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Editor: Daniel Johnson
Editorial Assistant: Tom Barlow-Brown
Production Manager: Nicola Stuart
Publications Sales Coordinator: Henry Owen
Publisher: Dmitriy Ponkratov

Advertising Sales: J P Media Services
Email advertising: jpayten@jpmediaservices.com
Telephone: +44 (0)1737 852135

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The Royal Institution of Naval Architects
Editorial Office:
8-9 Northumberland Street
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Telephone: +44 (0) 20 7235 4622
Telefax: +44 (0) 20 7245 6959
E-mail editorial: editorial@rina.org.uk
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IPCC REPORT ADDS URGENCY TO IMO ENVIRONMENTAL AMBITIONS

By **Daniel Johnson**

Released in March, the Intergovernmental Panel on Climate Change's (IPCC) sixth assessment report is a sobering read, which some describe as a "final warning" from scientists. Its core message remains much the same as prior IPCC reports, namely human-driven climate change is happening, it's bad, but we can act – although we now have even less time. In light of this, it is hard to argue against Vanessa ZoBell's assertion in this issue of *The Naval Architect* that we need "all hands on deck" to establish solutions for a more sustainable maritime industry.

Vanessa's remarks feature in an article (page 30) highlighting co-operation between Danish shipping company Maersk and Scripps Institution of Oceanography in the US to identify vessel designs that could reduce radiated noise and source levels. A truly interdisciplinary effort involving industry, marine scientists, naval architects and policy experts, the study is a great advert for the mantra of the age, partnership and collaboration.

There's no doubt that the ocean is becoming a noisier place. Over the last 50 years, noise along major shipping routes is estimated to have increased 32-fold. The impact of global warming is likely to exacerbate this, with research suggesting that as seawater turns more acidic, due to absorption of CO_2 building up in the atmosphere, sound waves will be able to travel farther; one paper estimates that on current projections underwater sounds in 2050 will travel up to 70% farther in some areas, such as the Atlantic Ocean, than they do today.

Due to an increased focus on underwater radiated noise from shipping in recent years, IMO agreed in 2021 to review the existing non-mandatory guidelines in order to encourage the uptake and awareness of the subject and provide updated recommendations based on the latest developments in ship design and technology. The revised guidelines were finalised during the IMO Sub-Committee on Ship Design and Construction (SDC 9) in January and provide an overview of approaches applicable to designers, shipbuilders and ship operators to reduce the underwater radiated noise of any given ship. While some see it as much welcome progress, there are others who question how effective new "voluntary" guidelines will be in curbing ship-generated noise.

The new guidelines are subject to approval by IMO's Marine Environment Protection Committee (MEPC 80) in July, which will also be under intense scrutiny to enact a GHG plan that is much more ambitious than IMO's original GHG Strategy from 2018.

Tasked with further refining the revised strategy and accompanying policy instruments to ensure the aspirations set out in the strategy are met, the latest Intersessional Working Group on GHG (ISWG-GHG 14), held 20-24 March, ended with much of the specifics still up in the air.

ISWG-GHG 14, HELD IN MARCH. SOURCE: IMO

Maritime's rule makers now have just two more meetings, ISWG-GHG 15 in June and MEPC 80, to finalise the strategy.

In response to ISWG-GHG 14, the International Chamber of Shipping (ICS) said that it was both frustrated and hopeful. "We are disappointed by the lack of progress on setting new levels of ambition for GHG reductions to provide shipping with a clear net-zero target for 2050. But we remain optimistic that a deal can still be struck at the crucial MEPC meeting in July," commented ICS chairman Guy Platten.

And while a number of voices from the shipping industry, academia and environmental groups said they were encouraged by an apparent growth in support of measures, other commentators were less supportive, calling on IMO to work harder to cut greenhouse gas emissions in line with the Paris Agreement and the latest IPCC report which warns of a need to cut GHG intensity 43% from 2019 levels by 2030 to limit global warming to 1.5°C with little or no overshoot. Whilst they may blame the UN maritime agency for slow progress, it should not be forgotten that IMO decisions are made by national delegates representing governments so it cannot act independently.

Therefore, the nature of off-IMO conversations leading up to MEPC 80 could be seen as pivotal. "Reading from the numbers [at ISWG-GHG 14] of how many support high ambition outcomes, there are positive signs. But this is a simplistic way to estimate how these debates will conclude," noted Tristian Smith, director of maritime academic and policy consultancy UMAS.

Despite its sober language, the new IPCC report does offer some encouragement. There are growing indications that humanity will avert worst-case global warming scenarios, and the report makes clear that technology is advancing rapidly and that feasible climate solutions already exist for every sector, including maritime. The question is, will regulation keep pace to make sure the industry can fully take advantage of them? ■

NEWS

DECARBONISATION

IMO, NORWAY AND SINGAPORE AGREE ON DECARBONISATION CO-OPERATION

THE MOU WAS SIGNED BY KITACK LIM, IMO SECRETARY-GENERAL OF THE IMO, SVEINUNG OFTEDAL, NORWEGIAN MINISTRY OF CLIMATE AND ENVIRONMENT CHIEF NEGOTIATOR, AND TEO ENG DIH, MPA CEO

The International Maritime Organization (IMO), Norway's Ministry of Climate and Environment and the Maritime and Port Authority of Singapore (MPA) have signed a memorandum of understanding (MoU) to provide technical assistance to developing countries as they work to lower greenhouse gas (GHG) emissions.

Under the MoU, which was signed during the 14th Intersessional Working Group on the Reduction of GHG Emissions from Ships (ISWG-GHG 14), participants will exchange experience, knowledge and best practice, and undertake joint resource mobilisation with a view to co-operate and collaborate on actions to reduce GHG emissions from ships and the activities of ships in ports, within the frameworks of the NextGEN Connect initiative and the GreenVoyage2050 Project.

The IMO-Norway GreenVoyage2050 Project currently works to provide support to countries that fall under the United Nations definitions of Small Islands Developing States (SIDS) and Least Developed Countries (LDCs) in their efforts to implement the Initial IMO Strategy on the Reduction of GHG Emissions from Ships.

IMO's NextGEN Connect initiative with Singapore aims to develop relationships between industry, academia and research centres to further decarbonisation efforts in shipping.

"Joining forces through this co-operation will strengthen the support to decarbonising the maritime sector in developing countries," according to Norwegian Ministry of Climate and Environment's chief negotiator Sveinung Oftedal. "We very much look forward to working together with Singapore in these supportive actions, as well as widening the co-operation with IMO in its leading role to assist decarbonisation of the maritime sector in developing countries."

LNG

GTT GETS APPROVAL FOR NEW LNG INNOVATIONS

ClassNK has issued four Approvals in Principles (AiPs) to GTT, following recent development projects focused on alternative fuels. They were awarded during a ceremony in Tokyo.

The design concepts include two new LNG duel-fuelled vessels, a further two designs for an LNG fuel tank, and the company's new Recycool system. This system can be applied to LNG-fuelled vessels and is designed for allowing the reliquefaction of LNG evaporation in order to reduce greenhouse gas emissions and economic losses.

8,000CEU PCTC LNG DUAL-FUELLED WITH NH3-READY NOTATION. SOURCE: GTT

The two LNG vessels include a 12,500m³ LNG dual-fuelled VLCC fitted with Mark III Flex system and an 8,000CEU PCTC LNG dual-fuelled with NH3-ready notation. The LNG fuel tank is designed with NH3-ready notation that includes material compatibility with NH3, risk assessment and boil-off gas management.

ClassNK issued the AiPs in line with its rules including Part N incorporating the IGC Code, Part GF incorporating the IGF Code, and its Guidelines for Ships Using Alternative Fuels. The AiP for Recycool is said to be a world first for a system of its kind.

Philippe Berterottière, chairman and CEO of GTT, says: "We are very pleased to have received these Approvals in Principle in person and to be back in Japan after the global pandemic. These certifications confirm the research and innovation work performed by GTT engineers and technicians. We thank ClassNK for their trust in our technologies on alternative fuels."

CRUISE SHIPS

OMEGA AND YSA DESIGN SHOWCASE CRUISE SHIP WITH 'LUXURY YACHT DNA'

Omega Architects and YSA Design have combined their respective expertise in yachts and cruise ships to create a boutique cruise ship concept which promises "the exclusivity of luxury yachting to high-end cruise clientele".

According to Omega Architects founder and lead architect Frank Laupman, the unique concept is the result of a long-running conversation between the two companies. The Dutch company has already developed an exterior concept for the ship, with Oslo-based YSA Design taking responsibility for GA development, cabin and suite lay-outs, guest flow-through and SOLAS compliance.

The concept vessel has cabins and suites located in a mid-section with the 'yacht DNA' integrated through the public spaces via elements such as a sun deck and a beach club deck located near water level.

The first modelled variation is of an eight-deck ship that has capacity for 200 guests. Other future variations could include ships with smaller capacities that would be available for mixed business models of corporate charters combined with seasonal bookings.

In addition, the companies will focus on sustainability and explore how they can accommodate lower carbon fuels, as well as power sources including batteries and fuel cells.

"Premium cruise guests are always open to the offer of fresh luxury experiences, and we are delighted to partner Omega in offering the very best in yacht and cruise ship design in a single concept," says Jan Krefting, chairman of YSA Design. "Our contribution draws on YSA's near 40-year track record in designing for cruise ship spaces, owners and builders and – critically – for safety of life at sea."

A FIRST VARIATION OF OMEGA AND YSA'S BOUTIQUE CRUISE SHIP CONCEPT

IN BRIEF

HYDROGEN

WIND-TO-HYDROGEN PROJECT UNVEILED

The Dutch government has announced plans to use offshore wind power for the large-scale offshore production of green hydrogen. The project, which is scheduled to be operational around 2031, has approximately 500MW of electrolysis capacity and will be based in the North of the Wadden Islands wind energy area.

DECARBONISATION

AMAZON PUSHES FOR ZERO-CARBON SHIPPING

Amazon, German coffee chain Tchibo, clothing company Patagonia and the non-profit organisation the Aspen Institute have founded the Zero Emission Maritime Buyers Alliance (ZEMBA). The alliance is part of the Cargo Owners for Zero Emissions Vessels (coZEV) initiative and aims to accelerate the commercial deployment of zero-emission shipping, enable economies of scale and support shippers in maximising their potential for reducing emissions outside their own capabilities.

AUTONOMOUS SHIPS

SHI AND KONGSBERG EYE AUTONOMOUS LNG CARRIER

South Korean shipbuilder Samsung Heavy Industries (SHI) and Norwegian marine technology firm Kongsberg Maritime have signed an agreement to jointly develop a design for an autonomous 174,000cm^3 LNG carrier. The two parties will leverage the latest remote autonomous and low-emission technology, with SHI acting as a system integrator with overall design responsibility, while Kongsberg will provide integrated solution designs and serve as a strategic partner.

SALVAGE

NEW MARINE CASUALTY CLAIMS GUIDELINES LAUNCHED

The Salvage Committee of the International Group of P&I Clubs (IGP&I) has drafted new guidelines in collaboration with the Joint Marine Claims Committee (JMCC) to help improve co-operation in the handling of shipping casualties.

The protocol document seeks to promote more effective communication between the parties involved that will ensure the prompt deployment of emergency responses services to vessels in distress.

Amy Dallaway, chair of the JMCC, says: "There is clearly a huge benefit to all parties by having effective early engagement between insurers and shipowners involved in major casualties, particularly where pressing decisions are required. There are many advantages in understanding the concerns of all interested parties and this collaborative approach will result in clearer lines of communication and will assist in the efficient management of claims."

The 'Guidelines for Casualty Liaison Between the JMCC and the International Group' establish a structure to facilitate initial high-level contact between London Market underwriters and individual P&I clubs. They also outline minimum details that should be included for each case.

Ben Harris, chair of the IGP&I Salvage Committee, says: "The guidelines are an important step forward, providing a clear framework for property underwriters and the International Group of P&I Clubs to work closely together in the interest of the assured in a casualty situation. By sharing information and knowledge we can ensure that all stakeholders are aware of what is happening and to the extent possible, there is joined up decision making that avoids delay and ensures the best possible response to a casualty, especially where there is a risk to life, property and the environment."

THE GUIDELINES AIM TO SPEED RESPONSE TO SHIPS IN DISTRESS. SOURCE: FRENCH MARITIME AUTHORITY

HYDROGEN

CSL BAGS ORDER FOR TWO ZERO-EMISSION FEEDER CONTAINER VESSELS

SAMSKIP'S NEW HYDROGEN DUAL-FUEL FEEDER SHIP DESIGN. SOURCE CSL

India's government-run shipbuilder Cochin Shipyard Ltd (CSL) has won a contract from logistics company Samskip for the design and construction of two zero-emission feeder container vessels.

The project, which includes an option for two more ships, is said to represent one of the world's first zero-emission container vessels that will be powered by hydrogen fuel cells, with green hydrogen as the ultimate source.

Funded by the Norwegian government's green funding programme, total cost for the two ships is estimated to be US$70 million. Each vessel can carry around 365 x 45ft-long containers and once operational are intended to serve the European market where sustainable transportation solutions are in high demand.

The vessels will be delivered from Q3 2025 onwards and equipped with hydrogen fuel cells in a hybrid power system with diesel generator backup for longer endurance. They will also have an onboard hydrogen fuel storage facility and be fitted with azimuth thrusters for propulsion and high manoeuvrability.

In zero emission mode, each vessel is expected to achieve around 25,000tons of CO_2 reduction per year, and they will achieve zero emission operations in ports by also using green shore power at the port of call, according to CSL.

"With this order, CSL has further strengthened its position among the global league of early movers in sustainable high-end green future technology in the shipping sector," the shipyard says.

TANKERS

AL SEER MARINE ORDERS FOUR NEW TANKERS WITH K SHIPBUILDING

Al Seer Marine, a unit of Abu Dhabi-based International Holding Company, has placed an order with Korean shipbuilder K Shipbuilding worth US$175 million for the construction of four new tankers.

The medium range "IMO II/III product tankers" will be built at Jinhae Shipyard as Al Seer Marine continues to focus on expanding its fleet to boost growth.

The new ships are expected to be delivered before the end of the fourth quarter of 2024.

AL SEER AND K SHIPBUILDING REPRESENTATIVES DURING THE SIGNING OF FOUR MR TANKER NEWBUILDING ORDERS. SOURCE: AL SEER

The order increases the total number of vessels in Al Seer Marine's fleet to 12.

"Al Seer Marine is very serious about becoming a global market leader across different marine sectors," says Guy Neivens, chief executive of Al Seer Marine, "and the new order is yet another endorsement of our global expansion strategy."

The company recently acquired two liquefied petroleum gas tankers valued at a combined US$66.9 million and has large gas carriers currently under construction as part of a joint venture with BGN International. It is also expanding its freight solutions for bulk cargo globally to meet growing demand.

The new tankers are being designed to be ready to adapt to new fuels such as ammonia and methanol amid transition efforts, the company says.

"The economists point to the need to build new ships to meet the pending environmental regulations, forecasting that shipbuilding orders will rebound in 2024, and Al Seer Marine order confirms the market demand," says K Shipbuilding chief executive YK Jang.

NEWS ANALYSIS

BOXSHIP RECORD CHANGES AND FUEL DEBATE WARMS UP

By **Malcolm Latarche**

Following the delivery last summer of the 24,004TEU *Ever Alot*, February and March this year have been interesting months for the ultra-large container ship sector as new arrivals see the 'World's Biggest Boxship' title changing hands rapidly. Named in February and entering service in March, the 24,188TEU *OOCL Spain* is the first of six ordered by OOCL in 2020 to be delivered by NACKS and the first newbuilding for the company in over five years.

Beating *OOCL Spain* into service was the Hudong-Zhonghua Shipbuilding-built 24,116TEU *MSC Tessa* which itself was followed later in March by *MSC Irina* from Jiangsu Yangzi Xinfu Shipbuilding which at 24,346TEU has easily eclipsed the other two vessels. In terms of physical size, *MSC Irina* is actually very slightly smaller than *MSC Tessa*, but the simple expedient of moving the forward superstructure one bay nearer to the bow allows for more full height stacks behind the bridge with the consequent boost to capacity. MSC has several more of both types under construction which will help the Swiss-based owner consolidate its new position as the world's largest boxship operator.

MSC has recently joined other container ship operators in making a commitment to alternative fuels for future vessels and has orders in place for LNG and perhaps methanol-fuelled vessels. However, *MSC Irina* is an oil-burner and scrubber fitted reflecting MSC's position in 2020 when the ship was ordered.

Future fuels for the industry have been much in the spotlight in March with several developments taking place where views – often contradictory – have been expressed.

At CMA on 21 March in a keynote speech on the state of the industry, DNV Maritime CEO Knut Ørbeck-Nilssen injected a note of realism into the debate saying, "I'm sorry to disappoint anyone here today but I think new fuels and infrastructure will be late and in short supply". He did go on to say that in his view attempts to decarbonise shipping must continue and the industry should do what is possible now rather than wait for a magic bullet in the future. He also made the point that events in Ukraine have pushed energy security up the agenda and may have caused some to review their commitment to renewable energy.

Another speaker later in the week, Barbara Troner from S&P Global, predicted that alternative fuels such as ammonia, methanol, hydrogen, biofuels and even LNG were not likely to advance much before 2030. She also predicted that high sulphur fuels and scrubbers will feature in future newbuildings. That does go slightly against the trend for new orders in 2023 where LNG and methanol have featured strongly but perhaps it should not be forgotten that ships able to run on those fuels can also use oil.

MSC IRINA, CURRENTLY THE WORLD'S LARGEST BOXSHIP. SOURCE: YANGZIJIANG SHIPBUILDING

Colombia Shipmanagement's CEO, Mark O'Neil, was perhaps the most pragmatic saying, "contemplating shipping without fossil fuel does not make for an intelligent debate when the vast majority of this world will require fossil fuels, well beyond all of our lifetimes in this room, so we have to have a much more intelligent discussion".

While the industry was debating future fuels in the US, in Brussels, the EU reached a provisional agreement on reduced GHG emissions from marine fuels which now need ratification by the Council and European Parliament. The proposals would see shipping cutting GHG content of fuel by 2% in 2025, and progressively thereafter to 80% by 2050 for ships over 5,000gt.

The agreement includes a requirement that the regulations will introduce a 2% e-fuel minimum requirement by 2034 if the industry has not already started using at least 1% e-fuel by 2030. The new rules also introduce an additional zero-emission requirement at berth, mandating the use of onshore power supply or alternative zero-emission technologies in ports by passenger ships and container ships.

ECSA responded to the news describing it as a step in the right direction but called for more robust requirements for fuel suppliers to deliver the clean fuels needed and asked for binding targets on suppliers for clean marine fuels in the revised Renewable Energy Directive (RED). ■

NEWS EQUIPMENT

WIND PROPULSION

MOL AND VALE SELECT NORSEPOWER ROTOR SAILS FOR BULK CARRIER

RENDERING OF VESSEL WITH NORSEPOWER ROTOR SAILS. SOURCE MOL

Mitsui O.S.K. Lines (MOL) and Brazilian mining company Vale International SA have announced a partnership to retrofit a 200,000tonne class bulk carrier, currently employed under a mid–term contract for transportation of iron ore for Vale, with two 35m x 5m rotor sails produced by Norsepower Oy Ltd.

The Norsepower rotor sail is made of a lightweight and strong composite material and features a fully automated control system. The sail produces thrust as the wind generates differential pressure around the slewing rotor while the vessel is sailing. By applying this solution, the vessel is expected to achieve about 6-10% fuel and GHG emissions reductions, combined with voyage optimisation technology – enabling significant advancements towards decarbonisation goals and reducing fuel consumptions.

The installation of the rotor sails is expected in the first half of 2024, with both MOL and Vale aiming to continue to work towards both the stable transportation of iron ore and the reduction of GHG emissions.

Vale previously installed a Norsepower rotor sail on a 325,000dwt bulk carrier newbuild two years ago. MOL has also made significant investments in wind power technologies and recently publicised that it is launching a fund in conjunction with Hokutaku Corporation to support the construction of the Kitakyushu-Hibikinada Offshore Wind Farm, one of the largest offshore wind projects in Japan.

HYDROGEN

POWERCELL SECURES NORWAY FERRY DEAL

Norway's most extended and weather-exposed ferry connection between Lofoten and Bodø, Torghatten Nord, is to develop and operate 100% hydrogen-powered ferries. Two ferries operating the route will be provided with hydrogen fuel cells by Sweden-based PowerCell.

The ferries will operate daily all year in the extreme conditions of northern Norway.

Hydrogen is a critical component needed to meet the Paris Agreement's goals, and Norwegian authorities have supported the development of hydrogen technologies for many years. One of the fastest-developing hydrogen applications is the maritime and transport sector, and the ferry project is a significant step in the marine energy transition.

"The fact that future ferries between Bodø and Lofoten are run 100% on hydrogen is a new milestone when it comes to climate," says Norwegian Transport Minister Jon-Ivar Nygård.

It is expected that the ferries will reduce CO_2 emissions by 26,500tons annually compared to today's ferries operated on liquid natural gas (LNG), corresponding to the annual emissions from 13,000 diesel cars.

PowerCell will deliver its PowerCellution Marine System 200, with a total power output of around 6MW for each ferry. The fuel cell system is durable, has a high power-to-weight ratio, and is one of the world's largest for marine use, according to PowerCell.

The operation will run for 15 years, from 2025 to 2040, and PowerCell will provide the fuel cell system service for the entire duration.

"This is a groundbreaking project not just for PowerCell or Norway, but for the entire marine industry, and one that we are very happy and proud to be part of," says Richard Berkling, CEO of PowerCell.

SCRUBBERS

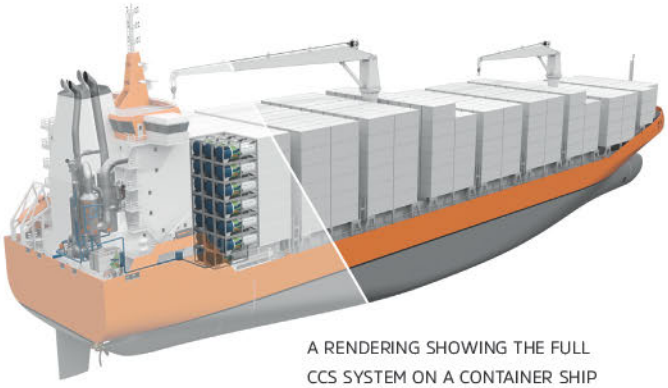
WÄRTSILÄ RECEIVES FIRST ORDER FOR CCS-READY SCRUBBER SYSTEM

Finnish technology group Wärtsilä has received its first order for carbon capture and storage-ready scrubber systems (CCS-ready scrubbers). Delivery is expected to take place this year.

Four 8,200TEU container vessels, being built at an undisclosed Asia-based yard, will be fitted with Wärtsilä's CCS-ready 35-MW scrubber in an open loop configuration.

The scrubbers are termed CCS-ready because, as part of their installation, Wärtsilä will perform additional design and engineering work to ensure future retrofits for a full CCS system on the vessels have already been accounted for during the newbuilding construction stage.

Measures will also be taken to ensure adequate space for the future installation of the CCS system, incorporate considerations for minimising idle load and optimising utilities, and prepare the control and automation system accordingly. CCS-ready scrubbers will also be designed for integration with a particulate matter filter. This will ensure that the shipowner has continued regulatory compliance for SOx emissions today and opens the door to smooth CCS system adoption in the future.



A RENDERING SHOWING THE FULL CCS SYSTEM ON A CONTAINER SHIP

Scott Oh, director at Wärtsilä Exhaust Treatment Asia, says: "CCS is one of the key solutions to enable maritime decarbonisation in a short timeframe, and we look forward to progressing our technology further."

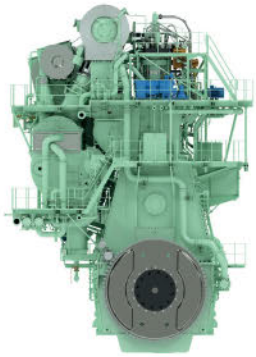
Wärtsilä is currently testing its CCS system at 70% capture rate and a pilot installation will take place within the next 12 months.

ENGINES

MAN G80 DUAL-FUEL METHANOL ENGINES ORDERED FOR HMM BOXSHIPS

MAN Energy Solutions reports it has received the first orders for its B&W G80ME-LGIM dual-fuel engines, which can operate on methanol.

South Korean shipbuilders Hyundai Samho Heavy Industries and HJ Shipbuilding & Construction (HJSC) have placed orders for seven and two of the engines, respectively. The engines will be used in nine 9,000TEU boxships that are currently being constructed for Hyundai Merchant Marine (HMM).



THE ENGINES CAN RUN ON GREEN METHANOL AND CONVENTIONAL FUEL OIL

Designed to run on green methanol and conventional fuel oil, the G80 engines can also be integrated with exhaust gas recirculation (EGR) systems.

"This world-first order for a G80 methanol engine is just a continuation of the general market trend toward methanol where the ME-LGIM engine has become the de facto industry standard for large, methanol-fuelled, merchant marine vessels," says Bjarne Foldager, senior vice president and head of low-speed, MAN Energy Solutions. "At MAN Energy Solutions, we expect further projects for this size of container vessel to be specified with our G80 methanol engine within the near future. As such, methanol is quickly becoming the most prominent alternative fuel in the container vessel segment."

Thomas Hansen, head of promotion and customer support, MAN Energy Solutions, adds: "This new order means that we now have over 100 ME-LGIM engines on order or in service. In our open project pipeline, container vessels make up around 61%, followed by both tankers and bulk carriers with 17%, and general cargo making up the remaining 5%."

The newbuildings will be delivered to HMM from 2025 and will operate on routes to North and South America as well as India.

COATINGS

NCLH GOES BIOCIDE-FREE WITH NIPPON PAINT

Nippon Paint Marine has announced the application of its biocide-free self-polishing coating (SPC) AQUATERRAS to the *Riviera*, a luxury cruise ship operated by Norwegian Cruise Line Holdings (NCLH) subsidiary Oceania Cruises.

The application follows pre-pandemic testing on NCLH's vessels. "After almost two years of the vessels being exposed to static, pandemic-enforced operation in a fouling rich marine environment, AQUATERRAS demonstrated superb resistance to fouling and marine growth," says Nippon.

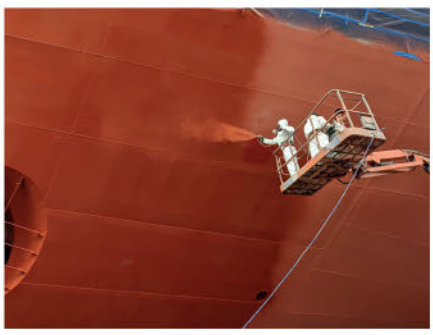
The coating was applied to the *Riviera* in drydock at Chantier Naval de Marseille. AQUATERRAS was applied to the vertical sides of the ship. The average hull roughness measured after the application of AQUATERRAS was a significantly low 40µm.

According to Nippon, this extreme smoothness will provide reduced friction between the hull and the water and will help NCLH to maximise fuel savings and reduce emissions.

AQUATERRAS is the world's only biocide-free self-polishing coating and is based on a unique micro-domain SPC developed by Nippon Paint Marine. Hydrophilic and hydrophobic micro-domain structures actively combine to naturally repel any biological adhesion onto the vessel's surface.

"Due to the impressive performance of AQUATERRAS in testing, we decided to broaden the scope of supply to ships in the Oceania Cruises' fleet and are exploring additional applications to the Regent Seven Seas Cruises fleet," says Carlo Paiella, senior vice president of technical operations at NCLH.

"The cruise industry has been an early proponent of Nippon Paint Marine's ground-breaking technology. NCLH is one amongst a group of proactive and forward-thinking cruise lines that recognise AQUATERRAS as a hugely significant breakthrough technology in the antifouling market, providing enhanced levels of performance to those systems containing biocides, such as cuprous oxide," says John Drew, director of Nippon Paint Marine Europe.



THE COATING WAS APPLIED TO THE *RIVIERA* AT CHANTIER NAVAL DE MARSEILLE

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‘SPEAKING 3D’ – CREATING A COMMON LANGUAGE FOR SHIP DESIGN COLLABORATION

By **Tommi Kurki**, sales director, NAPA Design Solutions

Earlier this year, a ship made history before it even left the drawing board. A 2,500m^3 dredger became the first Damen vessel to be entirely designed, reviewed, and class-approved using 3D models, the outcome of a year-long collaboration with NAPA and classification society Bureau Veritas (BV). This technical leap is the latest milestone in the ongoing 3D revolution in ship design, unlocking a new level of collaboration precisely at a time when we need it most.

Using 3D models in the ship design process isn’t a new idea. After all, ships are three dimensional objects. Every vessel is a unique arrangement of millions of steel parts that all work together. A 3D view is essential to fully capture this complexity, and this is why today ships are designed, for the most part, in 3D.

Powered by advances in modelling capabilities, 3D design software has gained ground in shipyards in the past 25 years, opening the door to new methods that enable naval engineers and architects to make key calculations from the early stages. For shipyards, 3D models have become an essential tool for structural design, weight estimations, out fitting co-ordination and finite element analysis.

The remaining gap – and the biggest challenge – is to enable the vessel’s 3D model to be used all the way through classification approvals. In the current standard process, shipyards create the vessel using a 3D model, but then have to translate it into a series of 2D drawings for classification approvals. Once received, classification societies generate their own 3D model based on these 2D drawings to perform their independent calculations and verifications, before they provide their feedback as comments on the 2D files. Finally, shipyards must translate the reviewed 2D files back into the 3D model to implement the changes. This standard process is clearly not optimal – it is not only time-consuming, but the multiple conversions between 2D and 3D also increase the risk that errors may creep in.

The process known as “3D model-based approval” (3D MBA) changes that. The aim is to skip the 2D drawings step altogether, by enabling classification surveyors to use the model generated by the shipyards directly to make their calculations. Beyond obvious gains in terms of saving time and limiting the risk of errors, 3D MBA is a game-changer for shipyards: giving all stakeholders in the design process access to a single and reliable source of truth on a ship’s design. Working with Bureau Veritas and shipyard Damen Engineering, this is what we achieved, in the first real-life production project to use 3D MBA throughout. Here’s how we did it.

TOMMI KURKI, NAPA DESIGN SOLUTIONS

The OCX technical milestone

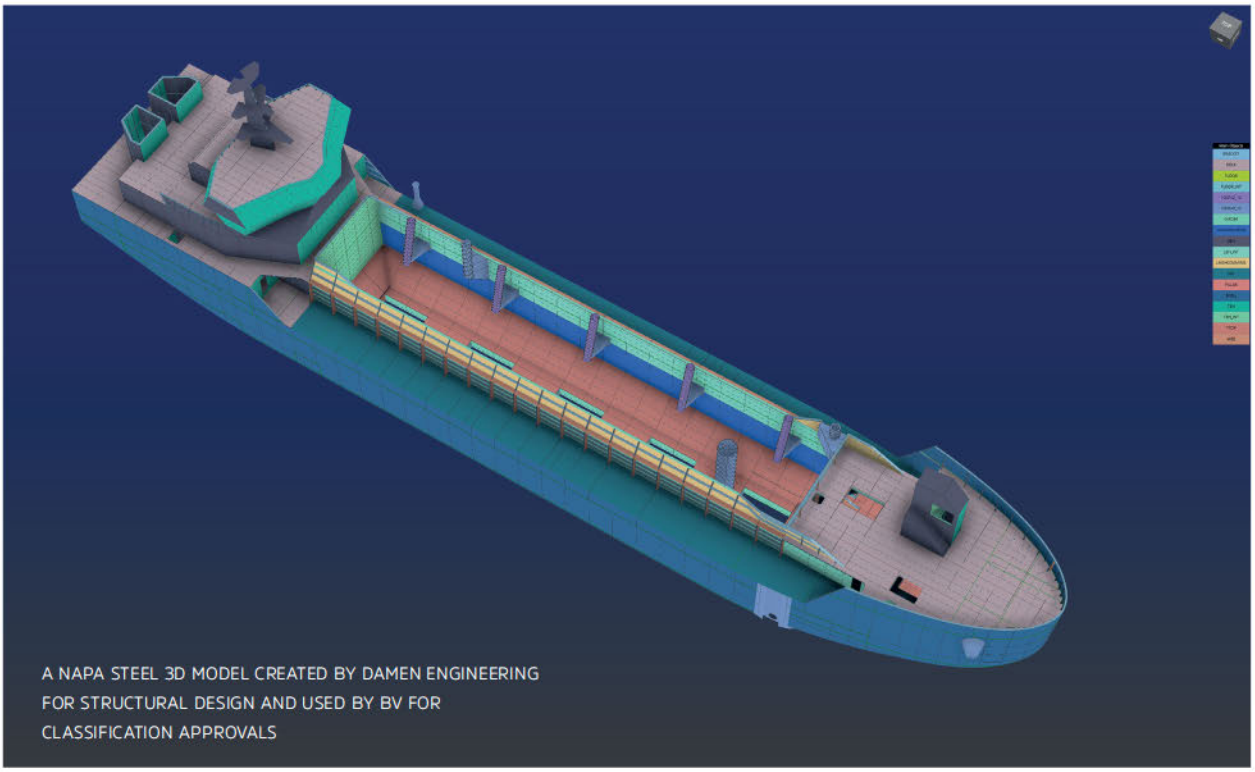
To make 3D MBA a reality, we needed to be able to bridge the software used by shipyards to design the ship and the platforms employed by classification societies for their calculations. In other words, we needed a common language to send information from one system to another.

This missing link was provided by a new standard file format, known as Open Class Exchange (OCX), which we have been developing in partnership with leading classification societies, design companies, shipbuilders and other software providers in the past few years. Generated by NAPA Designer (the platform used by Damen to design the vessel), the OCX file enables BV to perform its prescriptive rule checks and calculations utilising its in-house tools MARS and VeriSTAR Hull.

In simple terms, the OCX format extracts all the relevant information from the 3D model and puts it in a format that the software used by class societies can read. It was developed to accurately represent the vessel’s structural components, such as plates, stiffeners, as well as all their characteristics including thickness and materials, for example. Crucially, this common format works whatever the vessel’s type, reflecting the various geometries and structures involved. It enables the systems used by shipyards and class to speak the same language.

A single source of truth

This common OCX format enabled a significant evolution in the approval process: for the first time, BV



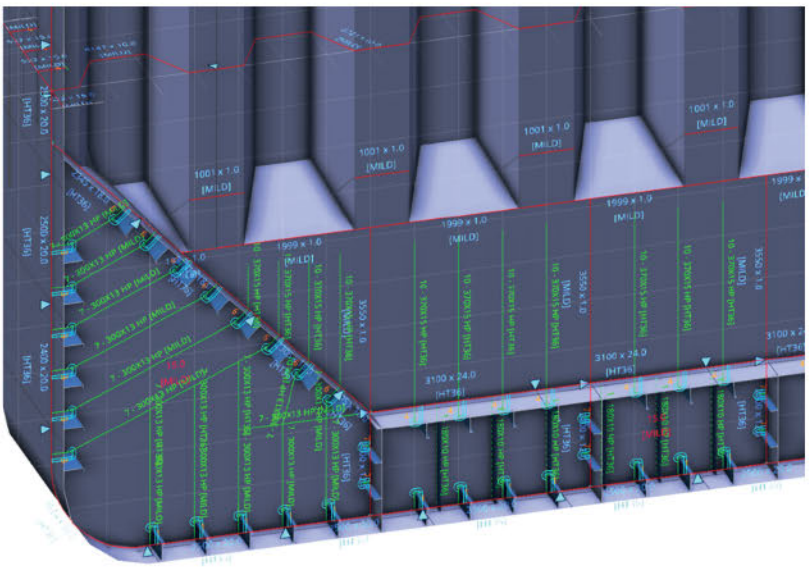
A NAPA STEEL 3D MODEL CREATED BY DAMEN ENGINEERING FOR STRUCTURAL DESIGN AND USED BY BV FOR CLASSIFICATION APPROVALS

could perform its classification checks and calculations directly on the 3D model used to design the ship. The result of these reviews and comments from class can be delivered directly on the 3D model, without any conversions to 2D drawings involved.

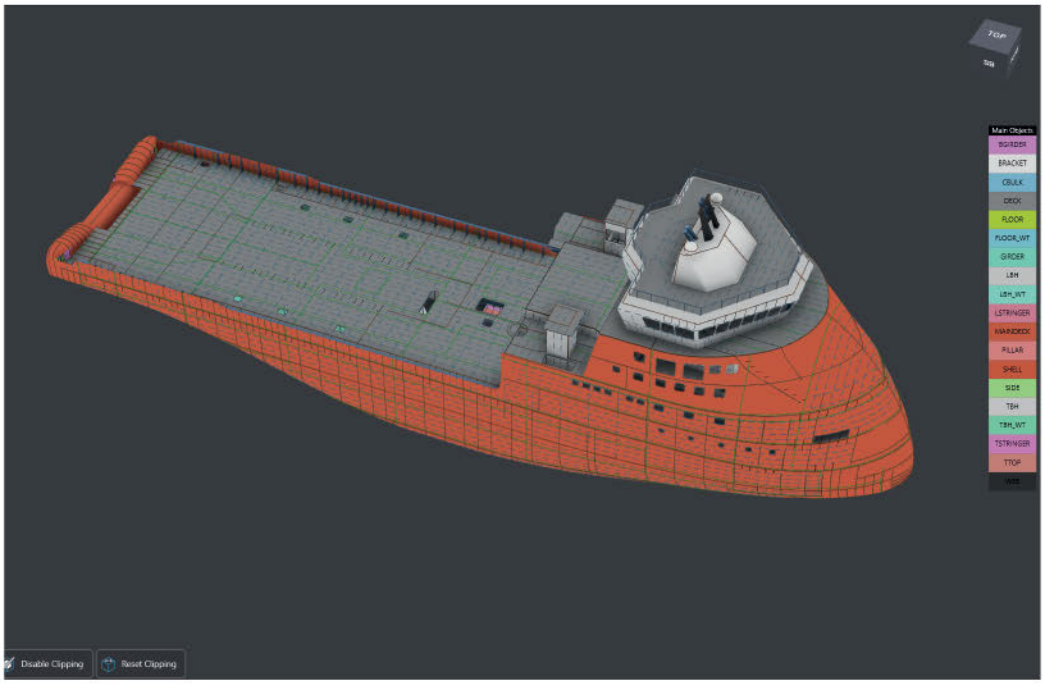
The transformation runs deeper into the workflows surrounding design reviews: shipyards, class and shipowners can now all connect to the same collaborative platform to view the 3D model, share comments and discuss feedback in real time. This is not dissimilar to how cloud-based platforms have enabled people to work collaboratively on a document and view edits in real time – but given the complexity of the information contained in a vessel's 3D model, this is a major milestone for ship design.

The new process had a stellar start. From the very first vessel design, 3D MBA delivered on its promises, helping Damen's teams save valuable time as they no longer needed to translate their concept into 2D drawings for classification approvals, and then back into 3D to implement the changes. Communication between class and shipyard was noticeably easier, which helped make design reviews more efficient and robust, with a reduced risk of errors.

Crucially, 3D MBA helped streamline the classification approval process without compromising on safety, as the same rigorous checks were taking place to ensure that all regulatory standards and rules were met. The results of this first project were so decisive that Damen is already applying the process to further designs, including two



DETAILED 3D STRUCTURAL DESIGN WITH NAPA STEEL



THE 3D MODEL OF A TYPICAL OFFSHORE SUPPLY VESSEL CREATED IN NAPA DESIGNER

hopper dredgers of 1,000m^3 and 4,000m^3.

Enabling collaboration

Beyond immediate time and efficiency gains, perhaps the greatest benefit of 3D MBA is how it enables and supports new ways of working. By bringing designers, engineers, surveyors, owners, and other partners together around a common source of truth, it unlocks a new level of collaboration in the ship design process. Working on the same 3D model makes it easier to share and manage design changes, which enables teams to make the most of limited time and resources to deliver the best possible designs. This is a prerequisite to help teams innovate together.

And this comes precisely at a time when the decarbonisation transition is increasing the pressure on shipyards and designers to innovate at an unprecedented pace, to create the new generation of vessels that will bring shipping to net zero. While it has always been the case that no two vessels are exactly the same, the number of variables involved in today's designs makes them more complex and unique than ever. Moving forward, ships will be powered by a broader range of fuels, technologies, and alternative energy sources. For designers, the challenge will be to integrate these systems onboard, ensure the ship's safety and stability, and find new ways of boosting fuel efficiency more generally.

This is something that can't be achieved without wide-ranging collaboration that must involve shipyards, technology providers, classification surveyors and the ship's owner. Streamlined processes like 3D MBA lay the foundation for this innovation to happen in practice, by enabling all stakeholders to communicate and collaborate more efficiently.

Overcoming the final obstacles to 3D MBA

Moving forward, we fully expect that 3D model-based approvals will become the norm in the industry. Cargo and passenger vessels, tankers, and even submarines and offshore structures, are already designed using 3D models, and crucially, the OCX format is already adapted to these vastly different vessel types. The technological ground has already been laid to apply 3D MBA more broadly in the industry.

Rather than technical, the main challenge ahead is in changing mindsets. We need to re-think how we approach the review process, accept that 2D drawings are no longer necessary, and trust the 3D model alone as the main, reliable source of information. This means changing some habits, both on the shipyard and classification side, and education to ensure that everyone involved knows how to deal with information presented in 3D. To this end, making sure that the software is accessible and adapted to its end users is essential.

The resounding success of this partnership with Damen can largely be explained by the team's open-mindedness and eagerness to explore new ways of working. Having used NAPA's design software for several years in the early design process, the team in charge of the dredger project was keen to take the next step forward and use the 3D model through classification approvals, too. They had the right mindset and vision to pioneer this new process.

For those who will follow, the road to 3D MBA has already been paved. We know that the process works, is robust, and brings much-needed clarity and collaboration at a time when shipyards face a period of fast-paced and profound transformations. By making the design process more efficient, 3D MBA is a means to help shipyards reach new highs. As such, it is a key foundation to help create the more efficient and sustainable vessels that will revolutionise maritime transport for this generation and those that will come next. ■

NEW SHIP DESIGN TOOL REDUCES LEAD TIME BY UP TO 50%

By **Roy de Winter**, R&D engineer, C-Job Naval Architects, and **Stijn Jansen**, CPO, VIKTOR

In the world around us, we see increasing signs of digitisation. Even in the world of shipbuilding and ship design, more and more is becoming possible. C-Job Naval Architects, the independent ship design company, has long said data holds a wealth of information and presents interesting opportunities. The company even has an R&D department that focuses on data science. Now it has taken the next step together with VIKTOR. VIKTOR specialises in low-code platforms to build and share user-friendly engineering apps. Together they have combined C-Job's ship design knowledge and experience as well as in-house created optimisation algorithms with VIKTOR's platform for parametric design in the cloud. The result? A ship design tool that reduces lead time by up to 50%.

STIJN JANSEN, VIKTOR

The Accelerated Concept Design framework

During the ship design process, naval architects have to make many decisions concerning the main particulars of the vessel, systems onboard, installed engine power, and space allocations for cargo and for technical systems, all while taking stability and strength requirements into account. Designing a sustainable cost-effective ship is therefore a challenging and time-consuming task. Often, there is also not a single solution that is best for all operational scenarios. It is for this reason that in recent years C-Job Naval Architects created the Accelerated Concept Design (ACD) framework. The company has been focused on the ACD framework for years, but it wasn't until the collaboration with VIKTOR that the framework transformed into an easily accessible and usable tool for engineers. The holistic modular ACD framework laid the foundation for the ACD Resistance Module; a ship design tool on the VIKTOR platform that is used to optimise hull ship design in the initial and concept design stage so that the vessels become cost-effective to operate and affordable to build.

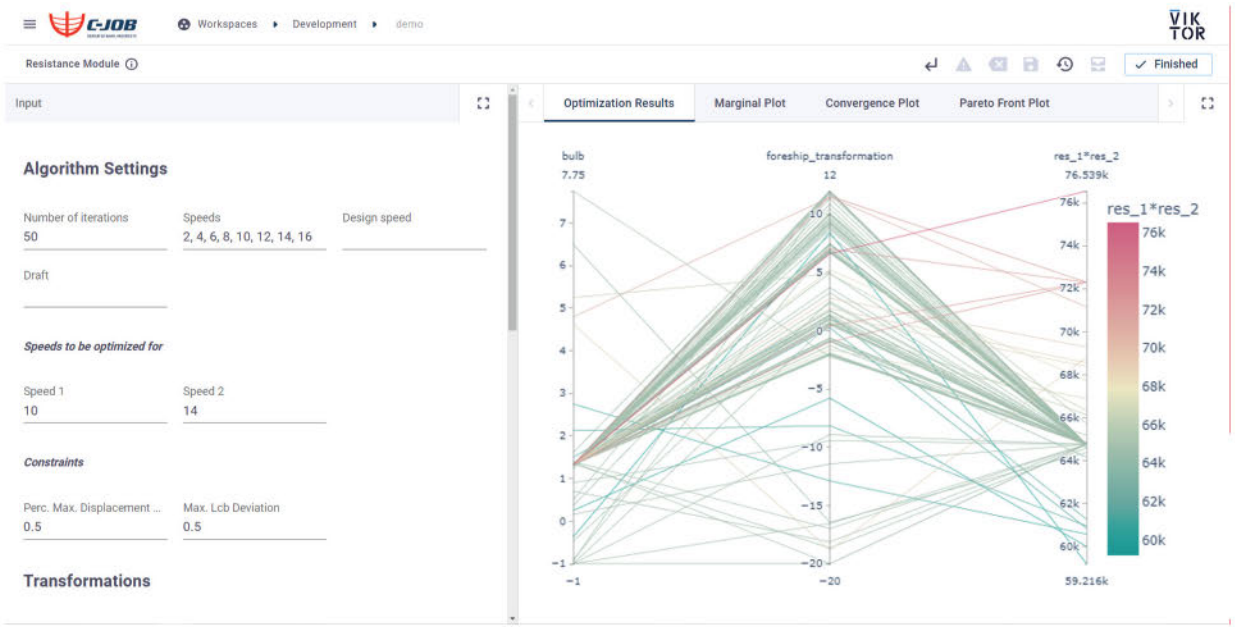
Cloud-based app

In order to support C-Job with the creation of the ACD Resistance Module, VIKTOR provided a team of developing engineers that offer expertise and co-development throughout the process of turning the idea into a usable web app. In essence, the VIKTOR platform is a web-based platform on which online applications can be built. These applications are developed using a very widely used programming language: Python. In an application, Python is used to program professional and business knowledge. One of the specific functionalities of the VIKTOR platform is the integration of all relevant data sources and software programs. As a software company with engineering DNA, VIKTOR was the perfect candidate to bring C-Job's vision to life with a team of developing engineers that offer expertise and co-development throughout the process of turning the idea into an easy-to-use Python web app. Moreover, the collaboration between VIKTOR and C-Job on a solution that helps people unlock their engineering to an exponential degree is a spot-on reflection of VIKTOR's mission.

ROY DE WINTER, C-JOB NAVAL ARCHITECTS

Energy requirement

One of the key aspects of the cost-effectiveness and sustainability of a ship is the energy required to be able to sail efficiently at the operational speed(s). The ACD Resistance Module ensures that the hull is optimised so that the design speed can be reached with the least amount of resistance possible. Therefore, the energy required to operate at the shipowner's desired speed is reduced. The energy requirement has become more important in recent years, especially now that carbon-neutral energy carriers take up more space per kWh compared to traditional fuels, we need to put extra effort into resistance reduction. This extra effort toward sustainable energy carriers and resistance reduction resonates with C-Job's vision 'A sustainable maritime industry within one generation'. Besides that, resistance reduction leads to energy and operational cost savings. Resistance reduction also directly impacts how much emissions are emitted during the operation.



ACD RESISTANCE MODULE

Parametric design

The ACD Resistance tool relies on parametric design principles. This is a design approach that uses flexible models that can be adjusted and solved quickly to automatically generate desired solutions. With parametric design, engineers can generate better designs in less time, find the optimal design solution fast, make better and more informed decisions, and become flexible to (last-minute) changes, without causing any errors or delays.

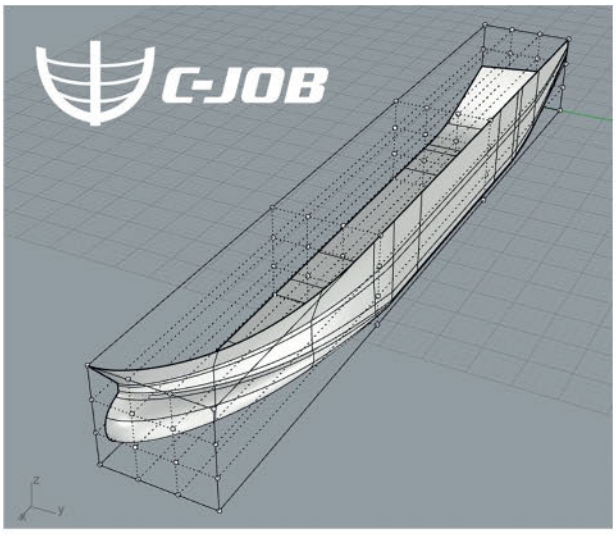
C-Job was able to leverage the principles of parametric design in their tool through the VIKTOR platform, as it specialises in leveraging parametric design in the cloud.

How it works

The Resistance Module optimises a hull for a set of design speeds. These design speeds are defined in the operational profile which is delivered by the client or realistically created by C-Job based on various data sets. After the set of desired design speeds is chosen, the vessel is parameterised. Parameterisation is carried out based on certain constraints varying the main particulars of the vessel (e.g. length between perpendiculars, moulded breadth, draft, depth, foreship length, aftship length, etc.). When the parameterisation process is finished, different design variations can be generated. Each and every design variation can be evaluated with resistance estimators. Based on the outcome of these simulations, the naval architect finally computes how much power and energy is required to sail at the desired operational speeds.

Simulators used to estimate the required power to sail at certain speeds can be fast or more computationally demanding. Tools integrated into the resistance module are the fast resistance estimation methods from NavCad (besides NavCad, C-Job also offers a special service for later design stages where STAR-CCM+ is used to compute the power requirements). NavCad is sufficient in the early design stages since during this phase, only the main particulars are varied and optimised. The exact sizes of the bulb, propeller, or other hull appendages for example, are not yet optimised and can still be modified in later stages.

Besides the parameterised vessel and a resistance estimation tool, the third and key ingredient of the Resistance Module is an optimisation algorithm.



THE HULL OPTIMISATION PROCESS

Where first naval architects would try many different design variations manually, at C-Job a state-of-the-art in-house developed optimisation algorithm is coupled to the resistance module in the VIKTOR platform. The self-adaptive optimisation algorithm learns on the fly and steers the resistance estimation tool toward the global best solution. The algorithm does so by proposing parameter values that modify the vessel design, this modified design is evaluated by NavCad,

the outcome is given back to the optimisation algorithm, the optimisation algorithm learns from this outcome, and then adaptively proposes better solutions until the most optimal hull for the given operational conditions is found.

Optimal solution

Following the combination of all required input into the ACD Resistance Module on the VIKTOR platform, the optimal vessel design that is found is presented to the user – in this case the naval architect. The naval architect works out the vessel in more detail and implements practical changes where needed. This is why engineers use the VIKTOR platform, it allows the automation of workflows and simplifies complex tasks, giving them more time and flexibility to analyse different scenarios, reduce risks, and, in this specific case, generate better designs. Finally, the optimised and detailed vessel is finally delivered to the client who can then decide to move on to the next design stage.

Capex

The ACD resistance module optimises a ship's hull based on its resistance, which in turn will result in superior building costs (capex) for shipowners. This creates a ship design that ensures the highest quality design is delivered in the shortest amount of time.

By using the tool during this process, the chance of having to make changes later in the process based on key decisions made earlier in the design is reduced to almost zero, allowing for a smoother process during the whole ship design.

Sustainability

Once the vessels optimised with the resistance module are built, they will emit significantly fewer greenhouse gasses (GHG) compared to their non-optimised counterparts. Both C-Job and VIKTOR are committed to solving complex, modern challenges such as reducing harmful emissions in the maritime industry.

Finally, with the amount of data available and the insights they provide, it should be the foundation of key decisions. Optimisation processes are labour-intensive but very essential to ensure reliability and efficient results. Together with the VIKTOR platform, C-Job was able to create this tool by combining its experience with R&D, data science and coding with VIKTOR's experience in software development for engineering. Thus creating the ACD Resistance Module, a handy tool that automates and speeds up the ship design process. One that allows naval architects to automate ship design optimisation which will lead to optimised vessels for any given scenario. ■

INLAND & COASTAL VESSELS

OPTIMISED PARSIFAL HULL DESIGN READY FOR LOW WATER LEVELS

By **Daniel Johnson**

Transport along Europe's inland waterways is vital to trade, with the river Rhine one of the continent's busiest waterways. Part of the Rhine-Alpine corridor, the 1,232km-long river runs from the Swiss Alps through Liechtenstein, Germany, Austria, France and the Netherlands.

In recent years the Rhine has experienced severe low discharge extremes which have impacted the river's transport capacity for periods of several months, causing shortages of source materials and fuels in regions far inland. Prolonged droughts of this magnitude are not uncommon historically, but concerns have been raised that climate change may further increase their frequency and severity. This and developing environmental regulations will likely have a considerable bearing on future vessel design.

Back in 2020, in a nod to its proven ability to build efficient and sustainable ships and experience in building vessels with a shallow draught, Dutch shipyard Concordia Damen was commissioned for 40 'eco-friendly' inland dual-fuel tankers, to be chartered by Shell, operated by VT Group/Marlow and used to transport mineral oils between Antwerp, Amsterdam, Rotterdam and various Rhine destinations. The 110m-long and 11.45m-wide so-called Parsifal tankers have a low-emission LNG propulsion system and extreme shallow-draught capabilities – 2,875tons of freight on a 3.25m draught – to maximise cargo capacity on the sometimes precariously low water levels on the Rhine network.

Optimal speed-power curve

Concordia Damen naval architect Pieter Baggerman tells *The Naval Architect* that the company's in-house design takes into account the different water levels and current speeds along the entire Rhine corridor between Rotterdam and Switzerland and that the ship can even sail with an empty draught of 1.15m. "Extensive CFD calculations were carried out to achieve the most efficient hull shape and optimal speed-power curve, resulting in low hull resistance in combination with high displacement and shallow water possibilities," he says.

"We see changes coming, understand what they mean and can thereby process them quickly and effectively in our services," adds Concordia Damen CEO Chris Kornet. "The Parsifal tankers represent a new generation of eco-conscious vessels that will play a significant role in the maritime energy transition."

The ships reaches a high speed with relatively low power: more than 22km per hour with 2 x 500kW engines.

The first vessel of the 40-vessel project, *Blue Marjan*, was delivered in December 2021 but following the Russian invasion of Ukraine in February 2022 and spiralling prices for LNG as a marine fuel, the number

BLUE MARJAN, THE LEAD LNG-POWERED INLAND TANKER FROM THE PARSIFAL SERIES FOR SHELL. SOURCE: MACHINEFABRIEK DE WAAL

of vessels in the series was shortened and so far just 11 of the tankers have been delivered.

However, the Parsifal design has caught the eye of other shipping companies in recent months. In January, inland navigation entrepreneur Luit Nanninga commissioned Concordia Damen to build and equip a version for his Zwijndrecht, Netherlands-based company, Quinto Scheepvaart. For Quinto, the order also marks the switch, after 25 years, from container shipping to tanker shipping.

Nanninga tells *The Naval Architect* that Quinto had been planning to go into tanker shipping for some time. "We came to Werkendam [Concordia Damen's hometown] for repairs and were interested in the Parsifal tankers," he says. "After a conversation with Chris Kornet, we visited the shipyard and viewed the ships. What particularly appealed to us was that this type was designed in such a way that it combines low resistance and a shallow draught with a large cargo capacity. This makes the ship more efficient and the transport per ton also more environmentally friendly."

He adds: "Another advantage is that smaller propellers can be used, which is very useful when the river is low – something happening a lot these days. We quickly came to the conclusion that this barge was a good fit for us. Both my sons then went on a trial run, after which we decided to make a contract for construction and finishing. Of course, we have a number of specific wishes and we have had good discussions about them. Concordia Damen nicely picked up on our wishes and adapted their basic design accordingly."

The stern side installation of Quinto's tanker will be split into two 'houses'; a house for the family and a house for the crew. CCM3, part of Concordia Damen Shipbuilding, has been chosen for the installation and finishing of the vessel.

Pieter Baggerman notes that Parsifal tankers are designed in such a way that the type of propulsion per ship can be adapted to the wishes of the customer: diesel-electric, diesel-direct or LNG-electric. Quinto's ship will sail with Caterpillar engines and is Stage V compliant. The tanker is expected to be delivered within a year, in December 2023.

Dry cargo design

The Parsifal's optimised hull shape has also attracted the attention of Dutch inland shipping company Amer Shipping. With a fleet of 57 vessels, including owned tankers, dry cargo and container vessels as well as associated ships, the company is active in the Netherlands, Belgium, Germany and Switzerland and transports approximately 8 million tons of cargo per year, mainly raw materials for construction projects and project cargo for various industries. It recently placed an order with Concordia Damen for two 'CDS Dry Cargo 110' vessels.

"The design of the lower section is the same as that of our Parsifal tankers," says Baggerman. "It works really well and so we have applied the same design principles to our container and bulk carriers and with the same results."

THE HULL SHAPE OF THE CDS DRY CARGO 110 VESSELS IS BASED ON THE PARSIFAL TYPE TANKER. SOURCE: CONCORDIA DAMEN

This was a decisive factor in Amer Shipping's choice of newbuild. Peter Buijks, the company's co-owner, says: "The CDS Dry Cargo 110 transports no less than 200tons more cargo compared to the existing '110' in our fleet. At the same time, fuel consumption and emissions are reduced due to the low resistance. In addition, we can continue sailing with it for longer periods in water levels of 1.15m, although the ship is of course not fully loaded in those circumstances."

Buijks adds that in Germany there are not only draught restrictions, but also numerous waterways spanned by low bridges. "Due to the favourable air draught of these ships, we can sail under bridges of 4.3m with a draught of 2.5m. This way we can continue to do business in a responsible manner in different circumstances," he says.

Amer Shipping's vessels will be fitted with Stage V engines and shaft generators to ensure that the energy supplied by the propeller shaft during journeys is not lost. This energy will be used for the general power supply onboard. Energy is also fed into a 48-battery system which provides energy to the living quarters and spud poles for at least 12 hours. This solution makes a generator (65kW) largely superfluous and saves 10l of gas oil per hour, according to Buijks.

Buijks explains that Amer Shipping's customers are increasingly looking at their CO_2 emissions and that the company has been working on making its daily operations more sustainable for a number of years. "The two bulk carriers are based on Concordia Damen's Parsifal tankers and a lot of research has been done on them, such as speed versus fuel consumption, resistance and future adaptability. These ships fit in well with that goal," he says.

What was also really important to Amer Shipping was short delivery times. "Since we started building some of our proven designs in stock, we can deliver faster. In this case, we expect deliveries in June and the end of 2023," concludes Baggerman. ■

MARINE 4.0

DIGITAL CHEMISTRY

By **Daniel Johnson**

SOURCE: FUELTRUST

As shipping moves towards its 50% carbon reduction target in 2050, the progress of vessels in relation to this goal will be assessed based on historical baselines going back to 2008. Finance decisions, tax levies and ESG reporting will all be driven by this assessment of vessel performance and could result in major financial implications.

"Whether you're calculating carbon emissions in support of CII, ETS, or your own ESG initiatives, producing detailed and accurate emission assessments is no longer a reasonable 'nice to have' goal or a 'too hard to get' response. With impending EU and ASEAN tax schemes coming in 2024, guesstimates or generic calculated reporting could leave you unfairly financially penalised," warns Darren Shelton, chief product officer at software-as-a-service (SaaS) startup FuelTrust.

According to Shelton, shipowners with a detailed and verified baseline assessment of historical emissions, based on scientific analysis, will have a commercial advantage over those using current emissions models that can only estimate performance.

AI-based emissions analysis

Last year, FuelTrust – headquartered in Houston, Texas, and co-founded by Shelton, a 27-year veteran of the maritime industry, and CEO Jonathan Arneault, a former IBM executive involved with the Watson AI technology – launched Carbon Baseline. The cloud-based solution uses an AI 'Digital Chemist' and blockchain technology to deliver a validated historic carbon baseline "in weeks, not months".

With this validated historic carbon baseline, owners can increase charter pricing for validated green ships, certify applications for carbon credits, and with FuelTrust's independent emissions scoring, seek lower carbon taxes and fees globally, says Shelton.

He adds: "Current emissions models offer only rough estimates based on generic calculator models that don't account for chemical interactions, source fuel data, or supply and delivery chain impacts. Many also require massive amounts of manual input, or the installation of costly, high-maintenance devices aboard vessels."

As an example, Shelton points to a shipowner client who had reported fleet emissions using the standard DCS emissions ratios. "When we examined their fuel lab results and operations data using our artificial intelligence technology, we discovered that the fuels they purchased, and the engines that burned them, produced at least 8% lower CO_2 emissions than reported... and that was before any equipment and operational improvements. If they had to pay EU carbon taxes on a typical year's European destination voyages based on their DCS analysis, they would have overpaid by more than €500,000 per year."

The company's patent-pending Digital Chemist uses historical operational data to calculate prior-year GHG emissions profiles for a vessel or fleet. Its AI algorithms provide calculations based on a simulation of combustion at a molecular level, which considers differences between batches of fuels, and deliver an assessment of fuel performance and regulatory compliance based on specific and actual vessel activity, rather than manufacturer and supplier specifications alone.

"Exact calculation is essential for the industry as not all fuels are created equal," says Sheldon. "Recent studies have shown that, for example, there can be an energy density difference of up to 3% between batches of the same fuel. There is also a significant carbon difference between batches.

"By offering this higher level of granularity in our data, we can give owners and charterers a far better picture of what their GHG performance has been in the past and what will be in the future."

Shelton continues: "With Carbon Baseline, class or flag authorities can be provided a more accurate, third-party verified report on the emissions reductions actually achieved, meaning the fleet owner, their customers and their investors can benefit."

Carbon Baseline outputs a blockchain certificate for its findings, creating a fixed-in-time, immutable record. As explained by Jonathan Arneault, this makes it easier for fleets to apply for carbon credits, and the permissioned blockchain allows only authorised persons to view the data. "Blockchain allows companies to share information but not have it reshared...," Arneault says,

"...it gives really good privacy while at the same time allowing trust and transparency."

Return on investments

Since Carbon Baseline can provide emission results from previous voyages, it not only helps to certify past emissions, but it can also help to verify the return on cleantech investments shipowners have made over time, such as adding a scrubber or hull coating. In March, FuelTrust announced results of its work with Ridgebury Tankers to validate emissions reductions for the maritime asset management firm's fleet.

Using FuelTrust's AI technology, Ridgebury has assessed fuel and operations data from past years for its Suezmax tanker *Ridgebury John Zipser*, comparing month-by-month and year-by-year performance to establish a baseline for carbon emissions, from which it could measure vessel improvements. The analysis also showed the value of a scrubber retrofit for the vessel and the impact of HFO fuel quality on carbon emissions.

According to Arneault, analysis using Carbon Baseline has helped Ridgebury to understand, to the kilogram, the entire emissions stack of the vessel, covering CO_2, NOx, SOx, CAP and HAP emissions.

"At low cost, Ridgebury has been able to analyse the effects on vessel performance of installing a scrubber, a silicone hull coating, and buying higher quality fuels. The insights available to Ridgebury through FuelTrust's technology would previously have been possible only by using an extensive and costly assortment of physical sensors and emissions-lab assessment consulting," he says.

FuelTrust's approach goes beyond simply applying a reduction in estimated emissions for each new piece of technology fitted to a vessel. The company uses AI-based virtual models of engines, scrubbers, coatings, and other clean technology when it analyses ship performance. The AI technology can switch a particular virtual technology 'on' or 'off' and observe outcomes for past and future investments. It can therefore provide insights into investments in technology, changes to operational practices and fuel choices, and accurately model the benefits of combining these decisions.

Building on this initial project with Ridgebury, FuelTrust is now analysing additional tankers to assess how fuel choice and operational behaviours could reduce emissions. As part of the next phase the firm will produce an analysis of the relative financial and environmental benefits that could be accrued through the installation and effective operations of a scrubber by model. The company will also provide insight into optimal HFO outcomes versus continued use of VLSFO without retrofit. ■

SMARTER ROUTING

By **Alan Johnstone**, Correspondent

When you climb into your car it doesn't matter if you don't know how to get to your destination. Thanks to your smart phone, and/or smart vehicle, you can plot a desired location into whatever satellite navigation system you have and, voila, off you roll. At sea, however, it's a little more complicated.

"Well, for one thing, you have a lot more 'roads'," says NAVTOR's Aslak Dirdal, one of the driving forces behind the development of the Norwegian maritime technology company's new Auto-Routeing solution. "There's a huge number of variables and a great many decisions that have to be made. Plotting optimal routes can be a painstaking process, but obviously a crucial one.

"It's something our customers have been dreaming of simplifying for at least the last decade... if not more."

Dirdal then sits back to demonstrate how Auto-Routeing, a subscription-based module on NAVTOR's NavStation platform, works. He zooms in on an exact berth in the port of Southampton and then another in the Port of New York and New Jersey. Clicks a tab, and two seconds later a detailed berth-to-berth route (including voyage distance and duration) emerges.

NAVTOR's solution is built on the firm's track record with ENCs, an integrated eco-system of digital solutions (gathering all voyage critical information on a single platform, NavStation) and a constant feed of real-time global AIS data. The result is an intuitive solution that instantly calculates the shortest available routes, down to the very finest details.

"NAVTOR's Auto-Routeing is unique in that it takes you, if desired, from one individual berth to another, anywhere in the world," Dirdal states. "It is simple, highly efficient and dependable. Furthermore, if you want to plan from point to point, then that's fine too. Using the route planning function you can plot from one waypoint to another, press calculate, and all the other waypoints along the route will appear. This can be done from a vessel's current location, or from any given point for that matter."

"It puts navigators in control," he says. "And when that functionality is combined with NavStation's other layers – such as weather routing, environmental regulations, NavArea warnings, passage planning, port data and so on – everything they need is at their fingertips, in one place. We believe it's a transformational tool."

The suggested route can be compared to alternatives (also generated by the module's proprietary algorithm at the touch of a button), with navigators reviewing and refining suggestions to meet their exact needs. For example, 'blockers' can be activated along the way to avoid areas, such as busy straits, shallow water, port entries or canals, additional ports or waypoints can be added, cargo specified, and all routeing alternatives controlled. Suggestions can also be saved for further route and passage planning purposes.

NAVTOR'S BØRGE HETLAND AND ASLAK DIRDAL

And crucially, Dirdal adds, it is "a living thing".

"We're not just releasing this to the market and that's that," he stresses. "This is constantly consuming data and updating on a weekly basis, leading to continual improvements and optimal accuracy.

"It's important that this is a solution the whole industry can trust (NAVTOR has e-Navigation and performance monitoring and optimisation products and services on over 8,000 vessels), so we're investing in continual refinements and development."

Driving development

Børge Hetland, NAVTOR's chief commercial officer describes the development of the module, which launched last year, as "a perfect demonstration of both NAVTOR's vision and ability".

He comments: "We always want to be the forefront of innovation, driving change. But not for ourselves, not at all. It's our mission to listen to this industry, understand our customers' key challenges and see if we can design smart, digital solutions that solve them, delivering competitive advantage.

"Shipping is complicated and, some would argue, constantly increasing in complexity; with new regulations, commercial demands and operational challenges. However, with innovations like Auto-Routeing we can turn that on its head, automating tasks, integrating planning and greatly simplifying life at sea. That benefits navigators, of course, but it also drives efficiencies for shipping companies, and that impacts positively on the bottom line."

Hetland concludes that the rapid uptake of the solution, and ongoing positive feedback, demonstrates the demand for such a breakthrough. "But then that's not too unexpected," he jokes. "After all, they've been dreaming about this for some time!" ■

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NOISE & VIBRATION

CANADIAN STUDY TAKES CAVITATION AWARENESS CLOSER TO THE EDGE

By **Richard Halfhide**

As any marine engineer or hydrodynamicist can tell you, propeller cavitation is a reality of shipping. But as the causes of anthropogenic underwater radiated noise (URN) fall under increasing scrutiny from environmentalists and regulators there is mounting pressure to develop a deeper understanding of this perennial problem. This has been particularly true in Canadian territorial waters, where under the auspices of Transport Canada the mitigation of URN has led to sponsorship and assistance in a variety of research endeavours.

BODO GOSPODNETIC

Last year, a Canada Transport-funded study into the impact of manufacturing tolerances on propeller performance – undertaken by Memorial University of Newfoundland, Defence Research and Development Canada (DRDC) Atlantic Research Centre, and led by Ontario-based propeller manufacturer Dominis Engineering – revealed that even the slightest deviation in propeller geometry can have huge implications for propeller cavitation. With IMO's Marine Environment Protection Committee (MEPC) due to discuss a draft of its revised URN guidelines at MEPC 80 in July, there are calls for this research to fall under its consideration.

Ageing standards

While Computerised Numerical Control (CNC) machining of ship propellers has been in use since the late 1980s, when Bird-Johnson first deployed the technology for the manufacturing of propellers for the US Navy, it's a technique that's only really used for rough machining. The overwhelming majority of blades are still laboriously finished using hand grinding, radial arm drills and metal templates, introducing inaccuracies and deviations from the intended design that reduce efficiency and cause cavitation.

It's also remarkable that commercial ship propellers continue to be manufactured to the same tolerance standard, ISO-484-1, which was formally established in 1981 but originally recommended as far back as 1966, an era when the Wageningen B-series propeller had firmly established its supremacy.

Moreover, ISO-484-1 only measures thickness at seven radial section points, where the leading edge is also measured, and allows for a significant margin of error. The US Navy uses its own ship construction standard, NAVSEA [Naval Sea Systems Command], which is broadly similar, although with a higher number of radial section points on the propeller which have to be measured during an inspection (see Table 1).

Dominis Engineering president Bodo Gospodnetic explains: "For propellers it's important that the propeller design is optimised for performance inside the wake behind the propeller. Whilst you may have a good design, you have to manufacture it to as close as possible a replication of that design.

'Hands free' propeller milling

Unlike traditional manufacturing Dominis Engineering, the company founded by Gospodnetic and his late father in 1985, crafts its propellers without any manual grinding. Convinced that no amount of hand grinding skill can ever deliver the necessary quality, they spent years developing a proprietary process for CNC machining capable of delivering propellers to their final form and finish, as well as new protocols for representation of all propeller surfaces and their edges. These edges are manufactured cord-wise, rather than the more conventional approach of span-wise.

After initially securing contracts to deliver hydro turbines it later secured jobs with the US Navy (USN), which it has been supplying now for some 20 years, including projects

TABLE 1: NAVSEA CLASS I VS. ISO 484-1 CLASS S TOLERANCES

Propeller dimension	NAVSEA Class I		ISO 484-1 Class S	
	Imperial	Metric	Imperial	Metric
LE form	±0.015 inch	±0.38mm	±0.020 inch	±0.50mm
Surface roughness	63µinch	1.6µm	79µinch	2µm

such as the USN's Littoral Combat Ships, as well as naval vessels for other countries. Much of Gospodnetic's time is now spent engaged upon propeller tolerance research, presenting a paper at SNAME's Propeller & Shafting Symposium in 2015, but Dominis also has the merchant shipping sector in its sights.

He explains: "It's important to realise that all propellers will eventually cavitate, whether that's at 12, 15 or 18knots. When designing a commercial propeller it's really a balance between efficiency and cavitation, because the propeller tip is so important when it comes to propeller loading... What we've done at Dominis Engineering is say forget about the standard, let's see what kind of precision we can really achieve."

Cavitation can be divided into three categories: bubble cavitation, which can be managed by changing a propeller's geometries so that it only occurs above a vessel's top speed; sheet cavitation, which occurs at locations along the leading edge; and vortex cavitation, which typically begins at the propeller's tip and hub and trails downstream. The latter is usually the first type of cavitation to form and has the lowest cavitation inception speed.

Despite their shortcomings, both the ISO And NAVSEA standards place an emphasis on the leading edge. Although the ideal is for a curved outline, the grinders used for finishing can often cause flat spots that compromise this. Another possible cause of damage to the leading edge can be cleaning of fouling from the propeller during maintenance.

Research project

For the study undertaken by Dominis and its project partners a propeller blade from an in-service Royal Canadian Navy vessel, HMCS *Nipigon*, was examined for defects. This identified a sharp-edged flat adjacent to the leading edge which deviated by 0.5mm from the 'as designed' form, at the limit of tolerances permitted by ISO-484 (see Figure 1).

Using Reynolds Averaged Navier-Stokes (RANS) CFD, researchers at the DRDC-Atlantic Research Centre, and Memorial University of Newfoundland, ran simulations for sections of the propeller blade both for the ideal geometry and leading edge defects of 94µm, 250µm and 500µm.

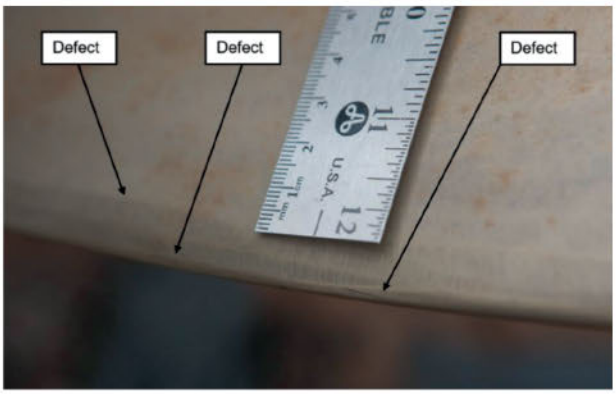


FIG 1: LEADING EDGE DEFECTS ON THE IN-SERVICE PROPELLER BLADE. SOURCE: DRDC-ATLANTIC

Meanwhile, physical experiments of cavitation inception on these sections were conducted in a cavitation tunnel using 2D foil model, incorporating sections both 'as designed' and 'as built' (containing the same flawed surface as the original propeller blade). These had been CNC milled from solid blocks of aluminium to 'final form and finish' using Dominis's own 'hands off' process and laser scanning of the models found them to be accurate to within +/- 0.100mm (+/- 0.004inch). Minimum pressure coefficients and cavitation numbers were developed and measured over a variety of different angles of attack.

The CFD calculations predicted that a typical propeller blade section with a 0.5mm defect on the leading edge would result in a narrower cavitation bucket, indicating that such defects have the potential to cause much earlier cavitation on propellers. But perhaps the more dramatic results were the contrast between the perfect and defective physical models of the typical propeller blade section, where the loss in cavitation inception speed caused by a 0.5mm leading edge defect was found to be as much as 35%. In other words, to avoid cavitation the vessel would need to drastically reduce its speed compared to a propeller without those flaws.

Next steps

Having identified and demonstrated the problem, Gospodnetic and the Dominis Engineering team are now busily engaged in further investigations. He explains: "We originally planned for this research to have four different parts: Phase 1 was the two-dimensional propeller section with a rectilinear flow with defects on the leading edge which hinder tolerance. I repeated the experiments which we conducted for Transport Canada and expanded it to two more types of defects – just in case that was a fluke – and the trend was the same.

"The next part will be to see what is the impact of these leading edge defects on the tip vortex cavitation and the impact on the leading edge vortex. Does this defect precipitate the tip vortex cavitation? We plan to do this in what I call a wing plan form of a propeller blade, where you have all the sections but they are de-pitched so you have a 100% rectilinear flow.

"The third phase would be to do this in a full-size propeller. Two propellers, one that is manufactured as best as possible and the other with defects on the leading edge, and run it on the ship sea trials with cavitation observations from the inside of the hull. We're hoping to get this going together with Defence Research and Development Canada for a propeller that's less than 2.5m, with a fourth phase for propellers greater than 2.5m."

However, he remains concerned that some of the findings may be swept under the carpet by those who would sooner propeller tolerances weren't held to such exacting (i.e. potentially more expensive) standards.

"Nothing's going to happen until IMO tells shipowners it may cost them but they have to do it if they want a licence," he warns. ■

MAERSK'S 'RADICAL RETROFITS' STUDIED FOR NOISE REDUCTION SOLUTIONS

By **Brittany Hook**, Scripps Institution of Oceanography at University California San Diego

Researchers at the University of California San Diego's Scripps Institution of Oceanography have been eavesdropping on the marine soundscape for decades to study the ecology of marine animals and the threats they face. This effort is made possible with instruments known as high-frequency acoustic recording packages, or HARPs, that use an underwater microphone, or hydrophone, to record everything from whale songs and dolphin clicks to passing ships and military sonar.

For more than 10 years, one such HARP instrument has been continuously recording sounds in the Santa Barbara Channel, a heavily trafficked shipping route off Southern California that is an important foraging region for the endangered Northeast Pacific blue whale and other marine life. Sitting on the seafloor at a depth of 580m, the instrument opportunistically measured noise from container ships operated by shipping company Maersk before and after a major retrofitting initiative.

This long-term dataset has informed a new study led by researchers in the Scripps Whale Acoustics Laboratory in collaboration with Maersk. The Scripps and Maersk teams worked together to identify vessel designs that would reduce radiated noise and source levels, with implications for quieting shipping on an international scale. Their findings were published in March 2023.

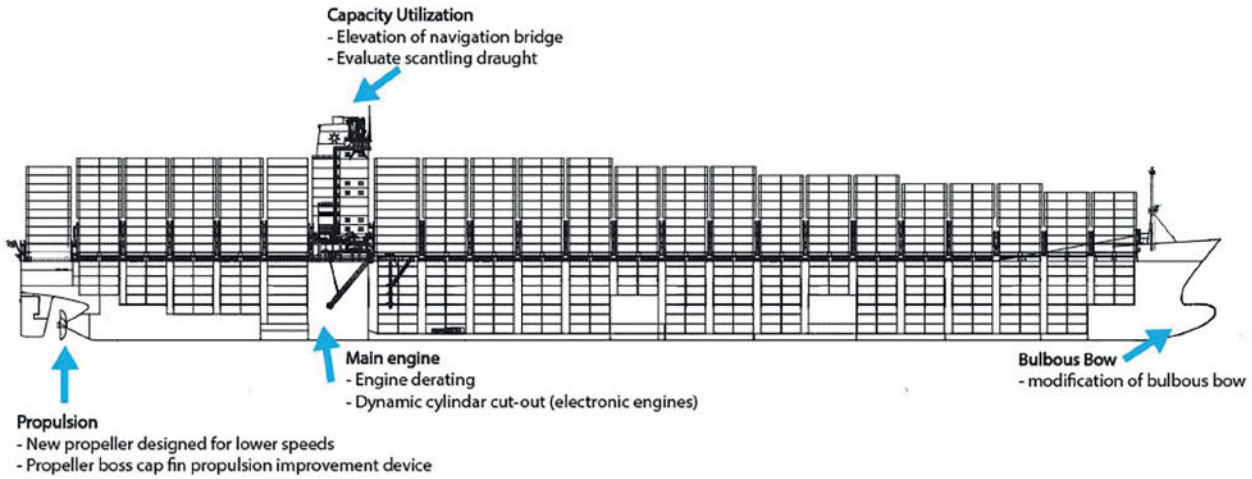
"Human-made underwater noise in the ocean can negatively impact marine organisms that rely on sound for daily life functions like communication, navigation, and foraging," says Scripps PhD student Vanessa ZoBell, lead author of the study. "This paper was a first step in assessing whether retrofitting had an impact on noise levels, and it was an interdisciplinary effort involving marine scientists, industry, naval architects, and policy experts. We need all hands on deck to establish solutions for the modern ocean."

The research collaboration emerged following Maersk's completion of a US$1 billion, five-year "Radical Retrofit" initiative focused on improving energy efficiency and fuel consumption to reduce emissions. During this effort, 12 of Maersk's G-class container ships were retrofitted from 2015 through 2018. The Radical Retrofit programme included redesigning the bulbous bow to reduce drag and derating the engine to improve vessel efficiency at slower speeds. Additionally, the propeller blade number was reduced from six to four, engine rpm was increased by 10%, propeller diameter increased from 9m to 9.3m, area and thickness of the propeller blades was reduced, and propeller boss cap fins were installed to reduce cavitation. Post-retrofit, each vessel's capacity was increased from around 9,000TEU to approximately 11,000TEU, which required a draft increase of the vessel by 1.5m on average.

While the primary goal of the retrofitting effort undertaken by Maersk was to increase fuel efficiency, both Scripps and Maersk were interested in exploring noise reduction as a potential co-benefit of the effort.

"Underwater noise is increasingly recognised as an important environmental factor, and is starting to be addressed at the International Maritime Organization level," says Lee Kindberg, head of Environment and Sustainability for Maersk North America and a study

DOLPHINS DANCE ALONGSIDE A CONTAINER SHIP AT THE PORT OF LOS ANGELES. SOURCE: PORT OF LOS ANGELES



G-CLASS VESSEL POST-RETROFIT, MODIFIED FROM THE ORIGINAL BLUEPRINT PROVIDED BY MAERSK. CHANGES FROM PRE- TO POST-RETROFITTING ARE IDENTIFIED WITH ARROWS. SOURCE: ZOBELL *ET AL*, HTTPS://DOI.ORG/10.1371/JOURNAL.PONE.0282677

co-author. "The team at Scripps has unique expertise in this area; it is clear that we need additional info to design most effectively to both reduce underwater noise and greenhouse gas emissions. The best solution must address both of these issues."

The study identified retrofit-induced changes in the ships' radiated noise levels and monopole source levels. Radiated noise measurements account for the distance between the recording device (such as the hydrophone) and the sound it is recording (the ship noise) by correcting for the distance in-between the ship and the recorder. Monopole source levels account for what you would hear if you were positioned one metre away from the source, which in commercial ships is predominantly the sound from propeller cavitation, or pressure-related water cavities due to propeller motion.

The researchers focused on 111 transits from the 12 sister ships, pre- and post-retrofitting, as they made their way to and from the ports of Los Angeles and Long Beach. Marine animals including humpback whales, blue whales, fin whales, and dolphins were also recorded at the study site. Of the 177 total transits recorded between 2008 and 2018, 66 were excluded because of the presence of singing whales, as well as acoustic interference from other vessels and hydrophone cable strumming.

Looking at the data, the team identified a significant decrease of monopole source levels in the low-frequency band by over 5dB post-retrofitting. This noise reduction was likely due to the changes in the propeller and bow design, according to the authors.

Post-retrofit, they also measured a slight increase in the radiated noise level from the ships, likely due to the increased number of containers stacked on top of the retrofitted vessels. The additional weight likely caused the vessels to sit deeper in the water, changing their draft. The authors note that from one perspective, the increased cargo capacity will lead to fewer trips and thereby reduce ocean noise, however, this will only be true if global demand stays constant.

"One of the goals of the vessel retrofit was to add more containers, allowing the ship to transport more cargo," says John Hildebrand, principal investigator of the Scripps Whale Acoustics Lab and a co-author on the study. "This changed the draft of the ship which had an impact on the noise. It forced us to think about the noise relative to the number of containers transported, which was a new perspective."

The interaction between retrofit and speed in this study was also noteworthy, highlighting that the effect of retrofitting on monopole source level was greatest at slower speeds.

The IMO has recognised vessel design as a potential method to reduce underwater noise from commercial ships and recommends investigating specific propeller and hull design modifications to identify the most effective designs for noise reduction. Because multiple design changes occurred at once in the retrofitted ships highlighted in this study, it is difficult for the authors to disentangle which changes were most effective in reducing sound levels, so further research in this area is needed.

"I am hoping that this paper can be used to start discussions within committees focused on noise reduction efforts in the International Maritime Organization, International Whaling Commission, and International Union for Conservation of Nature, whether that be to focus on reducing noise per transit, reducing transits, or reducing noise per container," says ZoBell.

The authors also recommend that future studies further test the noise reductions found in this study with larger sample sizes, different ship types, and different design approaches to identify the most efficient methods for reducing underwater noise on an international level.

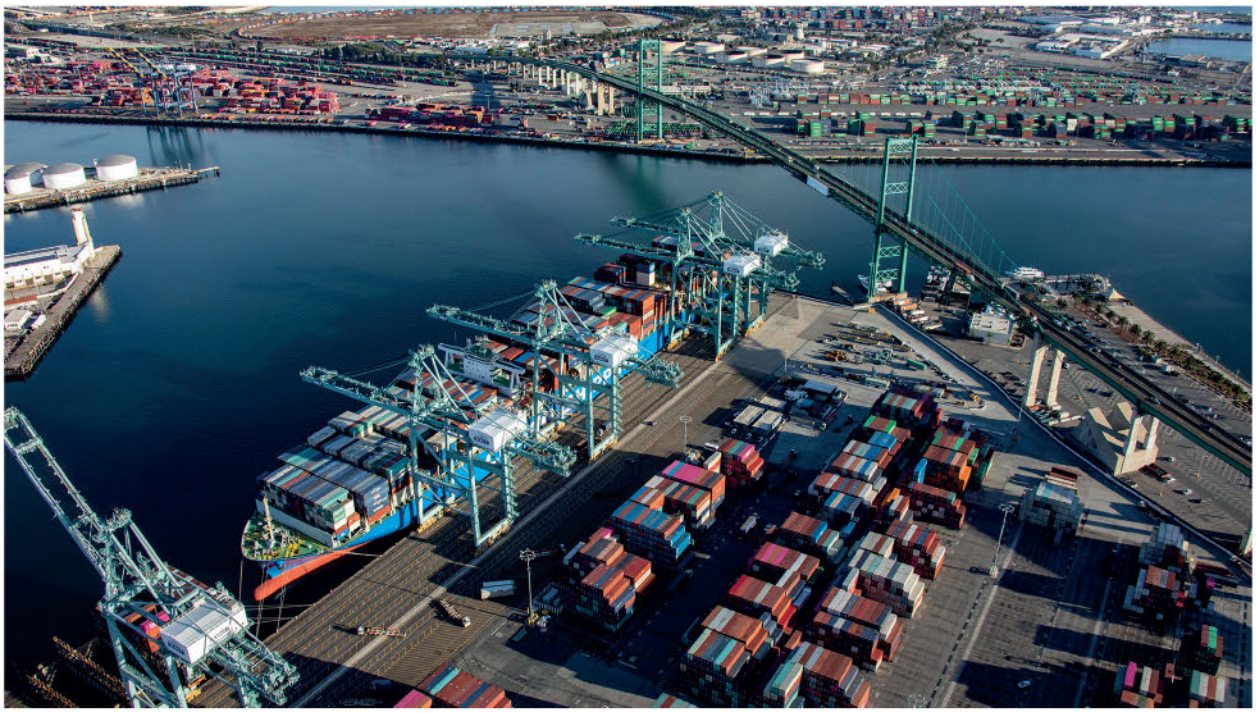
"Understanding the details of the vessel retrofit and ship operations, information that could only come from Maersk, was what made the study possible," says Hildebrand. "We look forward to similar collaborations as commercial shipping is adapted to have a lower carbon footprint and hopefully less underwater noise." ■

A copy of the research paper can be found at https://doi.org/10.1371/journal.pone.0282677

PORT STATE CONTROL

PORT STATE CONTROL'S INFLUENCE IN MARITIME SAFETY

By **Miguel Ángel Gómez Ruiz** and **Rodrigo Pérez Fernández**, Universidad Politécnica de Madrid (Spain)



Within the maritime safety field it's important to understand which actions must be taken at the moment when maritime accidents happen. As a consequence of this several states have decided to take actions to decrease the number of vessels with the potential to cause harm, and it's here that the Port State Control (PSC) was created. The PSC allows for the inspection of foreign vessels by participating states, in order to check if a vessel and its equipment fulfill the requirements in place according to the current international legislation.

Immediately after the maritime administration chooses a vessel for the PSC inspection, the PSC officers (PSCOs) rigorously evaluate its documentation, as well as the vessel's crew and compile a record of any problems detected. Within their main responsibilities, the PSCOs must make sure that a vessel follows the necessary requirements in its flag state.

The PSC regional schemes allow several states to carrying out inspections together in a harmonised way. The main goal being that sub-standard vessels cannot perform functions in their waters and that their states are not affected due to their way of conducting the inspections.

It's important to note Port State Control must have the capability of performing analysis of the causes that provoke maritime accidents and of getting the most amount of information regarding the characteristics and descriptions of the faulty vessels. It should also be noted that PSC is considered one of the most important tools for governing states of the ports to enable the control of compliance with maritime safety regulations, work conditions and contamination precaution.

Some studies have statistically and historically examined PSC inspection records, making note of variations recorded in historical PSC inspections and the relationship between these and vessel characteristics, for example, types of ships, flags of the ship, age of the ship, etc. and detention or deficiencies (Özçayir, 2004). McDorman (2000) analyses how regional PSC agreement and harmonised inspection promotes a continuous improvement in maritime safety. Other authors have studied the influence of PSC in reducing pollution from ships (Cuttler, 1995).

Even though the said analysis provides valuable information related to PSC inspections, the maritime administrative bodies can take either proactive actions or passive ones to solve problems in PSC inspections. To conduct maritime inspections in a

safe and efficient way, the administrative bodies require a tool in order to supervise PSC time-sensitive inspections and to facilitate a quick facilitation of the inspection's recommendations.

Methods

The statistical process control (SPC) is a quality control method that uses statistical techniques to track and evaluate a process (Salacinski, 2015). This article points out how SPC techniques could be used on PSC inspections to see if the occurrence of discrepancies detected in the inspections is normal at the time.

It is important to consider if SPC techniques are usable in maritime inspections. According to events detected in SPC, the motives of the inspection and anomalies are researched and debated. On the other hand, from a management point of view, the results can help the port administrations to take proactive measures to improve the inspections and reduce the occurance of future mistakes in a controlled environment.

Furthermore, it's important to note the role that the International Maritime Organization has taken in PSC. In 1981 the IMO decided to take into account the circulars and resolutions in reference to PSC with the goal of establishing the proper procedures to perform the inspections. Initially, a diverse series of resolutions were made that corresponded to the varied areas encountered during an inspection. With the passage of the time, this has turned into a more general and complete sketch of the resolutions.

At the time that it is required to perform the initial inspection a series of necessary criteria must be considered. The decision to inspect a vessel may be made because:

- A governing state of the port decides to begin an investigation.
- Another state communicates the information necessary to conduct an investigation and communicates it.
- Information is received from one or several members of the crew, union, association, professional association, or an individual that has any interest in the vessel's safety, passengers, protection.

When the inspection is performed by the PSCOs, the general impression of the state of the vessel must be noted. Within the ideal steps to follow we find the following:

- At the time of boarding the vessel, a checkup must be done, and first impressions should be noted on any damage that hasn't been repaired, the state of the paint and signs of corrosion.
- The history of the vessel should be researched and, inside it, corresponding data such as its dimensions and construction year should be considered. In this way it will be known which agreements can be applied.
- When the PSCO boards and introduces themselves to the captain or official in charge, they must review the relevant documentation and certificates according to the following cases:

1. Vessels

1.1 International certificate corresponding to arching.
1.2 International certificate corresponding to the freeboard/international certificate corresponding to the freeboard exemption.
1.3 Document corresponding to the minimum safety endowment between them: medical certificates and competence certificates.
1.4 PSC historical reports.
1.5 Emergency plans onboard in case there is a hydrocarbon contamination.
1.6 Cargo logbook.
1.7 Exemption certificate, in the case that there is one.
1.8 Among others.

2. Cargo ships

2.1 Safety certificate for the cargo ship.
2.2 Safety certificate corresponding to the cargo ship crew.
2.3 Certificate corresponding to the safety to do the ship's construction.
2.4 Document that guarantees that the transfer of dangerous goods can be done.
2.5 International certificate that indicates that the ship is apt to transport bulk liquefied gases as well as the certificate to do it in the case of bulk chemicals.
2.6 Among others.

3. Passenger ships

3.1 Safety certificate corresponding to passenger ships.
3.2 Information about the A/A-max relation (corresponding to ro-pax ships)

At the time of checking the certificates, these will be validated, and any observations made onboard will confirm that the ship's maintenance measures are the proper ones at the time that inspection is limited to the discrepancies seen. If the general impression of the PSCOs is that a vessel's crew or equipment doesn't follow the established rules, a detailed inspection must be done.

If there are any discrepancies, an inspection must be done where the following must be highlighted:

- If any of the certificates aren't valid.
- If there is any deficiency in contamination prevention procedures and safety.
- When the PSCO believes that the ship is in danger due to existing damage to its structure or hull.
- When the main members of the crew don't appear capable of communicating with each other or with other members of the crew.
- At the time that there is no possibility of cancelling a false emergency alarm.

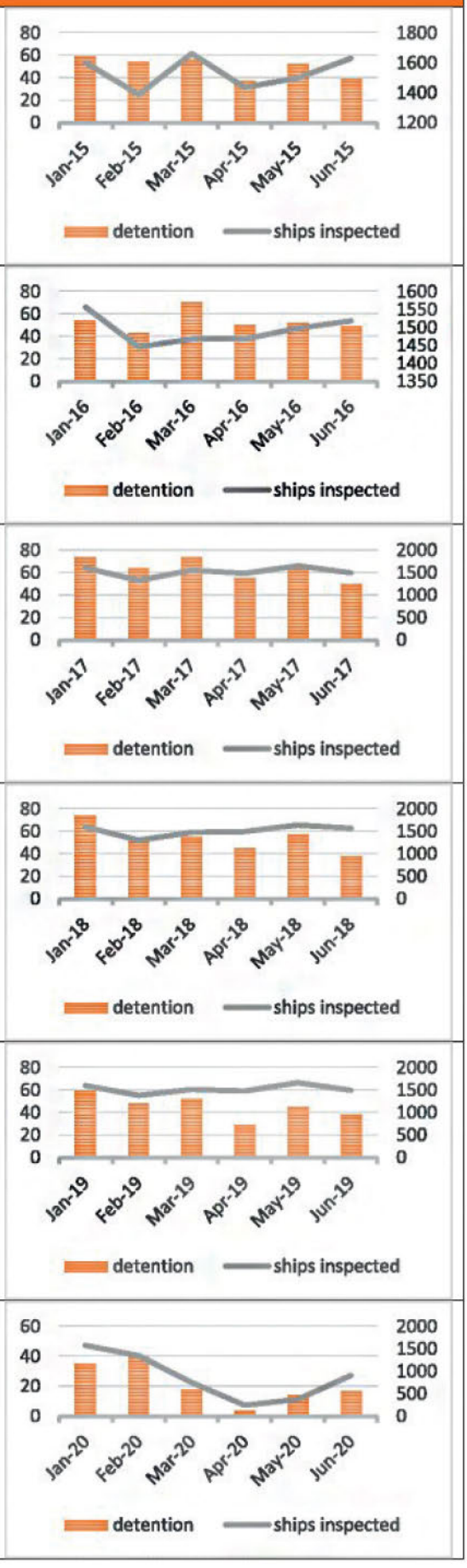
Main agreements and legal framework

According to Article 218, *Enforcement by port states*, in the United Nations Convention for the Law of the Sea (UNCLOS), if a ship is voluntarily in a terminal or port offshore of a state, the corresponding investigations can be done and if there is any evidence that warrants it, procedures can be done that allow for the ship's unloading.

Another article, Article 219, *Measures relating to seaworthiness of vessels to avoid pollution*, stipulates that "states which, upon request or on their own

FIGURE 1. PARIS MOU STATISTICS AND GREY RELATIONAL ANALYSIS DURING THE COVID-19 OUTBREAK

Month/Year	No. of detentions	No. of ships inspected	% of change in ships inspected	Ships inspected - detention graphics by year
Jan/15	59	1,600	-	
Feb/15	54	1,389	-13%	
Mar/15	56	1,662	20%	
Apr/15	37	1,436	-14%	
May/15	52	1,500	4%	
Jun/15	39	1,629	9%	
Jan/16	54	1,557	-	
Feb/16	43	1,446	-7%	
Mar/16	70	1,468	2%	
Apr/16	50	1,468	0%	
May/16	52	1,498	2%	
Jun/16	49	1,518	1%	
Jan/17	74	1,608	-	
Feb/17	64	1,330	-17%	
Mar/17	74	1,561	17%	
Apr/17	55	1,488	-5%	
May/17	64	1,653	11%	
Jun/17	50	1,499	-9%	
Jan/18	74	1,601	-	
Feb/18	53	1,302	-19%	
Mar/18	55	1,479	14%	
Apr/18	45	1,498	1%	
May/18	57	1,641	10%	
Jun/18	38	1,573	-4%	
Jan/19	59	1,602	-	
Feb/19	48	1,385	-14%	
Mar/19	52	1,516	9%	
Apr/19	29	1,482	-2%	
May/19	45	1,665	12%	
Jun/19	38	1,497	-10%	
Jan/20	35	1,577	-	
Feb/20	40	1,345	-15%	
Mar/20	18	746	-15%	
Apr/20	4	244	-67%	
May/20	14	375	-54%	



initiative, have ascertained that a vessel within one of their ports or at one of their offshore terminals is in violation of applicable international rules and standards relating to seaworthiness of vessels and thereby threatens damage to the marine environment shall, as far as practicable, take administrative measures to prevent the vessel from sailing." The states involved may permit the vessel to proceed only to the nearest suitable repair yard. When the causes of the vessels violation of the regulations have been eliminated it will be allowed to continue.

All of these requirements are stipulated by the International Maritime Organization, which has as its main goals the enhancement of maritime safety and security, the prevention of marine pollution, and increased energy efficiency. For this reason, the success that has occurred thanks to the implementation of these regulations has been emphasised by the maritime body. However, the responsibility of complying with the regulations falls on the ships' administrators, owners, crew and the flag state where the ship was registered.

Results and discussions Covid-19 impact

In the inspections conducted by the PSC regimes, the goal is to guarantee the possibility of always continuing with the global supply chain when the maritime normative can be followed and implemented, which guarantees the respect and safety of the environment. In light of the Covid-19 pandemic, inspections carried out onboard of ships have considerably diminished. As a result of this PSC regimes have created policies that focus on high-risk ships; for this they take into account the historical record of the inspections done. By looking at inspection numbers and detention factors, a current standard for the maritime sector can be generated.

According to the numbers obtained, it can be seen that by March 2020 inspections and deficiencies decreased dramatically in comparison to previous years. In the chart (Figure 1) the following categories are shown: month/year; number of detentions; the number of ships inspected; % of change in ship inspections; and detention graphs per year. These categories allow us to evaluate the results and inspections ratios from the selected period. Within the said chart, the number of detentions in the European Union is represented from the period of January 2015 to May 2020 in the number of ships inspected (Paris Memorandum of Understanding (MoU) Annual reports). It is represented in the following way: the number of ships indicates the amount of change in percentage in the number of ships inspected in relation to the previous month of the same year.

The average number of inspections included throughout the first six months of the years 2015 and 2019 is 1493 and 1536. It can be seen that there is a huge decrease in the number of inspections in the month of April 2020 which are affected by the pandemic outbreak. It's shown that between the years 2017 and 2019 (the last period without Covid-19), the number of ships inspected is comparable to each other; in that sense, the Grey relational analysis based on entropy compares these years.

On the flip side, the number of ship inspections and detentions during the last five years shows that there is a monthly fluctuation in the inspection and ship detention figures. Over the course of these years, the number of inspections has increased between February and March, with the exception of 2020. Moreover, the number of inspections has continued to decrease radically in March and April 2020 as a consequence of Covid-19. Furthermore, between 2015 and 2019 the comparison indicates that the number of inspections and detentions have constant figures. After 2020, as a result of the pandemic outbreak, the PSCOs did not inspect comparable numbers of ships as before.

Understand the trend in ship arrest factors pre-Covid-19

A reduction in the number of inspections and detentions of ships is an expected effect following the Covid-19 pandemic. This section details Grey relational analysis based on entropy to determine the transformations in the deficiencies and detentions trend, studying the deficiency codes that PSC uses during the inspection.

The Grey relational analysis (GRA) method can be applied as a decision-making method in the problem resolution that links more than one factor and answer in the framework of the level of relation between the analysed factors and the relation between changes (Liu, Yang and Forrest, 2017). Likewise, the fact that GRA

Deficiency code	Defective item (only main title)
01	Certificates & documentation
02	Structural condition
03	Water/Weathertight condition
04	Emergency systems
05	Radio communication
06	Cargo operations including equipment
07	Fire safety
08	Alarms
09	Working and living conditions
10	Safety of navigation
11	Lifesaving appliances
12	Dangerous goods
13	Propulsion and auxiliary machinery
14	Pollution prevention
15	ISM
16	ISPS
18	MLC, 2006
99	Other

FIGURE 2. DEFICIENCY CODE AND DEFECTIVE ITEM

Def.No / Year	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	18	99
Feb/19	4,67	6,54	4,67	10,75	2,34	0,47	15,89	1,40	0,93	14,02	13,55	0,00	2,80	3,27	12,15	6,54	0,00
Feb/20	8,23	4,53	6,58	5,35	2,06	0,82	13,99	1,65	0,41	15,64	7,82	0,00	6,58	4,12	11,11	10,70	0,41
Mar/19	13,01	3,52	6,23	7,59	4,61	0,54	18,43	0,00	0,00	11,65	12,47	0,00	1,90	3,25	8,67	8,13	0,00
Mar/20	9,09	6,49	6,49	9,09	2,60	0,00	15,58	0,00	1,30	14,29	9,09	0,00	1,30	2,60	14,29	7,79	0,00
Apr/19	8,15	5,58	3,00	12,88	6,01	0,43	12,88	0,86	0,00	9,44	12,45	0,43	2,58	4,72	8,15	11,16	1,29
Apr/20	17,65	5,88	0,00	5,88	5,88	0,00	11,76	0,00	5,88	11,76	23,53	0,00	0,00	0,00	11,76	0,00	0,00
May/19	12,09	6,05	6,05	7,44	2,33	0,47	13,02	0,00	1,40	10,70	7,44	0,47	1,86	6,05	13,95	10,23	0,47
May/20	8,08	6,06	9,09	10,10	2,02	0,00	10.10	0,00	0,00	19,19	6,06	0,00	0,00	10,10	5,05	11,11	3,03
Jun/19	19,89	4,55	7,39	6,25	2,84	1,14	12,50	1,70	0,57	9,66	6,82	0,00	3,41	1,70	14,20	6,82	0,57
Jun/20	20,02	4,04	4,04	3,03	4,04	0,00	22,22	0,00	2,02	13,13	7,07	0,00	0,00	1,01	12,12	8,08	0,00

FIGURE 3. DEFICIENCIES ANALYSIS

allows an efficient analysis with a reduced amount of ambiguous data means that it has some advantages over other statistical methods.

Due to the dimension or types of inconsistent data in the data that was used in the process of data analysis, a focus is introduced that can be used in the technical and engineering fields through integration with the entropy ponderation focus in the usual GRA.

To do the GRA, it is imperative to determine the deficiency codes to establish the model's factors. The Paris MoU has deficiency codes (Figure 2) that classify the discrepancies. These codes are also published on the Paris MoU website.

The percentage estimates of 2019 and 2020 show that in both years, in most part detention was caused by fire safety, navigation safety, lifesaving devices, the International Safety Management (ISM) code and the Maritime Labour Convention (MLC), 2006 (Figure 3).

Comparing February 2019 and February 2020, April 2019 and April 2020, and June 2019 and June 2020, deficiencies linked to the certificates increased.

Throughout the pandemic outbreak "06 – Cargo operations including equipment" did not cause any detentions. During the outbreak, discrepancies linked to fire safety decreased, except for June of 2020, in comparison to 2019. Detention caused by "13 – Propulsion and auxiliary machinery" also decreased during the pandemic outbreak in comparison to 2019, and no ship has been stopped for code "16 – ISPS" (International Ship and Port Facility Security).

On the other side of the coin, discrepancies related to "10 – Safety of Navigation" has constantly increased in the same period, and discrepancies related to "01 – Certificates and documents" have also increased, excluding March and May 2020.

The discrepancy type "99 – Other" presented a detention rate of 3.03% in May 2020. Unfortunately, this category hasn't been catalogued and there is a lack of information in relation to the root of this increase.

A monthly correlation for the years 2019 and 2020 is indicated in Figure 4. The correlation has been calculated for the period of February 2019 and 2020, March 2019 and 2020, April 2019 and 2020, May 2019 and 2020 and June 2019 and 2020. It is important to highlight that for the month of January this hasn't been calculated due to the Covid-19 outbreak starting during late February, early March of 2020.

Conclusions: impact on the future

Once all the information presented has been analysed, it is important to highlight that the main maritime safety concepts must be taken into account at the time of working with the PSC, since this is a stable process, and it is also important to know if they are affected by other factors.

By using the table, it allows us to do a time series control mechanism of past PSC inspections, and so realise that PSC inspections can be a variable process in terms of deficiency types throughout time. Like, for example, during the Covid-19 pandemic.

There are three patterns identified to prove viability and efficiency of the application of SPC in PSC inspections for maritime safety. The main contribution of this document is that this study is a pioneer in exploring the application of SPC in PSC inspections. It is because

Month/Year	Correlation
19/02-20	87%
19/03-20	91%
19/04-20	66%
19/05-20	76%
19/06-20	91%

FIGURE 4. CORRELATION STUDY

of this that when using this information, the behaviour throughout time can be shown in an efficient way, depending on the historical inspections' discrepancies and abnormal behavioral patterns highlighted in a specific time period.

For PSC it can be concluded that the practical and management implications of this study are that the port administrations can be used as necessary tools at the time of easily identifying abnormal cases depending on the time that the inspections take place, and in this way take the proactive actions necessary to mitigate non-random phenomena in PSC inspections.

Based on these results, the port administrations should provide persistent and consistent inspection requirements, so as to avoid non-routine inspections and to keep the deficiencies that happen at a constant and low level.

Constant formation tasks must be done by inspectors with diverse specialties and records, which is also considered necessary to meet the said objective. ■

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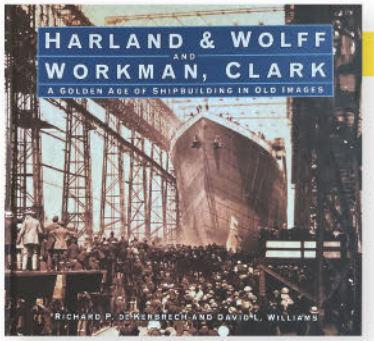
BOOK REVIEW

Review by: **Richard Halfhide**



THE GOLDEN AGE OF BELFAST'S SHIPYARDS

Harland & Wolff and Workman, Clark

By **Richard P. de Kerbrech and David L. Williams**

PUBLISHER: THE HISTORY PRESS, 2021

It's testament to the durability and longevity of what's perhaps the British Isles' most famous shipyard that although – on the opening page of this book – the authors refer to it as having ceased trading in 2019, reports of its demise have proven premature. Indeed, the latest post on Harland & Wolff's (H&W) official Twitter account refers to 'fruitful conversations with key players' at last month's Seatrade Cruise Global trade show, it's worth noting that the Belfast company was also among those that submitted designs for the aborted National Flagship.

What's less disputable is that halcyon days of H&W belong to another epoch, one in which British industry, and shipbuilding in particular, could still lay claim to being the envy of the world. Founded in 1858, the yard progressed rapidly during its formative years into iron and steel-based construction so that by the period this book roughly focuses upon, in the late Victorian and Edwardian eras, it had established itself as the pre-eminent shipbuilder of passenger ships.

Among the hundreds of vessels built by H&W it's those of the White Star Line with which it remains synonymous, in particular the 'Olympic class' liners *Olympic* (1911), *Titanic* (1912) and *Britannic* (1915). The three ships were exponents of H&W's notable specialism in vessels propelled by three propellers – so-called combination machinery – in which the two wing propellers were driven by high-power steam reciprocating engines, with the exhaust directed through a large steam turbine driving the central propeller.

In 1880, H&W found itself with competition when two of its former premium apprentices, Francis Workman and George Clark, founded their own yard just a short distance from the older company. Although initially making slow progress the 'wee yard' as it was disparagingly known, gradually poached business from its bigger rival until in 1901 it exceeded it in tonnage for the first time, becoming the world's biggest shipbuilder a year later. Among Workman Clark's greatest accomplishments was its first passenger liner, the *Victorian* (1905), which also earned the distinction of being the first ocean-going turbine-driven liner.

Over the next eight years the smaller yard launched 100 vessels, compared to H&W's 75, although with a smaller combined tonnage. Unfortunately these salad days didn't last; Workman Clark's fortunes slowly declined and it ceased trading in 1935, the company's South Yard and engine works being acquired by H&W.

THE ENORMOUS DOUBLE-ENDED SCOTCH BOILERS DESTINED FOR BRITANNIC (1915) IN HARLAND & WOLFF'S BOILER SHOP

Although only a slim volume, the book is prodigiously illustrated with photos from the yards that are often drawn from the authors' own collections, many of them originally taken by H&W's dedicated photographer, Robert Welch, between 1894 and 1920. The fascinating glimpse they afford not only of the ships themselves, but the shipyard facilities and of the labourers who toiled for 11 hours a day, for as little as GBP£1.10s per week, is a portal into a very different world.

That said, those looking for a detailed history of H&W and its technical accomplishments might be better advised to look elsewhere. Despite the rich subject matter the writers still conspire to make some rather eccentric decisions on where to turn their focus; the final chapter is about – of all things – the H&W toilet facilities! ■

Hardland & Wolff and Workman, Clark is available to purchase through www.thehistorypress.co.uk and other book retailers.

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