its own cruise fleet. Currently, two cruise ships are under design and are expected to be completed by 2023. "The successful construction of the first polar expedition cruise ship has filled our country's gap in this field and strengthened China's determination to build luxury cruise ships," he added. *NA*

A watershed moment for ship recycling?

The Indian Register of Shipping (IRClass) gives its response to India's historic accession to IMO's Hong Kong International Convention for Ship Recycling, announced in November

Around a quarter of the world's ships are recycled at Indian facilities, such as this shipbreaking yard in Darukhan

The International Maritime Organization (IMO) adopted the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships (HKC) in 2009, which is aimed at ensuring that ships being recycled after reaching the end of their operational lives do not pose any unnecessary risks to human health, safety and to the environment.

In November 2019, the Cabinet Committee on Economic Affairs (CCEA) approved India's accession to the HKC, which will help provide a boost to the ship recycling industry in India.

The accession to the Convention will bring in global best practices. The aim is not that India becomes a backyard of all rejected ships but, on the contrary, plans to scientifically deal with ship recycling. The accession will bring in environment protection and will provide safety to workers, which are of greater importance.

As per data available for 2018, India handles around five million gross tonnage (MnGT) annually, which is around 25% share of the world's ship recycling industry. The government plans to nearly double this by 2024, at around nine MnGT. The industry being largely concentrated in South Asia, India remains the leading market for ship recycling globally, with the Alang-Sosiya ship breaking yard in Gujarat handling around 450 ships every year.

Investment opportunity

The accession to the convention will allow global funds to come and invest in ship-recycling centers in India and a lot of international agencies are also looking at India's high-class recycling centres. It is considered that this accession, will help India get better assistance from these international agencies which are seeking to fund ship recycling centres.

IRClass has been instrumental in ensuring compliance of the ship recycling facilities with the Hong Kong Convention (HKC). Our services include:

- Certification as per Ship Recycling Management System (SRMS) and HKC
- Imparting training
- Evaluation on behalf of Gujarat Maritime Board.

Under its integrated certification scheme, IRCLASS has certified 32 ship recycling yards in India for "QMS, EMS, OHSAS & SRMS". Of these yards, 11 have also been certified for HKC.

Training is an important area where IRClass is playing a lead role in bridging the gap between the practices of recycling yards and the HKC. IRClass has been authorised by Gujarat Maritime Board for evaluation of training of workers. Based on our individual contracts with the yard, IRClass imparts High Risk Safety Training for their inhouse employees. IRClass also conducts public trainings to increase awareness.

Facility improvements

Subsequent to the involvement of IRClass, there has been a tremendous improvement in facility operations specially in primary cutting area and handling of oily block in intertidal zone. There is increased awareness with respect to the Ship Recycling Facility Plan (SRFP), safety procedures, segregation, handling and storage of materials, emergency preparedness. Emphasis is on environmental compliance through soil testing, sea water testing, noise testing, periodic health monitoring of the workers. Due to the practical based training evaluation pattern, there is a definite drop in the accident/incident rates.

IRClass is heavily engaged in training to help yards bridge the gap between current practices and HKC requirements

Though the HKC has not yet entered into force, the European Union Ship Recycling Regulation (EU-SRR) which is mostly aligned with the IMO instrument, will come into force from 31 December 2020 for non-EU flagged ships. Accordingly once the regulation (EU-SRR) comes into force, all non-EU flagged ships, including Liberian ships calling at an EU port or anchorage will be required to comply with EU-SRR.

For non-EU ships, compliance to EU-SRR can be achieved by having Statement of Compliance (SOC) in accordance with HKC which should also be supplemented by holding a verified Inventory of Hazardous Materials (IHM) onboard.

IRClass is providing these services to interested shipowners. Currently various flag Administrations including Bahamas, Marshall Islands, Malta and Netherland have already authorised IRS to undertake above survey and certification service on their behalf. *NA*

RINA conference evaluates the potential of wind assisted technology

The International Conference on Wind Propulsion, co-hosted by the International Windship Association, highlighted the benefits to the industry, but more studies are needed. Rupert Berryman reports

Rotor sails were one of the many types of wind propulsion systems discussed at the conference

The first International Wind Propulsion Conference took place in the RINA headquarters over two days, on 15 and 16 October 2019. The conference attracted speakers and delegates from Germany, Sweden, the Netherlands, Finland, France, Japan, Spain, the USA and the UK.

The conference was prompted by the need to reduce ship fuel consumption and counter global warming, which has become a critical world issue. Most of the papers presented covered the topic of wind assisted propulsion for conventionally powered ships rather than for fully wind propelled ships.

Diane Gilpin, the CEO of Smart Green Shipping and the event's keynote speaker, pointed out that our world economy is dependent on the environment rather than vice versa. Our economy is therefore negatively affected by climate change, which is largely caused by global warming gases, making their reduction is essential. This includes reducing emissions from ships that add to global warming. There are more than 50,000 ships at sea at any one time producing 3-5% of all greenhouse gas (GHG) emissions. IMO resolutions aim to reduce ship GHG emissions by 50% by 2050.

Theoretical modelling

The first day conference papers were largely devoted to the theoretical analysis and modelling of wind assisted ship propulsion devices using computational fluid dynamics (CFD), test tanks, wind tunnels and mathematical techniques. CFD modelling is already used to optimise the design of conventional ships, however, the introduction of wind assisted propulsion has increased the complexity. CFD is expensive and does not lend itself to simulating all conditions at reasonable cost. Hardware evaluated included rotor (Flettner) sails and wing sails, but modelling did not indicate which device was best. It appears that each ship needed to be modelled individually, taking into account ship parameters, navigation routes and the weather on routes to be sailed. Speakers stated that more modelling work needs to be done on wind assisted propulsion to produce more valid results. It was anticipated that this would take about a year.

It was found that the side thrust caused by the sail devices required rudder angle to maintain the ships on course and rudder effect was reduced due to the decreased propeller speed made possible by the forward thrust from the sail device to achieve the same vessel speed. The large rudder angles attracted more drag. For wind assistance devices to be effective, ship speed needs to be slow. Yet there was no definitive answer on ship speed requirements, although it was suggested to be a maximum of 12knots. Again, there was no definitive answer on fuel savings, but this seemed to be 10-15%.

Little work appears to have been done on the amount of energy required to manufacture and install wind assistance devices (over and above the energy required to produce the ship) or how soon this would be paid back in energy savings from the ship voyages. A ballpark figure of three to four years energy payback time was given (for a wind farm this is six to twelve months). The financial cost of the wind assistance installation payback time is dependent on the price of fuel, which can vary greatly during the life of a ship.

In order not to interfere with cargo loading and unloading activities, various methods of moving the wind devices out of the way of crane loading/unloading activities have been devised.

In order to maximise the wind benefits, analysis has been modelled using weather forecasting data in order that wind assisted ships can take the most wind beneficial route between ports instead of the most direct route taken by non-wind assisted ships. These are often longer than the shortest routes and longer passage times are required. This would increase the ship running cost per passage and also require more ships for the same throughput of cargo (and additional energy to build more ships).

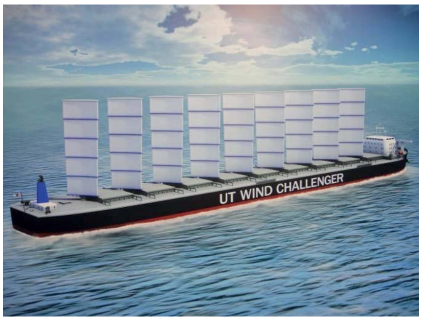
Conceptual and practical solutions

During the second day, more practical papers were discussed, including a conceptual design for a zero emissions ship. This was a sailing ship fitted with Wind Challenger telescopic sails and an external turbine/propeller. Whist under sail the turbine drives a generator, which produces enough power to create hydrogen from seawater. The stored hydrogen is then used to generate electricity in low wind conditions via fuel cells to drive the propeller. The paper presented no supporting facts or figures, although the Wind Challenger Sail has been tested on a bulk carrier producing fuel savings of 4-7%. The cost of running a zero emissions ship would be independent of fuel price.

The Matisse Ship Model demonstrated a method of identifying pathways to provide very low emission shipping. This was a highly theoretical model.

Practical tests fitting wind assistance devices to ships were presented in separate papers and proven fuel reduction results were given:

1. A single rotor sail on the ferry *Viking Grace* provided fuel (LNG) savings of approximately 90t/year (no % figure).
2. Single rotor sail fitted to the general cargo ship *Fehn Pollux* provided a fuel saving of 10-20%. This is a slow ship thereby allowing maximum benefit from wind assistance. Rotor sails cannot be lowered or folded for loading and unloading, therefore the number of sails fitted and their positioning is restricted. In this instance the actual benefit of the rotor sail proved more beneficial than the theoretical predicted benefit.
3. A single rigid wing sail fitted to 84,000 dwt bulk carrier provided a fuel saving of 4-7%. Fitting of additional rigid sails would produce greater benefits. These fold down telescopically to facilitate loading and unloading.
4. Two Ventifoils fitted to a short sea cargo ship provided a fuel saving of 10%. Ventifoils fold down onto the cargo deck for loading or can be removed. One solution demonstrated showed two Ventrifoils placed oppositely in a standard 40foot container. Raising and lowering is done by container fitted equipment. The container can be fitted to ships or left ashore as required.
5. The *Energy Observer* (an experimental zero emissions catamaran) was modelled with both one Oceanwing wingsail fitted centrally and two Oceanwing windsails, one on each hull. The two wingsail configuration when fitted to the Energy Observer confirmed the modelling result.
6. Windship Technology claimed an average 30% saving in fuel (and therefore emissions) when their three sail units were fitted to ships.



The Wind Challenger Project has tested the savings for a bulker

At present there appears to be little appetite for more environmentally friendly ships due to their cost. The answer may be in making greener ships more attractive to ship operators through incentives such as providing loans for building green ships at a lower cost, better freight rates, lower ports dues, etc. However, there are no trends towards these. A future spur towards greener ships might be the introduction of a carbon tax on ship emissions. The IMO may also continue to encourage reduction in ship emissions; however, it was stated that any IMO action might take some time.

The classification society DNV GL presented the benchmarking standards they have developed for sailing ships used for commercial purposes. Experience gained from this has been used to produce a certification standard for Wind Assisted Propulsion Systems fitted to standard ships.

Conclusion

Wind assisted propulsion is still at an early stage. Presenters demonstrated that fuel savings of up to 30% might be achieved using wind assisted ship propulsion on slow ships under certain conditions. Evaluations of the different types of wind assist devices have not indicated any clear preferred choice.

The consensus at the conference was that a lot more work needs to be done both in the realms of modelling and testing prototype wind assisted systems in the real world.

Currently there appears to be no financial incentive for ship operators to install wind assisted propulsion systems on their ships apart from the unpredictable cost of fuel, which could rise sharply. There are also no penalties for GHG emissions either such as a carbon tax. But financial incentives or GHG emission penalties are likely to encourage the introduction of wind assisted systems.

Work on wind assisted propulsion systems to reduce fuel consumption and ship emissions has gathered momentum. It was suggested that the next conference be held in 18 months to two years' time when a greater number of wind propulsion evaluation activities have been completed. *NA*

The conference attracted the great and the good of wind propulsion research

Financing greening: the quest for capital and returns

To realise IMO's climate goals demands a business model that spreads the risks and benefits, argues Prof. Orestis Schinas of the Hamburg School of Business Administration and green shipping financiers HHX.blue

Afros became the first bulk carrier to be equipped with Flettner rotors

The goal of decarbonising marine operations and generally maritime transport is clear, but the regulatory requirements toward decarbonisation, i.e. the rate or steps of mandatory improvement, are not clear enough. The International Maritime Organization (IMO) set the reduction of the carbon footprint of the industry in 2050 to at least 50% of the emissions from the 2008 baseline. Is this goal reasonable, sufficient and feasible?

Lately, increased pressure by the public and the media for a decarbonised economy drives policy makers to adopt stricter regulations focused on air emissions. Most of these regulations concentrate on both non-Greenhouse Gases (nGHG), such as sulphur and nitrogen oxides, as well as on GHG, such as carbon oxides and methane. Initiatives against particulate matter should be expected too. Due to the mortality rates, as well as the damage to the global ecosystems associated with these pollutants, such regulatory action is reasonable.

It is not clear though if it is sufficient, as different models and scientific approaches result in different projections about the future. Science is not questioning the disease but the dose of the medicine, considering the wellbeing of people as well as the current organisation of the international economy and of societies.

In this regard shipping, that contributes only 2.8% of the total GHG is justifiably targeted, yet the steps towards zero-emission operations are not clear or widely acceptable yet. This ambiguity reflects not only the conflicting interests of the Member States within IMO but also the lack of globally accepted common goals and priorities. Hence, shipping should be prepared for surprises from both IMO and other regulatory bodies.

Given the currently available technology, a substantial reduction of the carbon footprint, i.e. of the energy

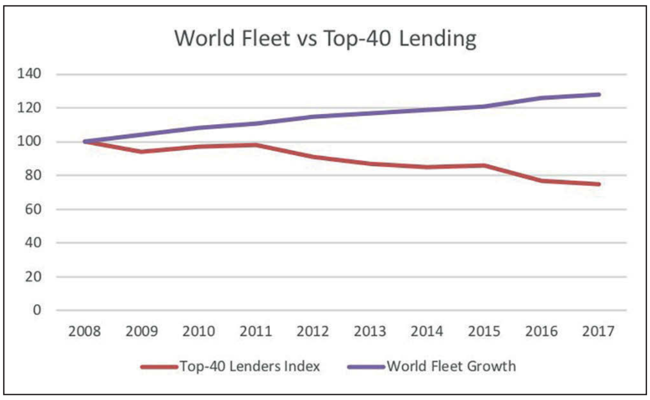


Figure 1: World fleet and Top-Lenders over time (indexed)

The coastal vessel *Fehn Pollux* was retrofitted with the Eco Flettner wind propulsion concept in a much-publicised project

used per unit of transport, is feasible. There are innovative technologies, such as wind assistance, that achieve a proven reduction of c. 10% on average, but hold potential for more substantial savings as those technologies are optimised as well as other existing technologies, such as novel and compact waste-heat-recovery units that improve the thermal efficiency of the propulsion plant significantly.

Hence, it is possible to set a goal of reducing the carbon footprint by 15-20% by simply installing proven, existing technologies, considering that aggregate savings are not linear due to the very non-linear nature of fluid mechanics, so a thorough technical analysis is required before any decision.

Any investment in technology requires an availability of capital. Nowadays the freight markets are not supporting high operational profit margins, and there is no clear sign from the market that 'greener' ships enjoy higher freight rates. It should also be noted that traditional lenders, such as major banks, are retreating from shipping for many reasons, irrelevant at large to the shipping risks (Figure 1); the fleet is growing by almost 3% p.a., while the lenders retreat by 3% or circa 15% in terms of new deals. Therefore, any decision on installing technology will drain the available equity of the owners and the cost of making a 'wrong' decision is extremely high.

In order to encourage operators to install, technology suppliers to provide, and financiers to support the installation of equipment for greening ships, a business model that spreads the risks and benefits among all actors involved is necessary. Schinas and Metzger (2019a, b) have developed a shared savings model, a 'pay-as-you-save' (PAYS) approach, where the risks are shared on a basis of ratio or a formula between the owner and the supplier of the technology or a financier, who provides the funding. The PAYS model has already been considered for the assessment of wind-assisted power boosting technologies, such as Flettner rotors and specialised foils; the numerical examples below are based on these projects and cannot be generalised, yet they offer useful insights.

In most cases, equipment providers require a full payment upon installation; as this is not always possible, a financial house or a relevant financial entity intermediates and assumes the risks and benefits on behalf of the supplier. The financial planning that supports the decision-making process is affected by:

1. The sharing ratio, i.e. the split of benefits, such as monetised fuel savings and carbon emissions
2. Fuel prices
3. Carbon prices (when CO_2 emissions get monetised)
4. Utilisation of the installed power-boosting equipment (and/or its availability in general)
5. Financial parameters of the power-boosting system, such as:
   a) the cost of the equipment including the cost of installation;
   b) the necessary first sum for the acquisition and installation (first payment);
   c) the economic and/or technical life of the equipment depending on the case;
   d) the expected maintenance outlay;
   e) the WACC of the project, that depends on the financial standing of the company and/or the financial scheme agreed with the supplier or the financiers.

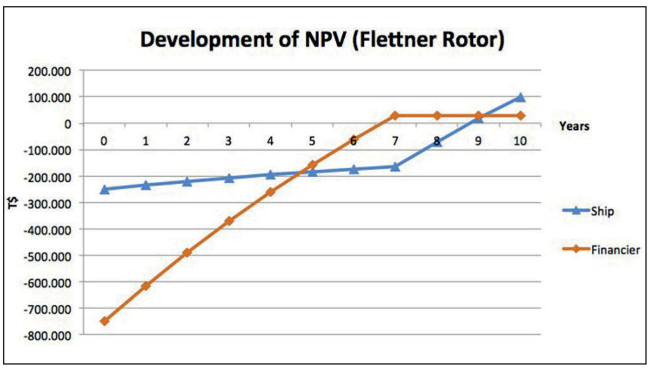


Figure 2: NPV over time

The benefit of splitting risks and benefits is illustrated in Figure 2; for a given project with Flettner rotors the financiers who replaced the supplier get a clear benefit after year 5, earlier than the operators. The operators enjoy a break even later, in year 7, yet enjoy net benefits afterwards. The split model can also include benefits for the financiers after the end of the tenure of the lease. Should this be the case then investors may also speculate and enjoy higher yields. The range of speculation over fuel prices is

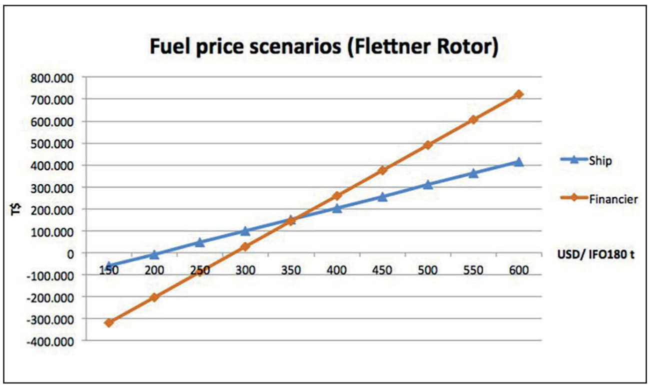


Figure 3: Sensitivity of NPV against fuel prices

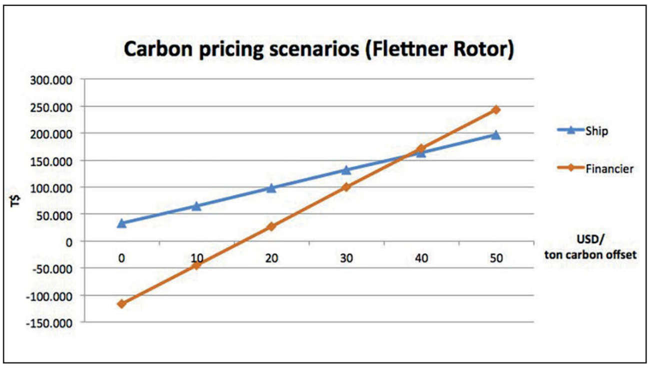


Figure 4: Sensitivity of the NPV against the carbon price

clear in Figure 3; the higher the fuel price the earlier the NPV becomes positive and therefore the higher the benefit for both operators and financiers.

The financial performance of a ship depends mainly on capacity, speed and consumption as well as on the operational profile, i.e. utilisation, routing, port times and congestion, etc. In this regard, wind-assisted power boosting technologies are lowering the consumption for a given speed. The decrease in energy requirements results in less emitted CO_2. Therefore, the benefit from installing such technologies is twinfold: less fuel is consumed, therefore the ship becomes more competitive, as well as less carbon emitted, thus operations become greener.

It should be noted that these benefits are delivered directly to the ship without any additional infrastructure required or costs, as no additional storage space requirements should be met; hence there is no loss of cargo and energy efficiency operating indices are substantially improved. Considering that market-based measures (MBMs) will be deployed in the near future in order to motivate further the decarbonisation of marine operations, this benefit will be further monetised.

The price of carbon that will be introduced by the MBM will critically affect the split and the returns as shown in Figure 4; the higher the carbon price the earlier operators and financiers enjoy the benefits. In this regard, fluctuating parameters, such as fuel prices and carbon prices, intrigue investors and financiers to consider new business models, as fluctuation is synonymous with risk, and risk is linked to yields. However, the delivery of wind power is stable, and this power is delivered 'for free' for the lifetime of the assets.

Apart from the financial aspects, it is also necessary to consider the technical and operational aspects of any ship greening project. The delivered performance of the installed technology, and therefore the monetised benefit of these technologies, depends on the following parameters:

- wind force;
- relative wind direction - angle of attack;
- clear flow of wind around the device/ apparatus;
- aerodynamic performance of the device/apparatus.

Ferry *Viking Grace* was fitted with Norsepower Flettners last year

Moreover, sound engineering and seamanship require attention to indicatively, but not exhaustively:

- stability;
- local strength;
- local protection, e.g. insulation, painting, corrosion;
- cabling for operation and control;
- required energy;
- obstruction of the visibility from the bridge;
- obstruction of cargo handling operations, e.g. interference with the operation of cranes and hatches.

It is to be noted that much research has been done on all of the issues highlighted above and the technical and engineering challenges are being addressed. All in all, and assuming the technical integrity of the greening project, wind-assisted power boosting technologies, among others, can serve the goal of decarbonising marine operations and at the same time spark the interest of financiers and investors to fuel all relevant processes.

In conclusion, it is feasible to decarbonise further as technology is mature enough. Skeptics would argue that it is not possible to reach the 100% goal. Indeed, this is not feasible for the current levels of power installed, however the combination of technologies, and especially of hydrogen and wind-assisted ones, may result in achieving the desired goal. It is a matter of time, but any speed limits, as currently discussed at the IMO, may also spur this combination of technologies, as the propulsion needs might be lessened. Hence, regulation can be a positive catalyst in this case, as long as the safety issue due to underpowering is not jeopardised. *NA*

Green ambition: solutions and investment for a decarbonised future

A study by UMAS and UCL has found efficiency technologies insufficient to realise IMO's GHG ambitions, writes Santiago Suárez de la Fuente

Recently, I was having lunch with a maritime consultant at the International Maritime Organization (IMO) and the consultant was reflecting on how the idea of shipping becoming greener and its urgency is finally starting to build momentum. The consultant had a point, on April 2018 IMO's Initial Strategy was agreed (see Figure 1); in June 2019, 11 global shipping banks formed The Poseidon Principles Association that bring a framework for assessing and disclosing the climate alignment of ship finance portfolios; and in September 2019, the Getting to Zero Coalition was formed.

These examples are just a few of what is occurring in the industry. While important advances have been made, much of what is happening right now is in the realm of shaping and defining ambitions of where the shipping industry should be regarding GHG emissions and when these goals should be achieved (e.g. IMO initial strategy aims to reduce CO_2 emissions by at least 50% from the 2008 levels by 2050).

Now, answering how the industry will do the GHG transition will involve more naval architects and marine engineers than the 'when' and 'where' questions being discussed now.

Santiago Suárez de la Fuente

Carbon intensity curves

Of the IMO's levels of ambition (Figure 1), the most serious is .3, which deals with the absolute reduction of GHG. This absolute target can be converted into a relative carbon intensity target (i.e. gCO_2/t-nm) using Shared Socioeconomic Pathways (SSP) [2] and Representative Concentration Pathways' (RCP). In this article, we use SSP 2 – Middle of the Road – and RCP2.6 – limits the increase of global mean temperature to 2°C from pre-industrial levels – while assuming a linear behaviour between the relevant years. Figure 2 shows that reducing by 50% the CO_2 emission and fully decarbonising shipping activity is much more aggressive than the IMO's targeted carbon intensity. For that reason, the next section uses the most aggressive decarbonisation curves to quantify how different measures affects the carbon intensity of three commercial ships.

The road to how: fuel, machinery, and energy efficient technologies

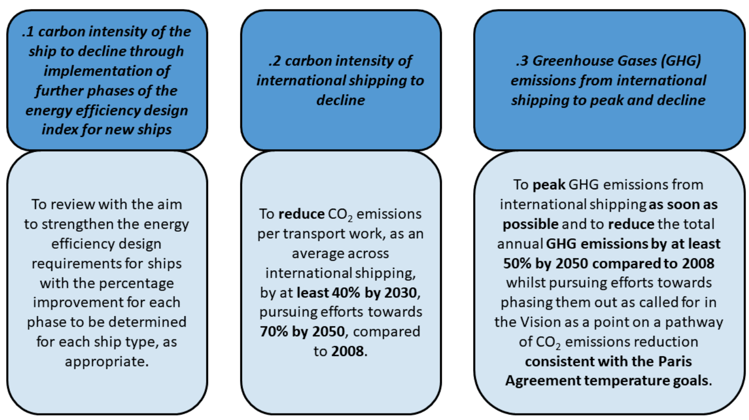
Together with some colleagues at University Maritime Advisory Services (UMAS), University College London's (UCL) Mechanical Engineering and Energy Institute was set the challenge to quantify the impact of different energy-efficient technologies, change of speed and alternative fuel (via a change in the fuel's carbon factor) in order to understand the potential of each solution to reduce the carbon intensity of three newbuilt ships (i.e. oil tanker, bulk carrier and containership).

We took the ship's annual averaged operational speed in the year 2010 as our reference point and added other operational speeds. With the reference speed, it was possible to calculate the carbon intensity using the Energy Efficiency Operational Index (EEOI)[1] which was already 13% lower than in 2008 (see Figure 2).

We found that no single energy-efficiency technology (even wind propulsion in its most optimistic scenario) could deliver the reduction needed. We then combined a maximum of eight different energy-efficient technologies with wind propulsion[2] and applied a range of operating speeds to estimate the consequent EEOI improvements. Against the 2008 baseline, the EEOI change due to energy-efficient technologies intervention was between 3% and 13% (See Table 1).

When reducing the ship's speed

Figure 1: The levels of ambition given by IMO's Initial Strategy (1)



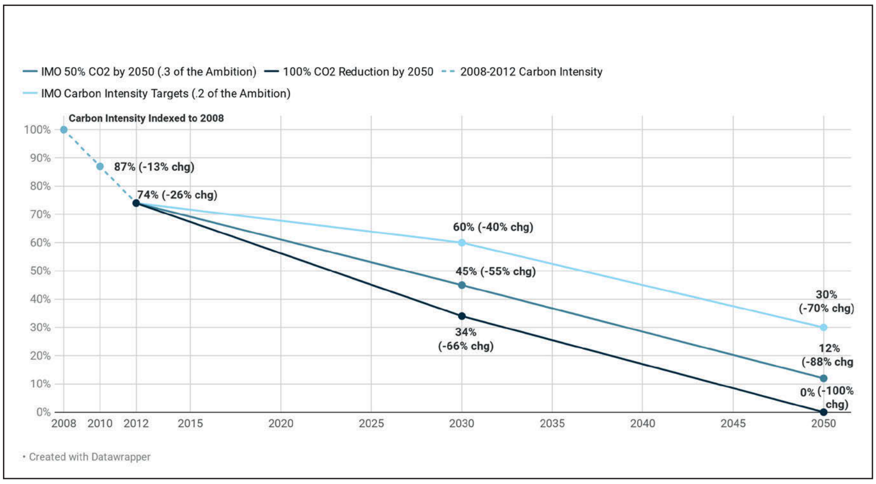


Figure 2: Possible carbon intensity reductions, with their associated changes, aligned with .2 and .3 of the IMO's Initial Strategy and the trajectory needed for the shipping total decarbonisation. The values are normalised to the carbon intensity of the shipping industry in 2008

alone, the reduction fluctuated between 20% and 34%, depending on the ship type. However, it is when combining technologies with speed reduction, that significant reduction in carbon intensity appears (i.e. drops between 25% and 76%). Still, these reductions are not sufficient for the levels of carbon intensity required of the sector in the coming decades.

However, when the fuel carbon factor is modified – which could represent a blend of biofuels or zero-emission fuels mixed with fossil fuels – it is possible to observe large drops in the EEOI, especially for the containership where previously technologies and further speed reduction did not have a large impact. For the bulk carrier, a 50% reduction in its fuel carbon content with speed reduction will align it to the IMO's vision while the tanker and containership need a 75% reduction in the fuel carbon factor. To achieve the full decarbonisation, the ships will need a zero-carbon fuel.

Investment for a decarbonised future

It is clear from the table that it is fuels with low or zero-carbon content (i.e. from well-to-propeller) that will enable the necessary decarbonisation. In light of our results, this summer our group was tasked with finding what will be the extra level of investment to achieve the sector total decarbonisation by 2050, compared to a Business-As-Usual (BAU) behaviour. To do that we used a scenario-based approach.

Scenario-based models allow scientists, engineers, and policymakers to explore different potential futures and fleet evolution. These models are constrained by predetermined conditions (e.g. a required/demanded emission trajectory) while being guided by objective functions (e.g. profit maximisation for the shipowner). In the past decade, our research group developed the Global Transportation Model (GloTraM) to look into the potential shipping futures and their mix of fuels, machinery, energy-efficient technologies and fleet composition [3].

The scenario I have used for this article describes the future where shipping managed to decarbonise completely by 2050. We had more than 30 different ship types and sizes, more than 30 energy-efficient and operational measures, seven fuels and their associated machinery. Every time step into the future – every five years – the model chooses the best techno-economic combination per ship type, size, and generation based on profit maximisation. The results give a picture of how the fleet evolves with time and what is the mix of fuel, machinery, and energy-efficient technologies.

Of the fuels considered and for this specific scenario's assumptions, ammonia was the most competitive zero-carbon fuel. It experiences rapid growth post-2040 and effectively displaces fossil fuel completely by 2050 (see Figure 3). The scenario also estimates a significant take-up of energy efficiency technology.

The exact combination is too diverse to be described here. Interested readers can look at [4] for a subset of the results looking to the UK fleet. To calculate the total investment up to 2050(3), the investment was aggregated in three main groups: fuels, machinery, and energy-efficient technologies. The fuel group considers upstream costs, while machinery included the cost of machinery and fuel storage, and energy-efficient technologies just considered their capex.

In this scenario, the total cumulative investment cost until 2050 needed to decarbonise the shipping sector by 2050 is US$1.65 trillion. Figure 4 shows that for this scenario, the largest proportion of the investment cost occurs upstream where the fuel is created, taking 87% of the investment cost. The production of zero-emission fuels was assumed to be a mix between fossil fuels with carbon sequestration and electrolysers. For this reason, the investment magnitude was driven by the cost of renewable electricity, carbon capture equipment, electrolysers, reformers and Haber-Bosch process. In second place, with 12%, we find engines and fuel storage on board. Energy-efficiency investment costs represented only 1% of the cumulative investment but was 11% more than in the BAU scenario.

Footnotes

1. *For the list of assumptions and methodology please refer to reference [5] and [6].*
2. *Contra-rotating propeller, stern flap, block coefficient reduction, air lubrication, waste heat recovery systems, engine derating, speed control of pumps and fans, energy-saving lighting, advanced hull coating. Wind propulsion and block coefficient reduction did not apply to the containership, and stern flap for the tanker and bulk carrier.*
3. *For uncertainty reasons, only capex was considered*

Ship Type	Annual Operational Speed (kn)	Speed Reduction	EE Combination	EE Combination + 25% CF Reduction	EE Combination + 50% CF Reduction	EE Combination + 75% CF Reduction
Medium Range Tanker	9.6	-28%	-61%	-70%	-80%	-90%
	11.7*	-13%	-56%	-67%	-77%	-89%
5000 TEU containership	14.9	-20%	-25%	-43%	-63%	-81%
	16.3*	-3%	-19%	-40%	-60%	-80%
Panamax Bulk Carrier	9.9	-34%	-76%	-82%	-88%	-94%
	11.9*	-13%	-67%	-75%	-83%	-91%

**Reference operative speed year 2010;*

Table: EE - Energy Efficiency; CF - Carbon Factor • Source: (5) • Created with Datawrapper

Table 1: Carbon intensity percentage change against the 2008 baseline due to the combination of energy-efficient technologies, change of speed and reduction in the fuel's carbon factors for three different ships

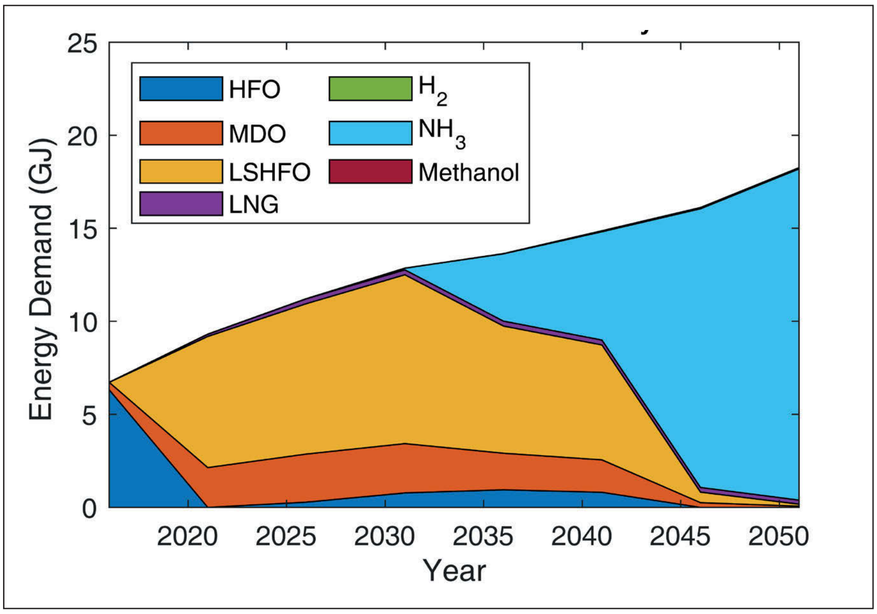
Conclusions

Through this article, I showed that to decarbonise the shipping industry in line with the IMOs Initial Strategy ambitions, energy-efficiency technologies are not enough. If the aims and goals are to be achieved, the industry needs to consider a mix of technologies, low or zero-carbon fuels and operational measures. Also, the investment challenge to decarbonise falls on the fuel arena, mainly in its upstream development, specialised machinery, and fuel storage. This does not mean that energy-efficiency technologies will not be relevant or that they will not play an important role in decarbonising shipping. They should play an important supportive role in the fuel transition period and, when the zero-carbon fuels enter the market, they should continue to allow ship operators to reduce their fuel costs, which is only likely to become increasingly important. Finally, this article shows that our fellow naval architects and marine engineers need to be aware of the challenge ahead in ship and system design in order to accommodate the needs of the future low and zero-emission fleet. *NA*

About the author

Dr Santiago Suarez de la Fuente is a mechanical engineer who lectures in Energy and Transport at the Bartlett School of Environment, Energy and Resources, UCL. He led work on developing different marine engineering technologies, propulsion systems and energy flows for UCL's holistic software solution, the Whole Ship Model. His research focuses on marine energy efficient technologies and fuels, holistic modelling approaches for the maritime sector and performance data analytics. Dr Suarez de la Fuente did his PhD at UCL on marine waste heat recovery systems (WHRS). He also has five years experience in the metal mechanics and electrical industries.

Figure 3: Fuel mix evolution for the global fleet to decarbonise the shipping sector by 2050



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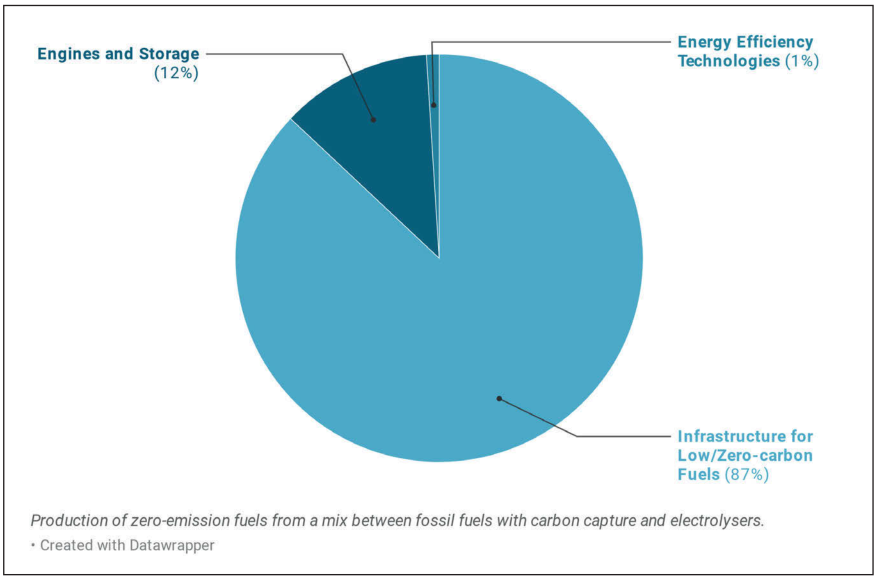

Figure 4: Proportion of the cumulative investment cost up to 2050 for the three main groups

4. SMITH TWP, O'KEEFFE E, HAUERHOF E, RAUCCI C, BELL M, DEYES K, et al. *Scenario Analysis: Take-up of Emissions Reduction Options and their Impacts on Emissions and Costs*. London; 2019.
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Supersizing solar power

Martín Giordano has filed a patent application in Argentina for the construction of the support structures of for solar panels on large-load ships. He explains the process to *The Naval Architect*

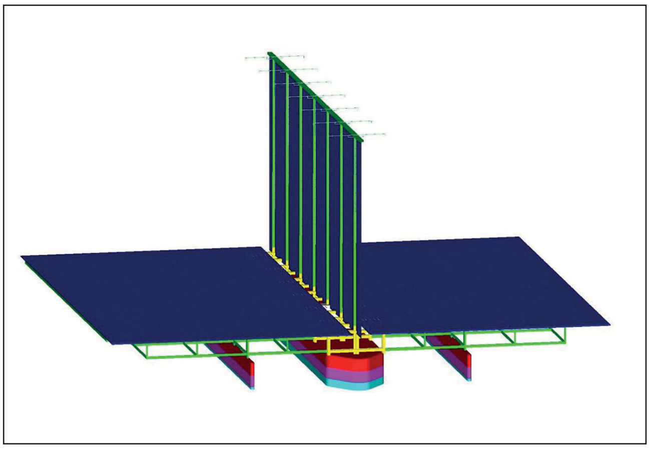


Figure 1: Horizontal solar panels can capture direct solar energy while vertical panels can capture reflected sunlight

With the depletion and increasing cost of traditional fossil fuels, solar energy is a promising alternative technology for the shipping industry. Solar power not only has the potential to reduce the cost of energy spent by current ships but also improve ships' navigability, particularly in the open sea where there is a large amount of solar energy readily available.

The surface of solar panels that a cargo ship requires in order to capture the solar energy necessary for its operation must be six to eight times larger than the surface of the ship's hull. This will ensure the ship can navigate autonomously during the day and night at the same speed today's cargo ships sail. Therefore, a solar energy system is needed that allows solar panels to be placed beyond the ship's own surface area.

My solution is a telescopic structure that can expand and decrease its size when needed. This design will enable a ship to navigate both the open sea – in calm sea conditions it can sail with the extended solar structure – as well as ports, narrow rivers and channels, during which time the structure can be adjusted to fit a ship's measurements.

To be able to expand and reduce the size of the structure that carries the solar panels, a telescopic structure was designed that has solar panels arranged horizontally and vertically. The horizontally arranged solar panels would capture direct energy from the sun while the vertically arranged solar panels would allow diffused solar energy and sunlight reflected from the sea water to be captured. Solar energy reflected in the open sea is an important source of energy (we consider this energy to be nearly 50% of the direct solar energy of the sun in the open sea), which can be added to the direct solar energy used in principle by the horizontally arranged panels.

If the support structure of the solar panels is very large, this type of ship also has as an option to have two floats attached to the sides of the hull in order to support the structure's own weight, taking the form of a trimaran, but where side floats only fulfill the function of supporting the weight of the structure of the solar panels and re not load bearing. Although these floats would increase the ship's resistance in a semi-folded position, it would also improve the lateral stability of the ship, allowing it to navigate the high seas better during storms and easily maneuver through shallow water depths.

Solar panel efficiency

At this time the maximum efficiency of commercial solar panels is approximately 20-21%. There are space-use solar cells with efficiencies of the order of 35-40%, however these would be prohibitively expensive to use on this type of ship. The maximum efficiency that a multi-juncture or tandem solar cell could achieve is 68.2%. Solar cells composed of silicon quantum dots, which have the potential to reach efficiencies of the order of 40-50%, are currently under development.

Laboratories around the world are working on new types of solar cells that have the theoretical potential to reach efficiencies greater than 70%. So, it can be expected that at some point 50% efficiency will be reached, if not exceeded.

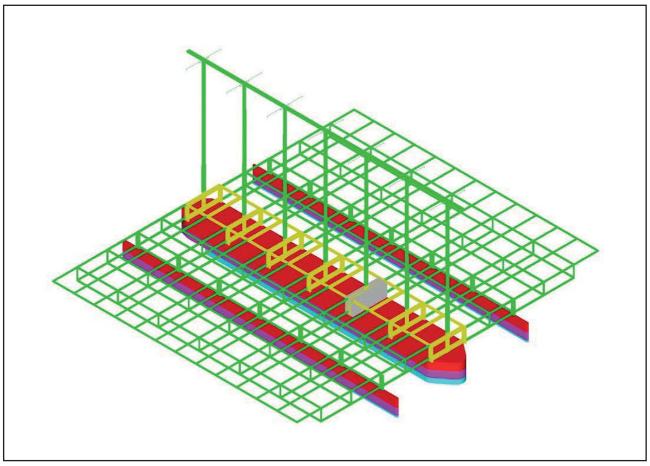


Figure 2: Solar panels will be organised in a telescopic structure allowing navigation on the open sea and in ports

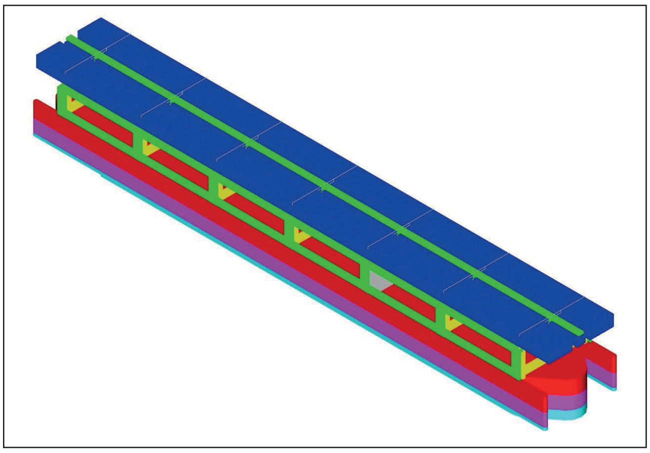


Figure 3: Solar panels in a fully folded position

Therefore, for the calculations in this article, we will consider solar panels with an efficiency of 50%.

Speed and characteristics

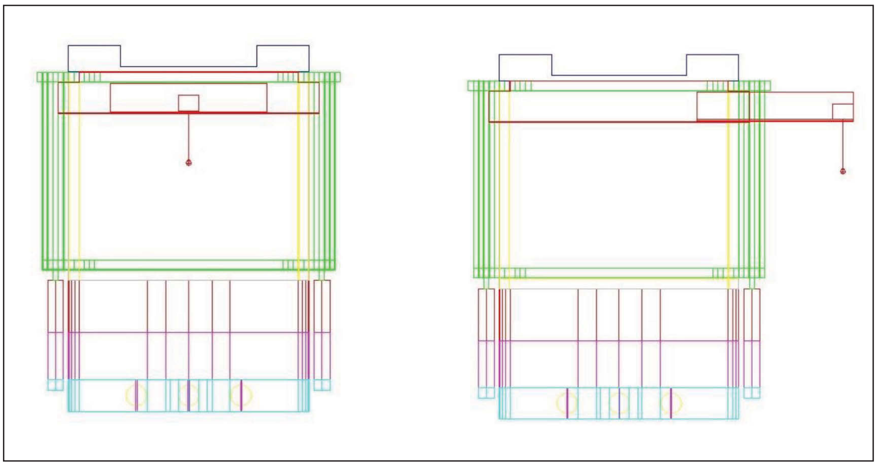
As an example, we will consider the application of this form of solar-powered propulsion system to a Panamax-type vessel of 50,000dwt with a total maximum length of about 250m, a maximum width of 32m and a draft of 12m. However, this type of telescopic layout of solar panels may also be applied to larger ships such as post-Panamax ships or smaller vessels where it is justified.

For a vessel of these dimensions, the maximum width of the support structure of the solar panels would be 256m (making it eight times larger than the maximum width of the ship), 250m long (equal to the maximum length of the vessel), with the height of the vertical solar panels 128m (half the width of the horizontal panels). For calculation purposes, we consider the hours of sunshine per day with a standard radiation of 1,000W/m^2 at a south latitude of 35° (the position of Buenos Aires or Cape Town) is 6.5h/day for an average summer day and 2.5h/day for a winter day in open sea conditions.

Consider also that the vertical solar panels that capture diffuse and sea-reflected surface solar energy have an energy radiation of the order of 50% of the direct solar energy of the sun. That is, that the vertically arranged solar panels will generate around 50% of the energy generated by the horizontally arranged panels, for a general situation of the ship, although this diffuse reflected solar energy will depend on the position of the ship and the vertical panels relative to the sun.

As stated previously, the solar panels used in this ship will have a maximum efficiency of 50%, generating an estimated 13,000kW of energy per day during the summer and 5,000kW of energy on a typical winter day.

Figure 4: The telescopic crane bridge



Further factors to be considered in this scenario include:

- The extra advance resistance generated by the ship's pontoons and the sail resistance of the vertical solar panel, as well as the structure of the horizontal solar panels.
- The vessel's two electric motors coupled to two propellers and direction of different turns, which generates an improvement in propulsion efficiency with respect to the use of a single propeller of 5-8%.
- The vessel and its pontoons will be coated with silicone paints, which have 4-8% less resistance than the conventional paints that are primarily used today.
- The overall efficiency of the electrical system of both motors and electric batteries is of the order of 80%.

Given all of the above, we expect the ship to have an average speed of 16.5knots (equal to 30,55km/h) on a summer day and 12.5knots (equal to 23,15km/h) on a winter day. This calculation is only to estimate what such a ship could achieve in the future with a solar cell efficiency of 50%. However, the efficiencies of marine solar cells today are lower than the values considered in these calculations.

Operation at higher speeds

This type of ship will have to carry electric accumulators to store the solar energy generated by the solar panels during the day for the night. Additionally, a sufficient amount of electric batteries are needed to guarantee the ship will have energy stored for at least four or five days of operation in case the ship has to go through an area of storms or cloudy days. If a greater speed is needed, the batteries carried by the ship can be recharged while at port. During its operation, the ship will be able to draw on the energy generated by the solar panels and the energy from the electric accumulators, allowing the ship to obtain a greater speed than a vessel which only relies on the energy generated by the solar panels.

Another interesting application that ships powered by solar energy may have

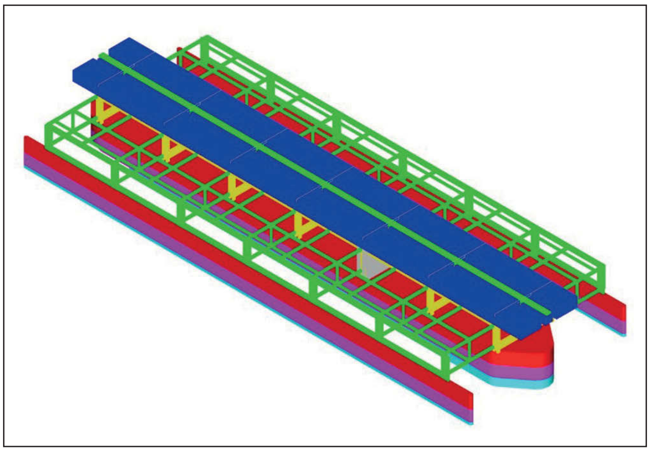


Figure 5: Solar panels in a semifolded position. The pontoons will increase the lateral stability of the ship

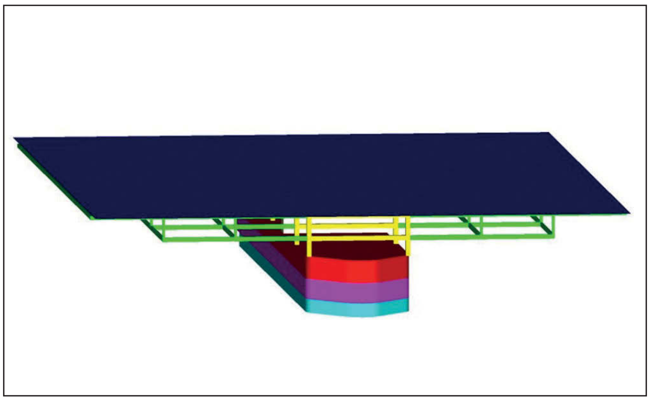


Figure 6: Concept design for the first hybrid solar-powered ship

is the generation of surplus electrical energy at sea that could then be used in coastal areas on land. Such ships could replace floating solar parks, which can be difficult to tie to the sea floor and struggle to withstand the swell of a strong storm. If we use a solar boat to generate energy with solar energy that radiates over the seas or the oceans offshore, it will be easier and more convenient than doing it with floating solar parks.

In addition, these power-generating ships in their offshore operation may function as electric power recharging stations for ships that need more electrical power for operation, either because there are winter days with little solar radiation at sea or because they need higher speed of transport of the loads than the vessel can give it with the solar panels that it carries with this type of solar panel carrier structures.

Loading and unloading

In this type of solar ship, when the structure that holds the solar panels is folded, the telescopic structure and its solar panels will be folded on top of the ship and above the loads that will be placed on the ship's hull, whether bulk cargo or containerised cargo.

To be able to load and unload a special telescopic crane bridge would be required for loading and unloading. Current port cranes would be incapable of performing this task correctly because the upper part of the ship is covered by the solar panels and its support structure when it is folded.

The crane bridge would have a main carriage that moves longitudinally along the ship's hull and transversely across the width. It can be seen in schematic form in Figure 4, illustrating how the crane bridge will load and unload while moored.

Ship side stability

As the telescopic structure carries solar panels and as the same solar panels are arranged in the upper part of the ship, this weight can affect its lateral stability during storms or heavy waves. One feasible solution to this problem is to place the pontoons at a certain distance from the ship's hull so that the lateral stability of the ship increases in rough navigation conditions (Figure 5).

Construction of the first solar ships in hybrid form

One way to start building this type of ships with the solar panels that currently exist - which as we said have a lower efficiency than those considered in the calculations we made - would be to make a solar ship with a smaller support structure. This means eliminating the side pontoons and vertical solar panel; therefore, reducing the solar energy generated by the ship but also decreasing the complexity of construction. Instead, a hybrid propulsion would be adapted. Current solar panels that have an efficiency around 20-21% could be paired with a fossil fuel combustion engine. This hybrid-system could cut fossil fuel consumption and reduce CO_2 emissions of conventional ships.

This type of hybrid ship could first be built in the manner indicated in Figure 6, where it is seen that the surface of the solar panels is smaller than the vessel designed to operate solely on solar energy. It is also surely easier to build and test this simplified system but will still provide insight into the manufacturing of the whole telescopic solar panel support system.

Project status

At this time, a patent application for the telescopic structure of the ship's solar panels has been filed, and we are seeking interested industry parties in hopes of being able to build this project. *NA*

About the author

Martín Giordano is a mechanical engineer educated at the National Technological University of Argentina, San Nicolas Regional Faculty. He is currently working in the commercialisation and installation of solar and renewable energy equipment and the application of solar energy in different transport systems.

Further information (in Spanish) at: http://tipos-de-energia.blogspot.com. To contact the author email: Martin-Giordano@hotmail.com

Practical use cases of Artificial Intelligence in the shipdesign stage

As shipbuilding projects grow increasingly complex so too does the desirability for effective AI tools during the design phase. Rafael de Góngora and Diego Fernandez Casado explain how AI has been applied to SENER's FORAN system

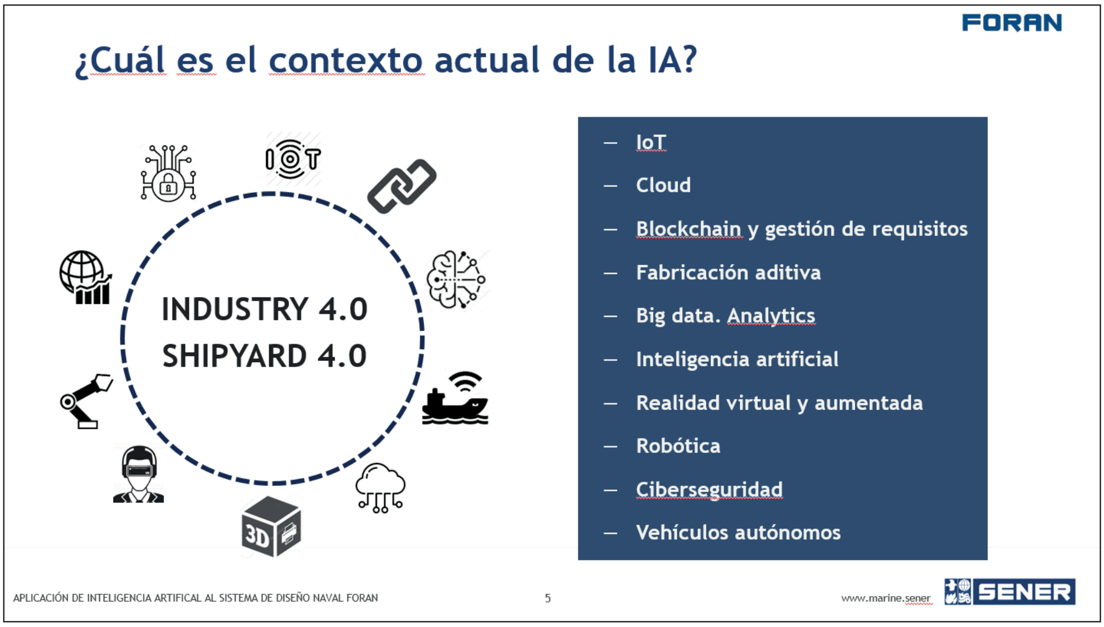


Figure 1: Enabling technologies for Shipyard 4.0

Artificial Intelligence (AI) has become a fashionable expression in almost every field of technology. It does not matter if we speak about retail, agriculture, urban planning or transport, AI seems the incantation or magical word that can change the destiny of all of us.

However, in the marine sector, there has been significantly less penetration compared with other sectors. Both in design, fabrication and operation phases of ships, there has been limited exploration of the possibilities that AI offers. An opportunity arises, therefore, to improve and to transform shipbuilding and shipping industries in modern and forward-looking ones.

Levels of AI

It is commonly accepted that there are four key points that machine must fulfil in order to be considered intelligent:

- To act as humans do
- To reason as humans do
- To reason rationally
- To act rationally

AI, as with any other technology, is not something monolithic, to be implemented as a whole. There exist different levels of AI (maturity) that define the capacity of the machines to reproduce behaviour patterns, or to create new ones.

- Basic AI. Covers everything that allows computers to behave like humans: automatic learning, natural language comprehension, language synthesis, computer image recognition, robotics, signalling and results analysis, optimisation and simulation, etc…
- Machine Learning (ML) is the subset of AI which deals with the extraction of patterns from data sets: deep learning, support vector machines, decision trees, learning Bayes, clustering k- means, learning of association rules, regression algorithms, etc.
- Deep Learning is a specific class of ML algorithms that use complex neural networks. In a sense, it is a group of related techniques comparable to a group of 'decision trees' or 'support vector machines': artificial neural networks, convolution neural networks, recursive neural networks, long, short-term memory networks deepest beliefs and many more.

AI in context

AI is not a standalone technology, but on the contrary, is only one of the technologies available in order to successfully arrive at Industry 4.0. AI should interact with the rest of the technologies, as all of them are involved in the digital transformation of the industry, and moreover, they become triggers and catalysers of the other ones. Among the most relevant ones we can specify the following:

- IoT
- Cloud computing
- Blockchain

- Additive Manufacturing
- Big Data & Analytics
- Virtual Reality
- Augmented Reality
- Robotics
- Cybersecurity
- Autonomous vehicles

All these technologies become the catalysts that allow the concept of Industry 4.0 to develop, and therefore we describe them as enabling technologies.

Why AI in shipbuilding?

Most of the reasons for advocating the appliance of AI to marine projects are common to other industries. Nevertheless, there are some reasons which are more specific to the shipbuilding industry, and whose impact is significant.

- More complex projects. Ships, and therefore marine projects, are becoming more sophisticated, with more demanding technical specifications, stricter national and international regulations, and with tighter budgets,
- Shorter delivery times. Parallel to that, projects are becoming more complex, the competitiveness obliges stakeholders to shorten delivery times, meaning that all phases are compressed, but without any compromise to the quality of the final product;
- Non-expert workers. This fact, common to all industries, is more acute in the marine sector, as with new projects shipyards and technical offices are obliged to involve new staff in shipdesign and shipbuilding, who are often young and with little or no previous experience;
- More complex tools. Tools used in design, construction and operation of ships are increasingly complex trying to provide solutions to the objective of shorten delivery times at a reduced cost. The use of such a tools requires knowledge that is difficult and takes time to get; time that does not exist according to project deadlines;
- Loss of know-how. The cyclic evolution of shipbuilding industry has forced shipyards and technical offices to dispense with significant older staff, who are often those with the most relevant experience and expertise.

All these reasons, among others, represent important risks in marine projects, that can be minimised with the use of AI techniques.

What does AI contribute to the process?

Taking into account that nowadays CAD/CAM/CAE 3D systems are so widely used, AI capabilities will need to be integrated into them, but what does AI add? For this case we will look at the FORAN system.

- Efficiency. Efficient handling of design

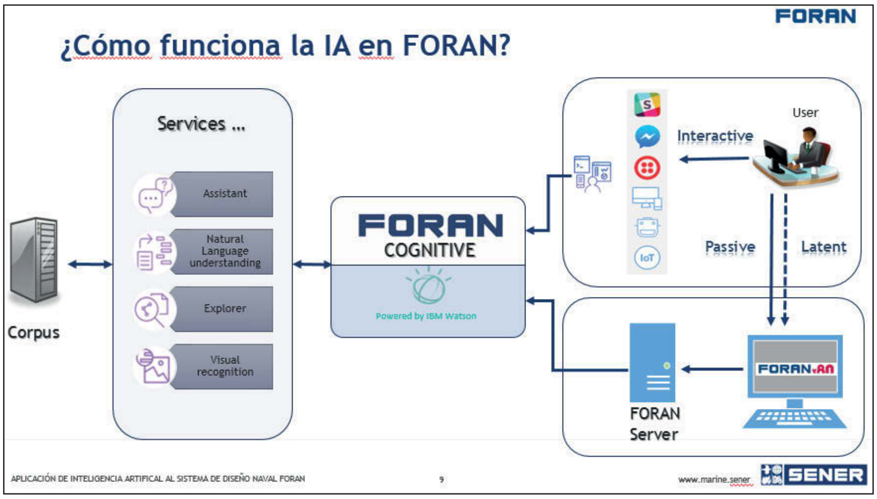


Figure 2: FORAN Cognitive on work

options is achieved by consulting use manuals, design guidelines, calculation norms, etc. that the designer can have, with the help of AI technology, in an interactive mode.

- Reliability. AI can incorporate algorithms that verify the fulfilment of certain KPI´s and making the tasks of designers more reliable, and the project more consistent.
- Experience. AI can help in providing designers with comparative and historic data, information from previous projects, or learned lessons, everything with the objective of helping to facilitate prototyping of new ships and identifying the best alternatives among existing ones.
- Optimisation. By means of AI, engineers can receive online recommendations and data for adopting best practices and for automating certain design tasks.

Additionally to all of this, AI technology integrated in design systems can enrich itself with data coming from current project, making it a real live project with self-learning capacity.

How AI works inside the FORAN system

FORAN modules are linked with AI services (Assistant, Natural Language Understanding, Explorer, Visual Recognition) by means of a new application called FORAN Cognitive that is invoked from the FORAN modules.

When working with FORAN against database, the user can launch FORAN Cognitive to receive AI assistance about the subject desired. In that instance the AI engine returns an answer based upon the type of query made, the historic data, the profile of the user, and in the Corpus created for the FORAN Cognitive.

The mode of operation of the FORAN Cognitive application can be:

- Interactive: FORAN Cognitive works on demand, once the user launches it requesting a solution for a particular need.
- Passive: FORAN Cognitive is running in the 'background', and every time the user executes a command.
- Latent: FORAN Cognitive entries into Passive mode only when particular circumstances, previously specified by the user, are matched.

In any of the working modes, FORAN Cognitive checks the action launched with the command (the required one for the interactive mode and every command for the passive mode), with the Corpus available, providing the user the information, suggestions, warnings, or misalignments from expected results.

What does Corpus mean?

It has been mentioned that the core of the AI application in FORAN is based in a Corpus. This Corpus of information is derived from any data considered valuable for the purposes of design and construction. FORAN Cognitive deals with the matter of comparing the level of affinity and importance that the different data of the Corpus has in relation with the action executed, selecting only data that is actually relevant.

The data included in the Corpus comes from different origins:

- Common: General data of general application for each project, as a standard for the designs (i.e. Regulations from Class Societies, or equipment information from suppliers).
- Restricted: Related mainly to data belonging to the know-how of each company, that is different (in many cases even contradictory) to the same data of other company (i.e. design guidelines or fabrication procedures).

The way of creating the Corpus also depends on its type. The part considered as "Common" can be fed with data coming from third party companies (suppliers, standardisation bodies, class societies,…), while the part considered as "Restricted" should be created by the company user of the FORAN Cognitive, to avoid disclosing this information to other users.

Among others, types of data composing the typical Corpus (Common and Restricted) include:

- Design and fabrication requirements;
- Design rules
- Class Societies and National Authorities regulations
- Best practices
- Technical specifications
- Information from suppliers
- Legacy data
- User manuals
- Learned lessons
- Operational data

Companies can decide the location of the Corpus: inside the network of the company with no access from outside the company, or 'public', accessible not only by a particular company, but by anyody else that might be interested in having data to feed their AI. Furthermore, it is not difficult to imagine scenario where the typical configuration might be a mixed one, in which the part of the Corpus considered as "Common" is available in a kind of public space, and in which the core "Restricted" data is partitioned from third parties and therefore only fed with data prepared inside the company.

Corpus does not mean fixed data. It

is dynamic data that can be refed and enriched during the execution of the project. And moreover, it is self-learning, automatically creating new data based in previous experiences, in actual results on similar processes, in optimisation processes, and others. In other words, the more the Corpus is used, the more it is enhanced and will give more valuable information.

Practical case: automatic routing of pipes

One of the most complex aspects of the outfitting design, as well the most time consuming for designers, is the routing of distributors (pipes, ventilation ducts, cable trays) on board. Due to this, routing of pipes is one of the paradigmatic cases in which the application of AI to the design can help designers and make the design itself more robust, consistent, and efficient.

In such cases, the Corpus to be used by the AI algorithms should consider all documentation relevant to the design: material specifications, requirements from the shipowner, fabrications constraints from the shipyard, applicable regulations, information from equipment suppliers and electrical connections, guidelines, experience from existing projects, available P&ID's or preliminary flow diagrams and structural consistency.

All these documents, once structured, would allow the user to ask for help (or to get this help without interaction in the case of Passive working mode) for any task in execution.

The application of AI techniques would assist the designer in taking decisions and adopting routings that optimise the design and minimise the design time. Among others, the following aspects are considered as suitable for optimisation and automation:

- To prioritise systems;
- To select main routing areas (reservation of space);
- To select technological attributes of elements;
- To optimise the routing geometrically and operationally;
- To improve results from previous projects;
- To consider the impact in production;
- To feedback on new designs with data coming from actual operations of the ship.

The result of the application of AI techniques in routing tasks would lead to the automatic routing, avoiding more than 70% of the hours currently spent in this part of the design. Furhermore, the design is more robust as the designer and workers know exactly the restrictions or incompatibilities of any design.

Practical case: mounting sequence of blocks

In an ideal situation, structural blocks are assembled once they are finished and completely preoutfitted (or to a level the shipyard considers acceptable). But in some cases, for a variety of reasons, blocks are not finished and the overall schedule of the ship reuires assembly without any delay.

In order to identify these cases, and with the objective of reducing as much as possible the construction time, the application of AI can help the production manager to decide to immediately assemble the blocks and to mount missing elements (mainly from outfitting) at a later stage. Among others, the following aspects are considered as suitable for optimisation and automation:

- Mounting sequence;
- Production planning;
- Preoutfitting of blocks;
- Blocks standby area;
- General impact of any decision on the cost/delivery time of the project;
- Optimisation of material;
- Production flow.

Practical case: operation & maintenance

AI can also serve to optimise the third phase of the shipping process, considering available information and comparing it with parameters coming from other sources, making suggestions and taking decisions based on the best performance of the ship.

Assuming that FORAN data base already includes all information relevant to design and construction of the ship the following aspects, among others, are considered as suitable for applying AI:

- Data sensorisation ;
- Performance monitoring;
- Meteorological conditions;
- Harbour situation;
- Consideration of cargo and consumables;
- Management of stocks;
- Management of permissions and certificates.

Conclusions

AI is not a matter for science fiction but a technology that has a tremendous impact on the shipdesign, shipbuilding and shipping industries, helping to build and operate ships better, faster and cheaper. However, the technology is not completely developed, being the responsibility of CAD/CAM/CAE system to adopt it in order to improve its functionality.

As a conclusion we note the following:

- AI is one of the enabling technologies that is going to change shipdesign, having a direct impact in the development of the concept of Shipyard 4.0.
- AI in shipbuilding is currently in development process with huge potential in all aspects of the production chain.
- AI can be adopted in every phase: design, construction and operation (lifecycle).
- As AI learns from previous cases (designs), it is essential to have reliable and correct data, allowing to learn and refine its application.
- AI implies the participation of experts. The collaboration of the best minds is the most secure guarantee for successful implementation. CAD/CAM/CAE vendors must involve in the development of their systems the best AI experts whose experience obtained in other industries is almost in full applicable to shipbuilding industry.

About the authors

Rafael de Góngora is a Naval Architect and Marine Engineer, Ph.D., and currently holds the position of General Manager of the Marine Business Unit at SENER. In the past, he worked in the ship design office of SENER as Design Engineer, Project Engineer, Project Manager, FORAN Sales Manager for East Europe, FORAN Product Manager and Operations Manager of the Marine Business Unit. He is also Associate Professor in the Polytechnic University of Madrid.

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The bulk carrier side shell and its vulnerabilities

In a continuation of the issues raised in October's *TNA*, Dennis Barber focuses upon the particular challenges ship and berth interfaces pose for bulkers

Regular readers will recall that in the October 2019 issue of this magazine I mentioned matters discussed at the PIANC-RINA conference held at the Institute of Civil Engineers last spring, at which ship/shore interfaces were scrutinised, mainly from the viewpoint of the civil engineers responsible for installation of fendering.

In the latter part of the 20th century a significantly large number of bulk carriers disappeared whilst on ocean passages. Most were loaded with dense cargoes such as iron ore but also steel products on the smaller ships. I was a member of the project management team of the Formal Safety Assessment for Bulk Carriers (FSABC) that examined these casualties closely on behalf of IMO. At the above conference I also noted that the paper presented by Rob Tustin and Steve Osborne left one question open, namely that there might be a phantom menace, with bulk carriers in particular, in relation to ship/berth interfaces.

Although most studies of fender impacts on different types of vessel have produced satisfactory results it was evident that bulk carriers might actually be an exception. However, it is difficult to prove this. The co-authors noted there were very few records of damage that could point to fender impacts. Having managed a fleet of capesize bulk carriers for 20 years, and having also been a sea-serving senior officer on the same class of vessel as well as tankers up to VLCC size, I am certain that the Tustin/Osborne suspicion should not be ignored.

Damages in port were a regular feature of management on the capesize bulkers and always needed careful repairs under Class supervision. Therein might lay some evidence, but as I acknowledged in the last article, it would be a major research task to collate the events. What is not generally appreciated is that the rules governing ship side strength do not generally consider point or restricted area loading other than the forces attributable to tug pushing.

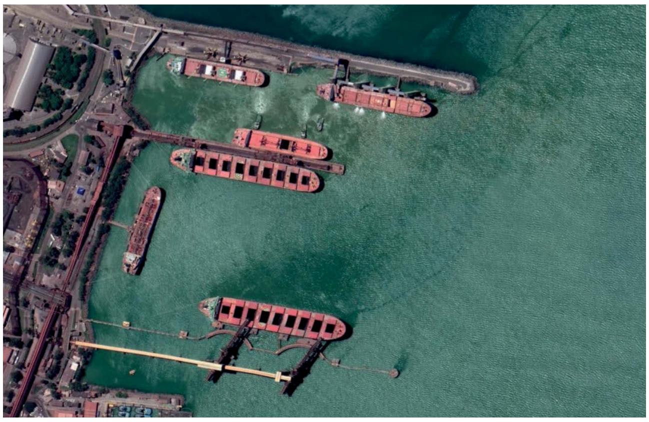


Figure 1: A typical Ocean side Loading facility including a jetty in the foreground for capesize bulk carriers. Note incoming swell radiating from end of breakwater out of picture top edge. Source: Google Earth

A typical high tensile steel capesize bulk carrier will have a single layer of side shell plating approximately 17.5mm in thickness between the ocean and the cargo space. The plate is stiffened by vertical frames of even smaller section that are attached top and bottom, by brackets onto tank hoppers that slope down to the ship's side from the topside tanks, or up to the ship's side from the lower hoppers. Some of the vertical frames align with occasional webs in the longitudinally framed tanks, but many intermediate frames terminate on a flat sloping plate between such webs.

A variety of forces are in play in a loaded or part loaded bulk carrier. This article cannot deal with all of them, but one scenario is discussed below.

In port: ocean side berths

This scenario was alluded to in October. Apart from the impact on berthing – generally the only impact considered by port engineers – there is the continuing oscillation of the vessel on the berth if there are outside influences such as underlying

Figure 2: Same berth closer view. The vessel is not loading. Hatches are closed with evidence of spillage of earlier operations at hatches 1, 2, 5, 8 and 9 (numbering from the bow), suggesting she may be deballasting from wet holds (typically 4 and 6). The loading arms are withdrawn. Source: Google Earth.

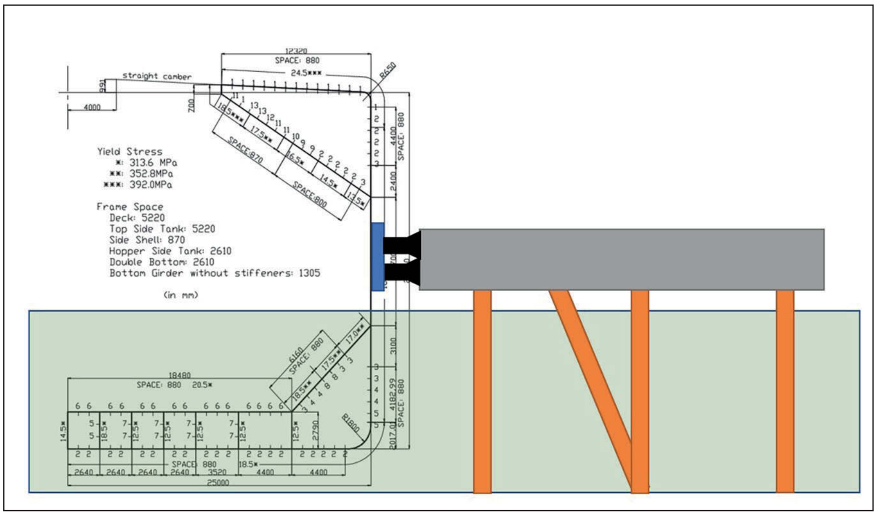


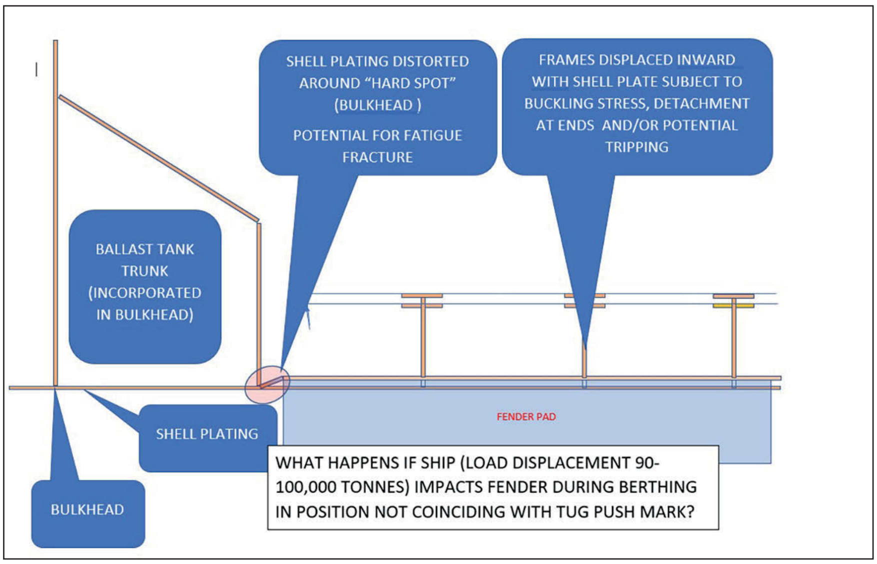
Figure 3: Capesize Bulk Carrier. Midship half-section. Depth 26.9m Keel to top of lower hopper 9.3m. Top of lower hopper to bottom of top hopper (single skin) 9.7m. Bottom of top hopper to Deck edge 7.9m. Typical arrival draught indicated by shaded (water) section area). Source: D.Barber

swell or passing vessels in a fairway. Of these the underlying swell is by far the most pernicious effect.

Deep-draught vessels, such as capesize bulk carriers are, by definition, often berthed in ports that are developed on the ocean side, simply because the more sheltered traditional ports in the developing world, where most are located, are unlikely to be able to accommodate deeper draughts without extensive, expensive and disruptive dredging.

It is simpler to throw up a breakwater (and in some cases I mean throw up) on the beach to enclose a body of deep water that then serves as the harbour for these vessels. The loading berths are often pile supported platforms with fenders attached to the platforms and often to independently piled dolphins on either side of the loading platform. Tanker berths have followed this pattern for much longer than bulk berths but many of the same building techniques are common to both types.

Figure 4: Plan view of single side-skin. The trunk on the left connects top and bottom ballast tanks. The double appearance of the side shell and frames indicates a possible reaction to fender pressure



The ship/berth interface

A vessel of capesize dimensions will have a ballast draught of around 10m to 12m. Figure 3 shows a typical half-section of a capesize bulk carrier (showing longitudinal stiffening and plating but excluding transverse framing and webs). The hull is lying against a typical loading platform similar to that shown in Figures 1 and 2 on a draught typical of arrival and the first part of loading. Note the height at which fenders are likely to be intercepting the hull. This level is maintained for up to half the duration of the load as the increase of displacement by load of cargo is balanced by discharge of ballast and a bulk carrier can carry up to approximately half its deadweight in ballast. All impacts between hull and fenders, between berthing until approximately half the period of cargo loading are therefore taken on the single skinned, transversely framed area.

Longitudinally the situation is equally onerous as the strongest areas, indicated by Tug "T" marks at the bulkheads do not necessarily coincide with the fender contact. The likelihood of making fender contacts coincident with "T" marks is extremely remote.

During the FSABC the above issues were understood but as with so much of that study the hard evidence was not to hand. Much of it is presumed to be on the sea floor as breaching of a cargo hold can be shown to be fatal for a fully loaded capesize. It is however a simple calculation to presume that if a tug impact is considered enough to cause damage, then the impact between the fixed fender, albeit with some built in resilience, and the moving mass of the vessel, which could easily be 100,000tonnes, causes the tug impact to pale into insignificance.

A number of side shell failures have been witnessed on partially loaded bulk carriers. They have often been put down conveniently to poor maintenance and corrosion with the pumping action of the seas providing the presumed force to cause a separation. There is no doubt that corrosion has been an identified factor. It weakens the structure but is not in itself the likely initiation of a failure. It is also known that separations tend to follow the harder linear zones dividing where the longitudinally structured topside and lower hopper tanks meet the transversely framed mid-hold single skin section. Similar hard edges occur where side shell adjoins bulkheads at the forward and after ends of the compartment.

The above considerations should indicate the possibility of repetitive impacts during surging and yawing in port as a possible initiating influence on shell failures. Hairline fractures created by such impacts would be extremely difficult to detect and with commercial pressure to sail would most likely not be given a second thought. Add to this the already mentioned pumping action of the ocean swells during subsequent passage(s) and there exists a mechanism for failure.

If a crack does open up the water can enter the hold, albeit slowly at first. Once in the hold it will increase until sloshing builds up and it is this sloshing that can lead to catastrophic side failure (Figure 5). The failure along the hard boundaries of the single skin area strongly suggest this and the mechanism was similarly identified from witness statements from survivors of a loss of a sister vessel to that depicted in Figure 5. A certain amount of liquefaction is also likely but in denser ores is unlikely to reach the side shell due to the small volume of the ore heap. In the broad beam capesize ships with enormous GM the effect on stability will be inconsequential.

Surge/yaw

Figure 6 illustrates the typical oscillation of a "ranging" vessel at a berth influenced by swell. The swell does not have to be aligned with the vessel. The movement depicted is exaggerated for clarity.

Figure 5: One that survived (part loaded) but a sister vessel to another that was lost and from which there was evidence from survivors. Source: D.Barber

The fibre ropes have sufficient elasticity to allow movement. Energy acquired during the ahead range (green outline) will be absorbed in the ropes and some will be transferred in the redirection of the hull from surge to yaw. The energy will then be transferred to transverse constraints and the fenders forward (which may be only one in contact) until equilibrium is reached between the reaction of the ropes and fenders against the inertia of the hull in yaw. The process will then be reversed as the hull energy dissipates and a mirror effect will occur with the astern range (red outline). This cycle will be repeated constantly for as long as the hull is responding to the swell.

As the displacement increases after approximately half the cargo loading period the increased inertia of the hull will interfere with the yaw and range period and the repetition frequency will decrease. Further reduction to damage will occur as the draught increases and the more rigid topside tanks enter the vertical range of the fender contact. With a typical fast load taking around 30 hours this could mean a large number of impacts in the first 15.

Conclusion

The international organisation representing ports and harbours – PIANC – is looking at fender performance at present and the above observations have been made known to them. They can recommend the use of certain types of fender to reduce point loads such as inflatable fenders used extensively in ship to ship transfers but the challenge should surely be for the designers of ships to conduct a full and complete analysis of all the forces at work on the hull. This scenario has not been routinely incorporated into rules for construction. It is time it was. A merchant ship must, by definition, regularly lie alongside in port or it will not be able to complete the full maritime adventure.

There is much more but space prevents it being expounded here. I would be pleased to answer further questions. *NA*

About the author

Capt. Dennis Barber, FNI, MRIN, Assoc.RINA, is former chief marine superintendent of P&O Bulk Shipping, flag and commercial ship inspector, port auditor, risk assessor and expert witness.

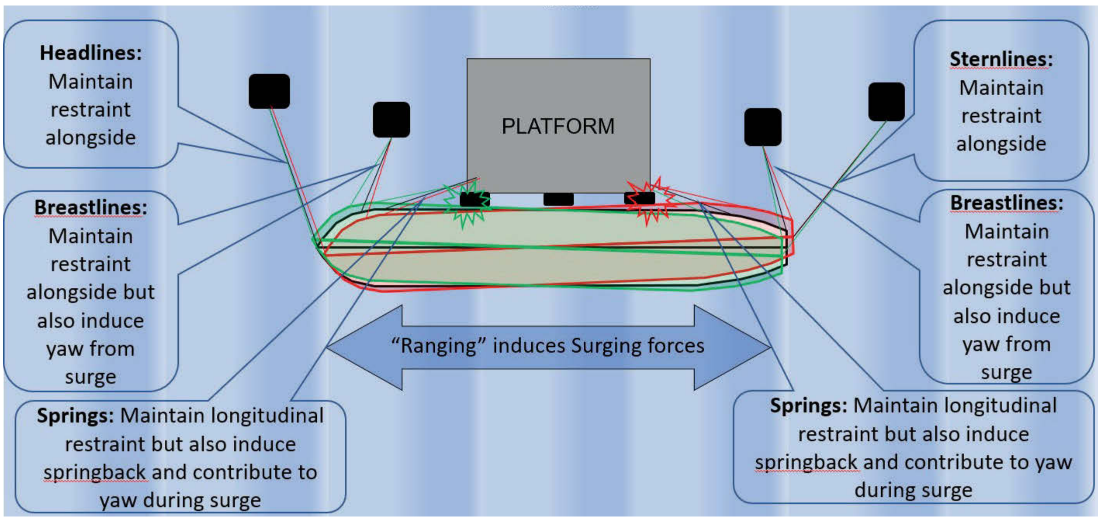


Figure 6: Deep water berth with swell aligned parallel to berth induces 'ranging'. Source: D.Barber

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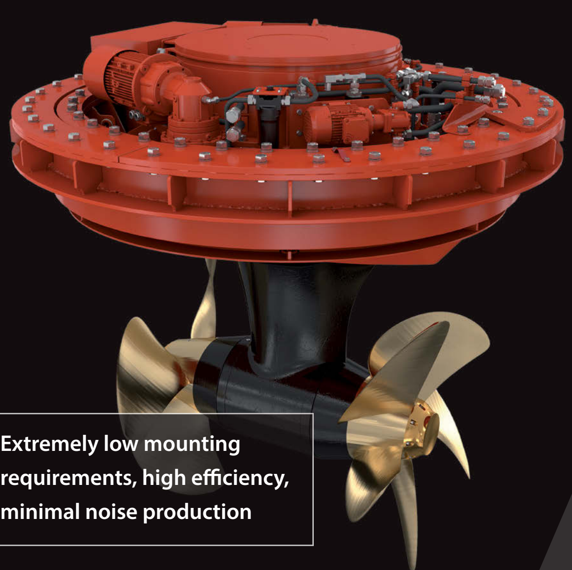

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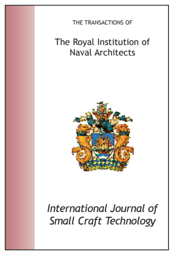

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Full Scale Ship Performance
RINA conference,
London, UK
www.rina.org.uk/events_programme

October 14-15, 2020
Smart Ship Technology
RINA conference,
London, UK
www.rina.org.uk/events_programme

November 4, 2020
Ice Class Vessels
RINA conference,
London, UK
www.rina.org.uk/events_programme