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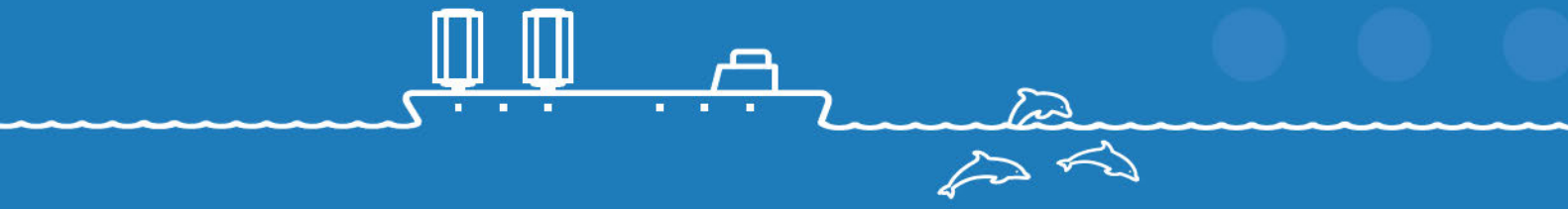

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SAFE AND SUSTAINABLE SHIP RECYCLING: A THORNY ISSUE

By **Daniel Johnson**

With the shipping industry facing unprecedented challenges in the decades ahead as it strives to meet decarbonisation and sustainability goals, there has been a palpable shift of focus to resource use and the entire lifecycle of a vessel: from the design and building phases, its operational maintenance, right through to its eventual scrapping and recycling. The importance of the latter phase to current thinking on circular and low-carbon economies is certainly becoming increasingly clear. It also raises the thorny question of how to recycle a retired ship in an environmentally friendly and safe manner.

Despite numerous shipowners having policies in place for responsible ship recycling, it is estimated that nearly 90% of the gross tonnage recycled is handled in India, Pakistan and Bangladesh. The shipbreaking facilities here are notorious for being extremely dangerous with precarious working conditions, little training and a lack of safety equipment and access to medical services. Global union federation IndustriALL reports that more than 20 serious accidents and six fatalities in Bangladesh this year so far.

The EU has strict recycling standards in place via the European Ship Recycling Regulation (EU SSR) and the EU List of Ship Recycling Facilities, with European policy makers keen to use these tools to improve working conditions and increase the environmental standards of ship recycling facilities across the world. While the EU SSR largely reflects the requirements of the IMO's yet to be ratified Hong Kong Convention (HKC), it also includes additional safety and environmental standards, including a ban on beaching. Listed ship recycling facilities are subject to scrutiny from independent certification and auditing third parties to ensure that they are complying with the Regulation.

One common criticism of the EU list is the lack of sufficient recycling capability among included shipyards to dismantle large ships and this concern is once again highlighted in shipping industry trade group BIMCO's 'Report on the European List of Ship Recycling Facilities'.

Released in October and now in its 3rd edition, the report notes that while the list of approved ship recycling facilities continues to grow, new additions have not added significant capacity to meet the demands of the global shipping industry. It argues that EU member state facilities typically provide either bespoke local solutions to a niche recycling market or are focused on offshore decommissioning.

According to the report, Turkey is the only major ship recycling nation contributing significant capacity but the recent removal of two Turkish ship recycling yards from the list due to failings has diminished recycling capability further.

SOURCE: NGO SHIPBREAKING PLATFORM

In what could be considered a controversial move, given the poor safety and environmental records of the shipbreaking facilities in South Asia, the report calls for the inclusion of non-European ship recycling facilities to meet industry demands. BIMCO secretary-general and CEO David Loosley states: "Today, there are still no facilities from the main recycling states such as India, Bangladesh or Pakistan included on the EU list to meet the demand for recycling of larger ships.

"Many yards have made significant efforts toward upgrading their facilities. We believe focus on getting some of these facilities added to the list should be increased if they meet the standards of the Hong Kong Convention, which we believe should be ratified as soon as possible."

As to whether the ratification of the HKC will be the answer to the question of safe and environmentally sound ship recycling or not is a moot point. The HKC has been strongly criticised by NGOs, the UN Special Rapporteur on Toxics and Human Rights, the European Parliament and a large number of developing countries party to the UNEP Basel Convention.

The NGO Shipbreaking Platform states: "The Hong Kong Convention rubberstamps the current conditions as it does not ban beaching and sets no requirements, beyond compliance with national standards, for the management of hazardous wastes once they leave the gate of the recycling facility."

The demand for ship recycling looks set to increase dramatically in the near future - analysis of fleet renewable trends from the Sustainable Shipping Initiative estimates that global recycling volumes will double by 2028 and near-quadruple by 2033. This surge of elderly vessels is likely to place global recycling capacity under severe strain and heralds what could be a crunch time for the industry. Radical thinking and urgent action will be required if it's serious about transforming ship recycling into a truly safe and environmentally responsible practice. ■

NEWS

CONTAINER SHIPS

VEER RECEIVES SUPPORT FOR WIND-ASSISTED HYDROGEN FUEL CELL VESSEL DESIGN

VEER PLANS TO HAVE TWO 100M VESSELS IN THE WATER BY 2024

US-based classification society ABS has granted approval in principle (AiP) to Veer Corp, a company based in the Bahamas, for its new container ship project which will feature DynaRig sail technology paired with green hydrogen fuel cell engines.

Veer aims to design, build, operate and manage a fleet of 100m-long clean shipping vessels that are speed and cost competitive.

"Receiving this AiP from a recognised organisation such as ABS sets Veer apart from other conceptual projects," says Danielle Doggett, CEO at Veer. "We are making significant progress – you can feel that it's really happening."

Also involved in the project are the naval architect team at Dykstra, the Netherlands, and the project management team at UK-based consultancy Brookes Bell.

Veer expects the first two ships to be built and enter regular service by 2024. Doggett says the company will consider proposals from several shipyards in the coming weeks, with the aim of selecting the facility by the end of the year.

Veer has also received support from global cosmetics brand LUSH as a potential future client. The company states: "The world needs us to progress much more rapidly in decarbonising transport, globally. LUSH's commitment to decarbonise our global transport is dependent on partnerships with organisations like Veer. Our roadmap to net-zero transport means being early adopters of hydrogen shipping and so we are very excited at the possibility of partnering with Veer's first vessel."

AUTONOMOUS SHIPS

ONE SEA APPOINTS SINIKKA HARTONEN AS SECRETARY GENERAL

Sinikka Hartonen has been appointed secretary general of One Sea, the high-profile ecosystem which promotes the adoption and standardisation of autonomous ship technology. She replaces Päivi Haikkola, who led the organisation for five years.

Prior to her appointment as secretary general, Hartonen was already a member of the One Sea advisory board. She started her career working onboard merchant ships before joining the Finnish Maritime Administration, where her primary duties related to vessel traffic services development. Hartonen joined the Finnish Transport Agency in 2010 and the Finnish Shipowners' Association in 2018.

Eero Lehtovaara, chair of One Sea, says: "This is a pivotal moment for autonomous shipping, in terms of its adoption and regulatory oversight. On behalf of One Sea and its members, I would like to welcome Sinikka's appointment.

"As a trusted advisor, she has already helped to shape the association's direction and priorities. As secretary general she will take the lead on One Sea's activities going forward, and I'm looking forward to working with her as One Sea starts its next chapter."

"One Sea has provided the maritime and shipping industry with a platform to contribute to the regulatory process for MASS. This remains a top priority for One Sea and its members; it is essential that progress is made swiftly on developing goal-based regulations which give precedence to safety but also allow technologies to be used efficiently," says Hartonen.

SINIKKA HARTONEN, SECRETARY GENERAL, ONE SEA

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ALTERNATIVE FUELS

WÄRTSILÄ, CARNIVAL CORPORATION AND GOODFUELS PARTNER IN BIOFUEL TESTS

VOLENDAM BEING BUNKERED WITH BIOFUEL IN THE PORT OF ROTTERDAM

Technology group Wärtsilä has partnered with cruise operator Carnival's Holland America Line and Netherlands-based GoodFuels to conduct ship trials using biofuel blends.

In addition to a 70% diesel / 30% biofuel blend, the tests were conducted with 100% biofuel to determine the effect on overall engine performance, as well as on engine emissions.

The trial was conducted on a Wärtsilä ZA40 engine fitted onboard *Volendam*, a Holland America Line ship.

According to Carnival, the biofuel tests support its overall environmental mission, goals and aspirations. Those include achieving a 40% reduction in carbon per available-lower-berth-day by 2030; expanding its alternative fuels strategy across its liquefied natural gas (LNG) programme and battery, fuel cell and biofuel capabilities; delivering a 50% reduction in absolute air emissions of particulate matter by 2030; and the aspiration to achieve net carbon neutral operations by 2050.

Wärtsilä's scope included the preparation of the testing protocols and assessment of the fuel testing and lube oil testing results. It is also involved in the supervision of tests and post-testing analyses such as engine inspections, performance evaluation, and measurements of nitrogen oxide (NOx) emissions.

Ricardo Opperman, director strategic account management and managing director of Wärtsilä North America, says: "We are continuously developing our engine technology to accept and retain operational and environmental efficiency levels with various future fuels, including biofuels.

"These sea trials with 100% biofuel will be especially important – for GoodFuels, for Wärtsilä, and for the industry as a whole."

FUEL CELLS

HHI AND SHELL TEAM UP FOR FUEL CELL PROJECT

Hyundai Heavy Industries (HHI) Group has signed a consortium agreement to demonstrate fuel cells for ships with Shell, Doosan Fuel Cell, HyAxiom, and DNV.

According to the agreement, HHI Group will use a 600kW high-efficiency solid oxide fuel cell (SOFC) for power generation on a 174,000m^3 LNG carrier to be run by Shell from 2025.

The LNG carrier will use fuel cells as an auxiliary power unit and perform its demonstration for one year on an actual trade route.

HHI Group will build the ship, design and install SOFC placements, and integrate the ship system. Shell will be in charge of managing and operating the ship, as well as managing the demonstration project, while Doosan Fuel Cell and HyAxiom will develop and supply fuel cells for the ship. DNV will conduct inspections of the structure and equipment of the demonstration ship for accreditation registration.

Karrie Trauth, SVP of Shipping & Maritime at Shell, says: "This consortium and the cutting-edge technology we're pioneering could help deliver less carbon-

THE AGREEMENT SIGNING CEREMONY

intensive operations in the near term while unlocking a pathway to net-zero through the blending of conventional and alternative fuels until zero-carbon options are available at scale.

"We're excited to be collaborating with some of the leading names in shipping who share a vision of a zero-emission industry and are working hard to progress shipping decarbonisation."

In addition to this agreement, HHI Group is developing its own SOFC technologies to promote fuel cell development projects.

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NEWS ANALYSIS

FUEL TRANSITION TRENDS AND NEW SCHEME FOR EARLY MOVERS

By **Malcolm Latarche**

A global energy crisis may be engulfing the world economy but for shipping it is decarbonisation and fuel transition that still dominates boardroom thinking. With the imminent advent of EEXI and CII in January 2023 affecting existing ships and all vessels respectively, it seems that there are very different views on how events will unfold.

A recent analysis of the newbuilding orderbook by Clarksons Research shows that while interest in alternative fuels is continuing to grow, shipowners are still investing in conventionally fuelled vessels. Arguably, they have no choice at this juncture since the availability and economics of switching do not yet work against vessels burning fossil fuels.

Ships capable of running on LNG or alternatives such as methanol, LPG, ethane and other options may only make up less than 5% of the in-service fleet but in terms of gross tonnage such vessels account for over 43% of the world orderbook. That represents a four-fold increase over five years ago and so far in 2022, 59% of new orders are for such vessels.

Also included in the analysis is the revelation that scrubbers continue to attract attention and orders more than two years since the IMO reduced the permitted sulphur content for fuels in 2020. The retrofit market for scrubbers is still active although numbers are down to around 15 vessels per month in 2022. However, at least 60 vessels ordered in the first nine months of 2022 are to be scrubber fitted.

A fledgling market is also developing for a new breed of scrubbers that double as carbon capture systems as well as removing SOx. In October Stena Bulk announced a decision to trial carbon capture on one of its Medium Range IMOIIMAXX vessels and Netherlands-based Samskip announced orders for two carbon capture systems from Value Maritime to be installed on *Samskip Innovator* and *Samskip Endeavour*.

Since ammonia seems to be the fuel of choice for the near future, it should not be surprising that 130 vessels on order are designed to be ammonia ready. In a further boost for ammonia, the European Maritime Safety Agency (EMSA) has published a study into the 'Potential of Ammonia as Fuel in Shipping'. The report highlights one of the barriers for ammonia – that of toxicity – but also points out that ammonia is used extensively in other industries so safety measures will not be breaking new ground.

SAMSKIP WILL INSTALL A CARBON CAPTURE SYSTEM ON *SAMSKIP ENDEAVOUR*. SOURCE SAMSKIP

On decarbonisation the International Chamber of Shipping (ICS) has presented new proposals to the IMO to accelerate the maritime sector's transition to net zero by financially rewarding ships and energy producers that invest in low/net zero emission fuels.

The ICS fund and reward (F&R) proposal combines elements of various recent GHG reduction proposals from a number of governments, plus a flat rate contribution system previously proposed by ICS and INTERCARGO, and ideas recently put forward for a global IMO measure by the EU 27.

The reward rate would be calculated based on CO_2 emissions prevented and funded via a mandatory flat rate contribution from ships per tonne of CO_2 emitted. A detailed impact assessment undertaken for ICS by Clarksons Research has identified that a financial contribution of up to approximately US$100 per tonne of CO_2 emitted would not cause disproportionately negative impacts on the economies of states. However, ICS believes that contributions could initially be set much lower and then be subject to a five-year review as increasing quantities of new fuels become available.

The quantum of the contribution by ships is of great importance to developing countries whose support will be required to get the regulatory framework adopted, the architecture for which is based on the industry's previous proposals for an IMO R&D Fund.

There are doubtless several ship operators that would disagree that the US$100 per tonne of CO_2 would not cause a negative impact. Burning one tonne of oil produces 3.5 tonnes of CO_2 so the proposal would add around US$350 to the price of all fossil fuels. Some would also say it is inequitable as all ships would pay the levy but only owners rich enough to order new ships would be likely to benefit. ■

NEWS EQUIPMENT

WIND PROPULSION

COSCO SHIPPING HEAVY INDUSTRY OFFERS ANEMOI ROTOR SAILS

CHI CLIENTS CAN NOW CHOOSE TO INSTALL THE ROTOR SAILS SYSTEM ON NEWBUILDS OR RETROFIT EXISTING VESSELS DURING DRYDOCK

Anemoi Marine Technologies and COSCO Shipping Heavy Industry Co (CHI) have signed an agreement that gives CHI customers the option to install Anemoi's rotor sail technology on newbuild vessels or retrofit during drydock.

Under the terms of the agreement, the companies can offer a turnkey installation solution to customers.

Rotor sails, also known as Flettner rotors, are an energy saving technology. The mechanical sails are comprised of tall cylinders which, when driven to spin, harness the renewable power of the wind to provide auxiliary propulsion to vessels which reduces fuel consumption and lowers harmful emissions entering the atmosphere by 5-30%.

Nick Contopoulos, COO of Anemoi Marine Technologies, says: "This is another exciting landmark for Anemoi and will accelerate the take-up of our emission reduction technology. We are proud to have secured the commitment of a top Chinese yard group.

"CHI shares our long-term vision of the role that wind assisted technology can provide in delivering carbon reduction today. We are looking forward to a highly successful co-operation in the years to come and we are currently lining up the first installation opportunities with CHI."

Anemoi already has over 170 staff at its production and assembly facilities in Jiangsu Province, China, and is currently scaling up production capacity to meet the continued increase in demand.

Guo ZhiQiang, assistant general manager at CHQ of CHI, says: "Our pool of 3,000 professional designers and 10,000 highly qualified technicians allows us to integrate the latest and most advanced solutions into the ships we build as well as retrofit in drydock. We are delighted to be working with Anemoi Marine Technologies and have been impressed by their solution which can be combined with a range of other fuel saving measures."

COMPRESSED AIR

HUDONG ORDERS TMC COMPRESSORS FOR NEWBUILD LNG CARRIERS

Hudong-Zhonghua Shipbuilding has selected TMC Compressors (TMC) to deliver the complete marine compressed air system to six LNG carriers the shipbuilder is constructing for Japanese shipping major Mitsui O.S.K. Lines (MOL).

TMC will supply multiple control and service air compressors and air driers to each of the six 174,000m^3 LNG carriers. In addition, TMC will provide feed air compressors to the nitrogen system onboard each vessel.

Norway-headquartered TMC will manufacture the equipment in the Nordic region and ship it to Hudong-Zhonghua Shipbuilding in China. Upon delivery of the vessels to MOL, CNOOC Gas & Power will charter the ships.

"We understand the contract for the six vessels is one of Hudong-Zhonghua's largest LNG shipbuilding awards to date. To be trusted to deliver the complete marine compressed air system to all vessels is a huge vote of confidence. It is a vessel type we are highly familiar with, and we will deliver an energy-efficient system that the vessel crew can easily maintain themselves if and when required," says Hans Petter Tanum, TMC's director of sales and business development.

TMC's single stage, oil-lubricated marine screw compressors are designed and manufactured for continuous operation in high ambient temperatures.

"Our technology is designed solely for marine and offshore use. Simply because we believe this technology approach provides more robust equipment performance compared to products that have been marinised for offshore use," adds Tanum.

COATINGS

SHELL APPROVES APC SHIP TANK COATING SYSTEM FOR MEG TRANSPORTATION

US-based Advanced Polymer Coating's (APC) MarineLINE ship tank coating system has become the first protective lining to be approved onto Shell's Cargo Handling Sheet to transport monoethylene glycol (MEG).

The approval follows a rigorous nine-month study, according to APC marine manager Onur Yildirim. He says the laboratory tests undertaken by chemists at APC and Shell proved that a coating can transport a cargo of benzene followed by a cargo MEG without cross contamination.

Previously under Shell's Cargo Handling Sheet, which is used for vessels chartered on behalf of Shell, tanker operators were not allowed to load MEG into lined tanks due to risk of contamination. As a result only tankers with stainless steel tanks could transport MEG.

"We are grateful to Shell for giving us this opportunity to demonstrate MarineLINE's capabilities," says Yildirim. "The testing, which was independently verified by the quality assurance company Intertek for Shell, showed it is MarineLINE's low absorption characteristics that enable it to transport these two chemicals without cross contamination."

He adds: "We tested for benzene as it is a cargo that can absorb easily into tank linings. But the MarineLINE performed robustly and did not absorb the benzene which ensured the MEG cargo's purity. This underlines why MarineLINE is unique in the coatings market for its ability to transport highly aggressive chemicals without absorption enabling operators to switch grades frequently."

MARINELINE IS THE FIRST PROTECTIVE LINING TO BE APPROVED ONTO SHELL'S CARGO HANDLING SHEET TO TRANSPORT MEG

PERFORMANCE MONITORING

ZERONORTH LAUNCHES AI-ENABLED FUEL MODEL

Danish technology technology company ZeroNorth has unveiled a new fuel model that uses a combination of AI and naval architecture best practices to predict the expected operational fuel consumption of any type of vessel in the global fleet.

The new service combines the ability to predict fuel consumption in real operational conditions for vessels that users have little or no data on, with the ability to learn and adjust as the vessel reports data and makes high frequency data available.

The fuel model will use machine learning technology to learn from data held within the ZeroNorth platform, across all vessels and vessel types.

It combines and learns over time from more than 1.2 billion data points, spanning vessel reports, high frequency sensor data, weather data, AIS signals, port stays, drydock and cleaning events, paint characteristics, vessel characteristics and more, according to ZeroNorth.

The company says: "Traditional fuel models that only rely on naval architecture principles are generally highly tailored to a specific vessel type and its design. This 'static' view of a vessel's fuel consumption has been useful mostly for owned fleets and for predictions requiring a certain level of accuracy.

"However, the industry's demand for ongoing optimised vessel operations requires a dynamic solution that can handle and understand complex situations for any vessel, whether owned or chartered, and whether it has sensor data available or not."

The company adds that its new fuel model generates 34% more accurate predictions when compared to existing solutions and the current industry standard and lowers the bias of results by 42%.

THE FUEL MODEL ALLOWS USERS TO PRECISELY PREDICT FUEL CONSUMPTION IN REAL OPERATIONAL CONDITIONS FOR VESSELS. SOURCE: ZERONORTH

ECO SHIP TECHNOLOGY

PATHWAYS TO EMISSIONS REDUCTION: WHAT IS THE OPTIMAL CHOICE WHEN CONSIDERING A HULL COATING?

By **Philippos Sfiris**, head of Go-to-Market Strategy, Marine, Hempel

Ship efficiency is today more than a commercial advantage. The advent of new International Maritime Organization (IMO) regulations on 1 January 2023 will index individual ships' efficiency levels, effectively designating some ships as suitable to trade and others as falling below the bar.

A ship's hull represents around 70% of its overall structure, protects the machinery, cargo and people within in, and is the only part of that sits in direct contact with water. Naval architects will understand how important hull design is to the hydrodynamic performance, stability and efficiency of ships, with great attention given to hull optimisation during vessel design stages.

It's therefore ironic that the hull efficiencies gained through simulation-based design and computer science can be undermined by some of the simplest organisms on earth. Indeed, biofouling – the build-up of barnacles, algae and other organisms on a ship's hull – frustrates shipping's efforts to reduce their fuel bill. To compensate for the friction created by these organisms and still maintain the desired speed, more fuel must be pumped through a ship's engine, which in turn results in more emissions released into the atmosphere.

Regulating emissions reductions

A recent IMO study shows that even light fouling on the hull will trigger an increase of 20-25% in fuel consumption and greenhouse gases (GHGs), while severe cases will lead up to 50% added emissions, depending on trade characteristics and speed.

To meet the IMO's GHG Strategy requirements of reducing carbon intensity of international shipping by at least 40% by 2030 and at least 50% by 2050 compared to 2008 baselines, two new regulations the Carbon Intensity Indicator (CII) and Energy Efficiency Existing Ship Index (EEXI) are working as a catalyst for change.

Hempel data shows that around 80% of global tonnage will have either taken or still needs to take action – whether operational or through investment in technology – to comply with these new rules. And whilst most owners and operators have made the necessary modifications to achieve EEXI compliance, the ongoing requirements of CII throughout a vessel's lifetime is still a concern for many companies. Right now, industry is looking to operational (speed optimisation)

PHILIPPOS SFIRIS

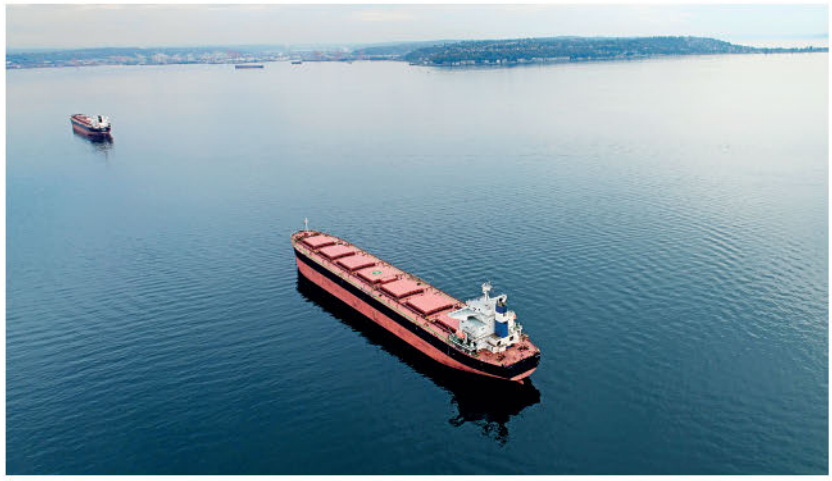
as well as technical (hull and propeller performance optimisation) measures, such as slow steaming in combination with just-in-time arrivals and engine power limitations, weather routeing, low-carbon fuels, and engine and propellor efficiency. It is clear from Hempel's conversations with industry that every option that makes commercial sense is under consideration.

Slow steaming can significantly reduce emissions, but has commercial implications and so owners are considering the use of one or a combination of energy saving devices, so that speed can be increased, whilst GHG emissions remain low.

Low-emissions fuels have clear emissions reduction advantages, but the technology and bunker network to support this transition is still in the developmental stages. And with the new IMO regulations soon to be a reality, Hempel has noticed that owners and operators are particularly looking into measures that can be implemented today based on current best available and proven energy saving technologies.

Only a few measures are recognised in the industry as having an immediate positive impact on a vessel's CII rating, including high-end hull coatings such as Hempaguard, Hempel's range of reduced friction silicone-based coatings based on Actiguard® technology. This range of Hempel coatings combines the smoothness of a silicone coating with non-stick properties that significantly reduces biofouling on a vessel's hull.

Investment in a high-end coating could increase the Vref (speed reference as defined in model test in line with IMO requirements) after power limitations, or limit



A GROWING NUMBER OF OPERATORS ACROSS ALL SECTORS ARE LOOKING TOWARDS HULL COATINGS AS A ROUTE TO EEXI AND CII COMPLIANCE. SOURCE: HEMPEL

the need for such limitations in the effort to reach the required EEXI if the shipowner is willing to conduct in-service measurement to get class approval.

Most importantly, however, Hempaguard can increase vessel efficiency from an operational perspective by reducing the actual fuel consumption, leading to reduced emissions and an improved CII rating. This makes a hull coatings upgrade one of the most attractive options among energy efficiency technologies, providing guaranteed high efficiency gains and at the same time low total cost of ownership and fast return on investment.

Calculating an investment

As a marine coatings provider, we believe that our role in shipping's shift to reduce emissions is as a trusted industry advisor. Shipowners and operators often ask about the various emissions-reducing options available to them and in response we have created a platform that can generate a coatings impact report for any vessel in the world fleet. These reports give ship-

REGULATIONS AT A GLANCE

The Energy Efficiency Existing Ship Index (EEXI) is a design index which identifies the volume of CO_2 emissions released by a vessel per ton mile, taking into consideration engine specifications, cargo capacity and ship speed. Described as a one off ticket to trade, the EEXI is only concerned with the design of the vessel and the achieved index stays with the vessel for its lifetime.

It is very similar to the Energy Efficiency Design Index (EEDI) introduced in 2013 for newbuild vessels.

The Carbon Intensity Indicator (CII), however, is concerned with operations and will be an ongoing concern for the shipowner or operator throughout each vessel's lifespan. It measures a vessel's operational efficiency in grams of CO_2 emitted per nautical mile and owners will be required to continuously reduce CO_2 emissions to achieve a 70% reduction by 2050.

Owners and operators will be required to submit their vessels' yearly CO_2 emissions to their flag state administrations. The ship is then rated from A to E with E being the lowest score. A two-tier market will likely emerge separating those vessels that score higher on one side and those that score lower on the other.

specific CII and EEXI analysis for any coating, and can compare and contrast between available products. It gives customers accurate data on the cost of ownership, return on investment and CII/EEXI impact of our coatings prior to investment.

The CII & EEXI Impact Analysis Tool determines the performance of a hull coating by the out of 'dock power gain' and the 'speed loss percentage'.

It can be visualised as follows: Out of dock power gain + speed loss in power = total savings percentage.

After the coating has been applied in drydock, the 'out of dock power gain' is realised within the first year and shows the decrease in power (and fuel consumption) at a specific speed. 'Speed loss percentage' is averaged over the ship's service period. Translating the speed loss percentage to power with a 3:1 speed-to-power relationship and adding it to out of dock power gain figure gives the 'total savings percentage' over the service period from a specific hull coating application.

We recommend that two or three paint systems are analysed including the existing system already applied to the vessel, so that accurate comparisons can be drawn.

Hempel understands the investment levels required by industry in order to bring their vessels in line with the new regulations, and suggests that the following criteria be considered before committing to a new hull coating product or service:

- Expected impact on CII for different coating systems, surface preparation scenarios and, if needed, the Vref (speed reference as defined in model test) change for the purpose of EEXI.
- Total cost of ownership associated with the coating choice, including the cost of the coating itself, shipyard cost for surface preparation and paint application, cost of cleaning based on the expected performance of chosen coating, fuel cost over the ship's service life, and return on investment in months.
- Any economic benefits for the owner and operator, including fuel savings for the charter period and increase in daily earnings (time charter equivalent).

One example of the value of coatings can be seen on Belgium-based tanker company Euronav's fleet. The company has been applying Hempaguard to 28 of its vessels since 2015. Data shows that these coatings, in addition to other efficiency measures taken by the company, have reduced fuel use on each vessel by an average of 1,000tonnes per year*, and an overall reduction in CO_2 emissions of 3,100tonnes per vessel during the period.

Industry-wide concern

The new regulations will require different commercial and operational priorities. Vessels operators will be focused on ensuring their vessels are suitable for hire in a future two-tiered market of high and low rated vessels. Maintaining a consistently higher score of between A to C (see box/side bar) will soon be a commercial imperative, as IMO is calling on ports and other stakeholders to offer incentives to the owners/operators of low-emissions ships. Further, banks and ship financiers are also rated on how their portfolio is aligned with decarbonisation.

Hempel is now receiving enquiries from shipowners who charter out their vessels and so do not usually get involved in their operations. As these owners do not pay for their ships' fuel, there has previously been no financial benefit or incentive to seek more efficient operations. They recognise, however, that to keep their ships operational and aligned with the forthcoming regulations they too must commit to an emissions' reduction pathway.

A wider range of sectors are also approaching Hempel as the January deadline approaches, including an increasing number of bulker, tanker, containership and cruise operators and owners all keen to keep their vessels in operation come next year.

With our CII & EEXI Impact Analysis Tool, vessel owners and operators can get full visibility of not only the efficiency improvements available, both operational for CII and technical for EEXI, but also the commercial advantages available. ■

** Calculation based on 3.11 tonnes of CO_2 emissions per tonne of fuel.*

AURAMARINE SUPPORTS GREENER OPERATIONS WITH METHANOL FUEL SUPPLY SYSTEM

By **Daniel Johnson**

As the maritime industry pivots towards greener operations, switching to alternative fuels will be crucial to decarbonising the sector. Although it is not clear which fuels will prevail, methanol is fast emerging as an attractive option for shipowners and operators looking to reduce their carbon footprint – container shipping giants Maersk Line and CMA CGM have both embraced it as future fuel.

Methanol is among the most accessible clean fuel alternative, with more than 100 ports worldwide already supplying the fuel. It reduces greenhouse gas (GHG) emissions, and full carbon neutrality can be achieved using "green methanol". Methanol also reduces other emissions, such as SOx, NOx, and particulates compared to diesel oil.

Another advantage is that existing fuel oil tanks can be used for storage with little modification as methanol can be stored at ambient pressure and temperature. Although methanol has lower volumetric energy density than LNG, the tank arrangements for methanol can still fit in a smaller space as no cryogenic or high-pressure infrastructure is required.

"I think, in the long term, we will see a mix of fuel options, but if you look at all the different alternatives and at what stage shipowners and OEMs are at with their R&D and development projects, methanol is clearly one of the most viable solutions at the moment – there is a lot of interest there," John Bergman, CEO at fuel supply system specialist Auramarine, tells *The Naval Architect*.

Auramarine's history is deeply rooted in the Finnish maritime industry. Since its foundation in 1974, the company has delivered more than 15,000 fuel supply and auxiliary systems to customers worldwide. Today, the company is harnessing its long-standing knowledge of marine fuels to support shipping's green transition, and has developed one of the industry's first methanol fuel supply units for marine engines.

The modular system is suitable for both two-stroke and four-stroke engines, and can be adapted to suit the conversion of existing engines to dual-fuel methanol operation.

Bergman says Auramarine has already received significant interest in the unit and is in advanced conversations with shipowners, operators, OEMs, and shipyards on supply and installation. The company expects to deliver the first system in 2023.

The new unit supplies methanol from the service tank to the master fuel valve, while at same time regulates the flow, pressure and temperature of the methanol. All this, combined with filtration, ensures it is suitable for engines and other methanol consumers. The system actively maintains the supply pressure within the specified tolerances during load changes.

All fuel supply system materials and manufacturing procedures need to be suitable for methanol service and for the specifications of a particular application. The unit is designed to fit on closed and Ex rated hazardous areas. All IECEx and Health and Safety Guidelines (HSE) have been taken into account.

This level of safety is achieved by using a self-draining mechanical design in conjunction with the nitrogen inerting process and double block and bleed configurations to any serviceable methanol line segments. Also, all components and electric equipment will be specially selected for use in a hazardous area.

In order to minimise the electrical equipment in a hazardous area, the electrical cabinets, control panels and variable frequency drives are designed to be fitted separately to a safe area.

A pilot fuel system is required for methanol operations in dual-fuel engines, and Auramarine has extended its experience of pilot fuel systems for LNG to methanol supply to provide shipowners with single-supplier synergies. The methanol unit can be applied as both a retrofit and for newbuildings.

The company also intends to expand its product offering with the introduction of an ammonia fuel supply system. "If you look at ammonia, developments on the engine side are roughly one year behind methanol so we expect to bring an ammonia unit to market within that time frame," concludes Bergman. ■

EXAMPLE OF AN AURAMARINE METHANOL FUEL SUPPLY SYSTEM ARRANGEMENT

BACK TO THE FUTURE – THE POWER OF THE WIND

By **Malcolm Latarche**, correspondent

TILTING FLETTNER ROTORS ON *SC CONNECTOR* SHOW EVOLUTION OF MODERN WIND TECHNOLOGY

Wind power is seen by many as being a significant solution to the decarbonisation of shipping but while there is no shortage of developers and pioneering shipowners, the use of wind still has a very long way to go before it can be considered mainstream.

Leaving aside a very few specialist vessels, wind as a means of propulsion assistance for commercial ships in the 21st century goes back to the period between 2001 and 2007 when the Hamburg-based company SkySails trialled a few prototype kite systems before the 9,821dwt multi-purpose vessel *Beluga Skysails* was built with a kite in 2007. Only one more kite system was sold by the company which filed for insolvency in 2016 although a successor company with a similar name has continued to develop the system.

Another wind assistance technology – Flettner rotors – was beginning to attract attention about the time of the *Beluga Skysails* delivery. Because the technology was almost a century old and was not protected by patents, the basic concept of using the Magnus effect was open to any developer to pick up and several have. Some have added variations to the original concept and there are now systems that can tilt or even be moved around the vessel for operational reasons when the system is not functioning such as when discharging or loading at ports.

Interest in wind assistance has blossomed since 2007 in response to a combination of rising fuel prices and increasingly stringent ship efficiency requirements and CO_2 reduction measures that could – but as yet have not – result in levies on emissions of the greenhouse gas. As well as kites and Flettner rotors, there have been developments in hard sail systems some of which have their genesis in racing yacht design.

Interest does not always result in commitment so the number of vessels in service with wind assistance systems installed is still quite low, sitting in the low 20s as of summer 2022. There are however several more ships under construction that will feature wind assist systems on delivery or be 'wind ready'. In addition, some owners have announced retrofit programmes that will take place later this year or next so that by the end of 2023, the number of wind-assisted vessels will likely have doubled.

Early uptake of wind-assist systems has mostly been on ferries – both ro-ro and ro-pax. This should not be surprising since the vessels involved operate on scheduled services where wind condition data can be used to design an optimised system as on Norwegian operator Sea-Cargo's *SC Connector*. The benefits for vessels working the spot market will be less predictable so the decision by those pioneering owners of tankers, bulk carriers and general cargo ships to install systems will probably be considered as a gamble by their less adventurous peers.

Of the 20 or so installed systems in operation seven are on vessels with fixed schedules and some of the others fitted on other ship types are prototypes being used as test beds for the technologies involved. More than half have been installed since the beginning of 2021 including most of those on larger vessels.

It is probably fair to say that most ships could benefit from wind-assisted propulsion with regard to reducing

FLETTNER ROTORS ARE NOW APPEARING ON SEVERAL DIFFERENT SHIP TYPES INCLUDING BULK CARRIERS. SOURCE: ANEMOI MARINE

emissions but in some cases the bunker cost savings may not equal the capital outlay. Until sufficient data has been collected from the systems in operation and those planned, the business case may be vague. It will however be clarified if at some point a market-based measure such as levies on fuel or CO_2 emission charges are introduced.

Evidence that wind-assist technology is beginning to enter the mainstream maritime sector comes from the number of maritime technology companies that are entering the arena and joining the pioneers such as Enercon which had equipped its E-Ship 1 with Flettner rotors in 2010 and Norsepower which four years later added a rotor to the ro-ro ship *Estraden*. Among these are Alfa Laval, Yara Marine Technologies, Chantiers de l'Atlantique, Becker Marine Systems, Wärtsilä, most of the class societies and several other companies that were all promoting wind power at SMM in early September 2022. These are in addition to companies such as Econowind, Eco-Flettner, BAR and Anemoi that are active in developing and providing systems and which have appeared on the scene in the last five years or so. Many wind-assist concepts have gained recognition in the form of Approvement in Principle from one or more class societies. ■

COMPETING TECHNOLOGIES IN BATTLE TO CATCH THE WIND

By **Malcolm Latarche**, correspodent

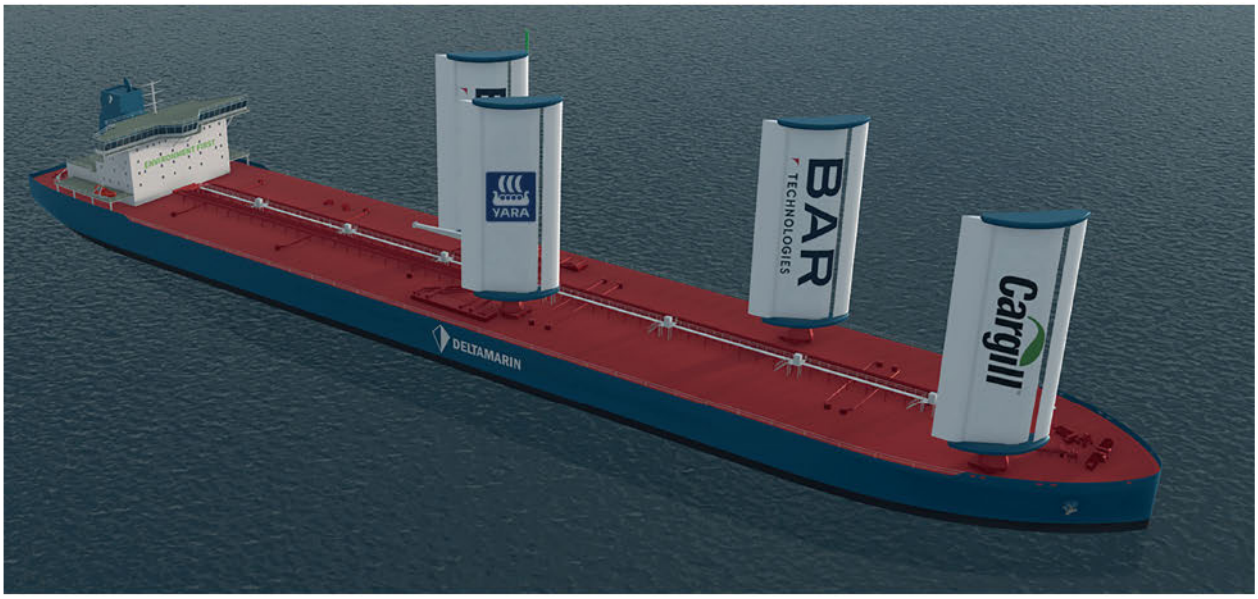
Modern wind-assist systems are a major departure from traditional sail systems in that they are not made of canvas and while there may be some systems that can alter their shape, most are made of rigid materials and have automated control systems.

Flettner rotors have been the most popular choice of system so far accounting for around half of all systems installed. Most installations have been carried out by Norsepower and cover several ship types including ferries, tankers and bulk carriers. The largest vessel to feature the Finnish company's products is *Sea Zhoushan* a 325,000dwt VLOC owned by Pan Ocean Ship Management and chartered by Vale.

Any structure on the deck of a ship that extends maybe 40m upwards from the deck has the potential to be a hazard when transiting under bridges or during cargo operations. To enable efficient cargo operations, the five 24m-high and 4m-diameter rotor sails on *Sea Zhoushan* can be tilted between the cargo hatches by using hydraulic cylinders. Tilting rotors were also installed on the ro-ro *SC Connecter* in 2021 and are said to be able to give a 25% reduction in emissions and in theory under ideal conditions can allow the vessel to operate on wind assistance alone.

Norsepower's rivals in the Flettner rotor segment include Anemoi and Eco-Flettner. All have references in operation or planned. Anemoi has a tilting system and an alternative rail-mounted system that allows the rotors to be moved along the ship during cargo operations. The first of this type was installed on the ultramax bulker *Afros* in 2018. On this ship the

SUCTION WINGS ARE BEING DEVELOPED BY VARIOUS MAKERS. ECONOWIND HAS SEVERAL REFERENCES. SOURCE: ECONOWIND



BARA AND YARA ARE MARKETING THE WINDWING SOLID SAIL SYSTEM. SOURCE: YARA MARINE

movement is longitudinal but other installations planned for the Kamsarmax bulkers *Axios* and *TR Lady* will have rotors that are moveable transversally.

Anemoi has some other interesting projects underway including tiltable rotors on bulkers for Berge that will fold across the vessel and a project involving Japanese operator MOL for a wood chip carrier to be built by Oshima that will feature Anemoi's rotors and a hard sail developed by MOL under the name Wind Challenger. This would be the first ship to incorporate two different wind assist technologies. In August this year, MOL and Anemoi announced that the co-operation would continue with plans for a second vessel that will be delivered in 2024.

MOL's in-house Wind Challenger system involves a telescopic hard sail comprising four tiers each around 20m high and 15m wide. The system has been in development for 13 years and should make its debut late in 2022 after the elements for it were completed at the beginning of this year.

After Flettner rotors, the most used technology is currently the suction wing method. Leading proponent of this technology is Netherlands-based Econowind. The system is related to Flettner rotors, but the rotating element is contained inside a ventilated shell that can be rotated to gain the maximum effect. Econwind's version of this technology goes under the name Ventifoil and has been fitted to a number of Dutch short-sea vessels.

The hard option

Econowind also produces a similar looking system called TwinFoil but this is a variation on rigid fixed sails and is commonly referred to as a wing sail. The TwinFoil features a moveable trailing edge similar to an aeroplane wing that increases the propulsion effect. The whole structure can be rotated to present the best surface to the wind direction. Both the Ventifoil and the TwinFoil have variants that can be collapsed or even mounted in a container to allow transfer between vessels.

Another type of wing sail has been developed by an Italian consortium comprising ship designer Naos, crane maker Concrane and the University of Udine. Known as the Wing Sail Module (WSM) it has received funding under the WEPAS (Wind Energy Propulsion Aid for Ships) project. Again, this is a structure similar to an aircraft wing that can fold flat. A prototype system comprising one composite sail of 36m height was installed on the 32,581gt ro-pax *GNV Bridge* operated by GNV and built in Italy by Vinsentini. The ship was delivered in 2021. Tests show that the additional thrust provided by the WSM exceeded expectations overall.

The next step is development of a full-scale system that would comprise four sails which would be of a recyclable material rather than the composite used in the prototype. Modelling tests show that for a ro-ro vessel operating on the Belfast-Heysham route equipped with four sails each of 150m^2 surface area a fuel saving of 7% could be achievable.

The makers of the WSM claim that the system can be more effective than Flettner rotors and can operate in a slightly wider range of wind conditions. The system includes a wind sensor and control system that automatically controls the orientation of the sail continuously so as to optimise the thrust effect. They also say that its slimmer shape and its ability to be feathered reduces the drift effect that other sail and rotor systems experience.

As well as MOL's Wind Challenger, another hard sail system that is gaining references is that developed by UK-based BAR Technologies and marketed by Yara Marine. The system known as WindWings features hard sails that are comprised of three sections. A larger central section is bounded on each side by a smaller hinged section that can rotate for optimising performance and for storage purposes.

Because the sails when fully extended are wide they have the potential to interfere with line of sight from the ship's bridge. To compensate for this, the system incorporates

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MARITIME SAFETY AWARD

Safety at sea is a crucial collective responsibility of the maritime industry. Naval architects and other engineers involved in the design, construction, and operation of maritime vessels; have a significant role in maritime safety.

To raise awareness and promote further improvements in this important field, RINA in association with Lloyd's Register are launching the **2023 Maritime Safety Award.**

The award will distinguish an individual, company, or organisation, who has made a **significant technological contribution to improve maritime safety.**

HOW TO PARTICIPATE?

Nominations may be made by any member of the global maritime community. Individuals may not nominate themselves, although employees may nominate their company/ organisation.

Nominations should include a 750 word summary, describing the technological contribution made towards the advancement of maritime safety.

Nominations are open until the 31st January 2023.
Online at: www.rina.org.uk/maritimesafetyaward
Or, by email: maritimesafetyaward@rina.org.uk

A panel of members of RINA and Lloyd´s Register will deliberate and the winner will be announced at RINA's Annual Dinner.

For Queries about the Award contact the Chief Executive at:
hq@rina.org.uk

THE ROYAL INSTITUTION OF NAVAL ARCHITECTS

2023

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EILY KEARY AWARD

RINA is committed to ensuring that all individuals, regardless of gender, faith or ethnicity, have equal opportunity of being part of the global maritime community.

To raise awareness on this important topic RINA is launching the 2023 Eily Keary Award.

The award will distinguish an individual, company, or organization who has contributed to increasing **equality, diversity and inclusion** in the maritime industry.

HOW TO PARTICIPATE?

Nominations may be made by any member of the global maritime community. Individuals may not nominate themselves, although employees may nominate their company/ organisation.

Nominations should include a 750 word summary, describing the nominee´s contribution towards the advancement of equality, diversity and inclusion in the maritime industry.

Nominations are open until the 31st January 2023.
Online at: www.rina.org.uk/EilyAward
Or, by email: EilyKearyAward@rina.org.uk

A panel of members of RINA will deliberate and the winner will be announced at RINA's Annual Dinner.

For queries about this Award please contact the Chief Executive at:
hq@rina.org.uk

OCEANBIRD FROM WALLENIUS IS ANOTHER HARD SAIL SYSTEM. SOURCE: OCEANBIRD

cameras that display the required view on the bridge. A first reference for the system was announced in June 2022 and involves Cargill and MC Shipping's Singapore Branch – the shipping arm of the Mitsubishi Corporation. The chosen vessel is the five-year-old 80,962dwt bulk carrier *Pyxis Ocean* with installation due to take place in early 2023.

Two WindWings will be delivered by Yara Marine Technologies and installed on the *Pyxis Ocean*, with one of those wings funded as part of EU Horizon 2020 Project CHEK, dedicated to demonstrating solutions for decarbonising international shipping. BAR has said that a projected reduction in average fuel consumption of up to 30% for a full-scale deployment is anticipated.

Almost immediately following that announcement a new reference was secured for WindWings this time with Berge Bulk. Under this contract, four WindWings will be installed on the 211,153dwt bulk carrier *Berge Olympus*. The sails for this project will measure up to 50m in height and will be capable of reducing CO_2 emissions by as much as 30% through a combination of wind propulsion and route optimisation. By doing so, Berge Bulk aims to take a major step in assisting the broader industry in achieving its emission targets for 2050.

Most of the wind-assist systems on offer or under development promise fuel efficiencies in the region of 10-40%. A very few such as the French Neoline project envisage wind being the sole source of routine propulsion requirements. The Neoline ship which is to provide a trans-Atlantic ro-ro service uses a rigid sail system supplied by Chantiers de l'Atlantique and given an AiP by Bureau Veritas.

Neoline only announced the decision to go with a solid sail system in May 2022 after having previously planned a more traditional flexible sail solution. After technical studies carried out by Chantiers de l'Atlantique and others it seems the 136m-long ship's rigging will consist of a pair of folding rigging systems, including two masts of 76m hight each equipped with the French builder's solid sail technology covering 1,100m² and a flexible jib of 400m² for a total sail area of 3,000m².

The calculations apparently showed that the rigid sails will provide equivalent or even better performance than the 4,200m² of flexible sails initially planned for the duplex rig, thanks to the thinness and vertical elongation of the structure, as well as the reduction of the masking effect of the sails. The expected lifetime of the sail is 25 years, which will reduce maintenance costs compared to soft sails. The announcement coincided with an announcement that a crowdfunding campaign would continue until a further €300,000 had been raised to progress the project.

Also planned to use wind as the main source of propulsion is a 7,000CEU car carrier planned by Swedish operator Wallenius Marine. In 2020, the company announced a new concept vessel under the name Oceanbird that it said could be operational by 2025. This was not the first environmentally friendly concept vessel the company had announced as another under the name Orcelle was in place a decade ago.

The new concept does seem to be more definite as marine technology firm Alfa Laval have joined with Wallenius to develop the concept. Furthermore, in June this year it was announced that Danish naval architecture and design firm Knud E. Hansen had signed an agreement to join the project of designing the world's first wind-powered ro-ro.

When initially announced it was said that the vessel would be fitted with five telescopic wing sails of 80m in height. While the basic parameters of vessel size and speed of 10-12knots under sail alone have not changed, the images of the vessel since the Knud E. Hansen involvement show a quite different wing sail arrangement.

The Oceanbird website also mentions that the height of the wing sails has been reduced by around 50% and there appear to be more than five. Instead of being telescopic, the latest Oceanbird wing sail consists of a main sail and a flap, optimising the aerodynamics forces. To allow the vessel to pass under bridges and reduce the power in hard weather, the wing can be folded and tilted and the ship will then proceed using a supplemental engine.

Wallenius has said Oceanbird is evaluating different suppliers for the new design of wing sail and will place an order for the first during the second half of 2022 with prototype testing to take place in 2023. Meanwhile, Oceanbird is investigating solutions for placing wing sails on existing vessels in several shipping segments. The first vessel with fully wind propulsion is now planned to sail in 2026. ■

ENGINEERING BUBBLES

By **Jon Wheeler**, programme director – Cruise & Ferry, Silverstream Technologies

Caught between the pressure to act immediately and the relative lack of economically viable net-zero fuel solutions, the installation of verified clean technologies is proving an attractive option, particularly if operators are looking for readily available solutions today.

No matter the fuel, clean technologies have the power to reduce fuel bills and emissions, maintain vessel operational flexibility, and increase profitability for shipowners. Consequently, air lubrication – and our Silverstream® System – is now increasingly seen as a priority technology to be installed on both new ships and the existing fleet.

JON WHEELER, PROGRAMME DIRECTOR AT SILVERSTREAM TECHNOLOGIES

Air lubrication is an approved technology under the IMO's Energy Efficiency Design Index (EEDI) for newbuilds, as well as the Energy Efficiency Existing Ship Index (EEXI), and the Carbon Intensity Indicator (CII) requirements, which come into effect in 2023.

From the second half of the decade onwards, CII regulations will tighten progressively, limiting the value of slow steaming and forcing reluctant shipowners to consider energy saving technologies. Oil majors and an increasing number of cargo owners will add pressure, as will measures such as the EU's pending Emissions Trading Scheme.

Adoption of proven clean technologies such as air lubrication will increase the post-payback value gained from them. This value will grow when new, more expensive carbon neutral fuels are adopted. With an orderbook currently comprising more than 110 vessels, of which 22 are already in service, we are making positive strides to implement our technology quickly and efficiently across the global fleet.

The past decade of developing and commercialising our technology has given us tremendous insight into what the sector needs to effectively scale incoming efficiency solutions. Silverstream has created a blueprint for clean technology adoption, with the intention of inspiring owners and operators to demand more from their technology providers as they navigate an uncertain and fragmented market.

We are not the only ones working on how to scale clean technologies in shipping. Recently, the Global Industry Alliance to Support Low Carbon Shipping under the IMO-Norway GreenVoyage2050 Project published its *Practical Guide to the Selection of Energy Efficiency Technologies for Ships* to support this exact challenge.

The guide aims to support shipowners looking into retrofits, with a simple yet flexible methodology for shortlisting technologies, based on a set of eight evaluation criteria – similarity, plausibility, accuracy, overall and specific volume of orders, repeat orders, consistency and compatibility.

It states that in general, a larger number of orders or installations reflects greater experience on the part of the equipment supplier, which manifests itself in better predictions of energy savings, as well as experience with the retrofitting process, obtaining class approval and aftersales support.

These are the qualities that Silverstream continues to advance in its own efforts to scale clean technology uptake.

Measuring success

It all starts with proof. In a capital constrained market, owners are right to want to scrutinise every investment decision for their new and existing ships. However, obtaining this proof can be a tall order for clean technology companies.

Determining and comparing the effectiveness of energy saving devices can be difficult owing to varying conditions that influence fuel consumption (for example, draught, trim, loading condition, speed, fouling and adverse weather), and because of varying data accuracy and measurement protocols. Savings could be reported gross of power requirements or net, ultimately leading to a generally uneven record of claims across the sector.

However, air lubrication is one of few maritime clean technologies that can be measured 'live' by switching the system on and off. When the Silverstream® System is turned on, an almost instant drop in shaft power and an increase in speed is observed as the frictional resistance of the hull is reduced.

Silverstream has pursued proof of the benefits of its system with rigour, industry-wide collaboration, and transparency. Third parties including Lloyd's Register, HSVA, the University of Southampton, Carnival and Shell have conclusively proven that the Silverstream® System generates an average 5-10% net fuel and emissions saving, depending on vessel type. Our technology enables fuel savings as high as 7% for LNG carriers and 6% for cruise ships, tankers and bulkers.

CARNIVAL CORPORATION IS TO IMPLEMENT SILVERSTREAM'S TECHNOLOGY ACROSS ITS OPERATING BRANDS

Managing the retrofit

Any request for our technology – but particularly retrofits – are managed through a process spanning evaluation, proposal, design, equipment supply, system installation and commissioning that has stood up to the demands of the world's largest shipowners and some of the sector's most unique vessels.

First, we evaluate. Specialist engineers will complete an initial assessment of estimated savings and outline system design, having received design and operational information about the vessel. Customers are provided with an assessment of estimated savings across a range of speeds and for ballast and laden conditions. The evaluation methodology is developed using research carried out with HSVA in Hamburg and from comprehensive operational data obtained from other installed systems.

Next, a formal proposal is created including delivery schedules. Typically, this enables customers to engage with their preferred installation yards and partners for installation pricing very early in the process. We work with customers and yard partners to ensure mechanical, electrical and HVAC requirements are understood and correctly specified.

Then, once an order is formally received, engineers produce detailed design information for class approval of the air release units, overall system arrangement drawings, and integration drawings for air release unit installation. Detailed plans are provided for equipment manufacture and delivery, and for the installation and commissioning phase.

After design approval, equipment delivery schedule will be confirmed with scope of supply comprising the air release units, compressors and automation system. These will be procured, manufactured and factory tested ready for despatch.

Following delivery at the installation yard, all equipment is checked to ensure no damage has occurred during transit. Silverstream representatives will be present to support a retrofit installation in drydock, and at key installation stages for a newbuild project, as well as the final commissioning stage.

During this final phase, the Silverstream® System's compressors and automation system will be commissioned by OEM engineers under Silverstream supervision.

After the equipment is commissioned, the overall system will be tested with adjustments carried out once the vessel is at sea. Crew training will be provided, along with operating manuals and procedures. After commissioning, remote support is provided by Silverstream's engineers.

Partnering for success

Silverstream's successful installations only work because of the strong global partnerships we have built over the last decade. This includes agreements with key shipyards in Asia and the Middle East, including new partnerships with Malaysia Marine and Heavy Engineering and Nakilat Keppel Offshore & Marine to specifically target and support retrofit installations.

These industry relationships complement a resilient global supply chain. Our supply chain is built on the principles of diversification to spread risk and increase supply, and localisation to ensure technology can be delivered and installed quickly and efficiently.

This approach has proven its weight in gold over the past couple of years: despite the ongoing challenges

in the global economy and the aftershocks of Covid-19, Silverstream has never failed to deliver a project on time.

Winning trust

It is this combination of trust, process and supply chain that has positioned Silverstream well for the coming years, and that has raised the profile of air lubrication within the sector more widely. It's crucial that we continue to gain the confidence of ship owners who may be evaluating a huge range of existing clean technologies.

A recent example is the frame agreement we signed with Carnival Corporation to retrofit the Silverstream® System across Carnival's various operating brands. The two companies worked together to evaluate the entire fleet and identify the vessels with hulls that were best candidates for air lubrication systems. These are now scheduled to have the Silverstream® System installed during routine drydocks over the next few years. This collaborative approach to the assessment phase and the subsequent implementation programme has proved to be a very efficient model for achieving EEXI and CII improvements.

At Silverstream, we believe that our measurable success in both system performance and system installations is helping to consolidate a new best practice service for shipowners and has lowered the barrier for entry for incorporating air lubrication systems into ship designs.

This is creating the blueprint for wider clean technology adoption to help solve the fundamental challenge of ship design efficiency – and ultimately make a tangible contribution to maritime decarbonisation. ■

THE AIR LUBRICATION SYSTEM EMPLOYED BY SILVERSTREAM USES A SERIES OF CAREFULLY POSITIONED AIR RELEASE UNITS ON THE SHIP'S HULL NEAR THE BOW

SCANDLINES' NEW ZERO DIRECT EMISSION RO-PAX FERRY *PR24* WILL BE INSERTED ON THE PUTTGARDEN-RØDBY ROUTE IN 2024.
SOURCE: SCANDLINES

FERRIES

HYBRID NEWBUILDING TO TAKE SCANDLINES FORWARD ON PATH TO ZERO EMISSIONS

By **Kari Reinikainen**, Correspondent

Danish ferry company Scandlines, which operates two services between Denmark and Germany, converted a ferry to hybrid propulsion in 2013 and has since worked on ways to reduce emissions and to meet its target of becoming emission free by 2040. A ro-pax ferry currently on order at the Cemre Shipyard in Turkey will take the company further forward on that path.

"We will continue to invest in green initiatives and strengthen our competitiveness by developing our business to cater to the needs of all customers. We have therefore set out to realise our zero-emission vision by 2040, and we aim to reach scope 1 and 2 zero direct emission operations on the Puttgarden–Rødby route by 2030 as an important first step on this journey," CEO Carsten Nordland notes in the company's 2021 annual report.

The new vessel has been designed jointly by the in-house technical team of Scandlines and LMG Marin, the Norwegian consultancy, which has an extensive reference list of electric- and hybrid-powered, double-ended ferries.

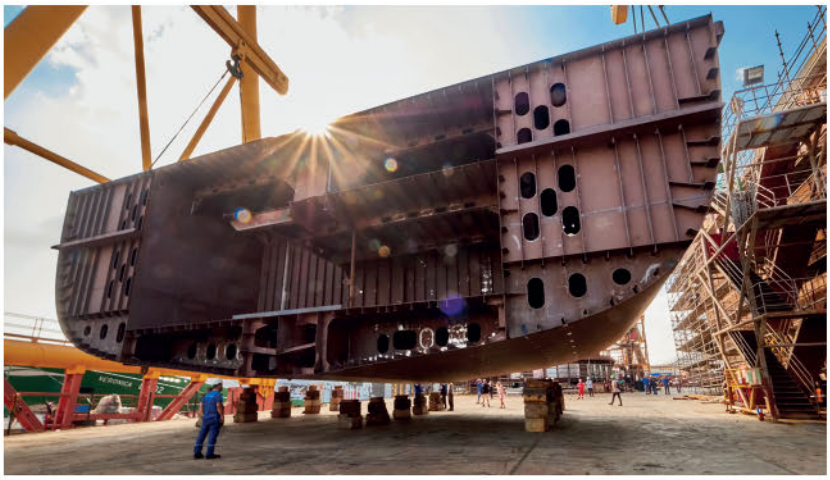
The keel of the hybrid ro-pax ferry that can make the 11-mile crossing between Rødby Havn in Denmark and Puttgarden in Germany entirely on battery power was laid at the end of August 2022.

Emission-free crossing

Called *PR24* at this stage, with the letters derived from the names of the ports the vessel will serve and the numbers from its anticipated year of service entry, the ferry will be emission free when using batteries. The crossing time will be 70 minutes in this mode, states Anette Ustrup Svendsen, head of Corporate Communications, at Scandlines.

The vessel, which will be 147.4m long, 25.4m wide and 5.3m design draught, will make the crossing at 10knots in battery mode. However, the vessel can also be operated as a hybrid ferry, which will increase the speed of the ferry to 16knots and reduce the crossing time to 45 minutes by using MTU's 1,560kW gensets. Cemre Shipyard said in a statement that provision is made in the design to allow the ship to use methanol as fuel later in its life.

This means that the new ferry can also be used as backup vessel for one of the four double-ended ferries that are currently operating the Puttgarden–Rødby route. "Our *PR24* has a modular design, so we can increase the number of passengers, if the need arises. Right now, we concentrate on our *PR24* and don't have any actual plans of building more ferries," Svendsen notes. The ship will be able to carry 140 passengers on delivery.



THE KEEL OF *PR24* WAS LAID AT CEMRE SHIPYARD IN TURKEY AT THE END OF AUGUST 2022. SOURCE: SCANDLINES

A key element in the concept is the battery pack system, which will be supplied by Leclanché. This will be a lithium-ion G-NMC battery system with a capacity of 10MWh with a maximum voltage of 864volts and the supplier will guarantee it for 10 years. The battery energy storage system (BESS) uses a highly redundant architecture with 48 battery strings distributed across eight switchboards. Delivery of the system will begin in January 2023, Svendsen continues.

Charging time 17 minutes

The BESS can be recharged in just 17 minutes by using a 50kV/25MW power cable in Rødby Havn, which was installed in 2019. However, as this does not currently extend to the berth that the vessel will use, work will start in the spring of 2023 to extend it and to build a transformer and charging station as well.

Norway's Kongsberg Maritime will supply the ship's Azipull thruster. "The thruster will be delivered with controllable pitch propellers, in an L-drive configuration with an integrated permanent magnet drive motor. This increases overall energy efficiency while reducing noise and vibrations, as well as reducing the physical footprint of the thruster system compared to previous deliveries," according to Kongsberg.

Kongsberg's Mcon propulsion and thruster control system will also be fitted on the vessel and this will allow the operator to check e.g. magnitude and direction of thrust and the condition of the equipment at a glance. The company has a long track record of co-operation with Scandlines as a main propulsion supplier.

The vessel will have capacity for a total of 66 freight units – equal to about 1,200-lane-metres – that will be carried on two decks. This means that a berth in both ports that the vessel will serve have to be rebuilt to allow handling of loading and discharging on two levels. Freight is very much in the focus of the vessel: it will increase freight capacity on the Puttgarden–Rødby Havn route by 23%.

'Climate Twin'

Scandlines has decided to employ ReFlow, a Danish tech start-up, to produce a detailed life-cycle digital model of the vessel that will represent its life span from construction to the time when it will be taken out of service.

"The model will show the environmental impact of the ferry, not only in its use but also from its construction at Cemre Shipyard along with the installed equipment. The digital 'climate twin' will make it possible for Scandlines to run simulations on the use of new green technology on the ferry, something that is nearly impossible today," states ReFlow.

The new vessel will make its debut in 2024 and will replace two old vessels in Scandlines' service. The 1986-built, 86m *Holger Danske*, which was designed for the 20-minute crossing between Helsingor in Denmark and Helsingborg in Sweden, was taken out of service last year. Scandlines no longer operates this service.

The much larger 152m *Kronprins Frederi* was built in 1981 for a domestic service between Nyborg and Korsor and is currently used as a freight only ferry. It will be phased out when the new ship enters service.

Scandlines has six hybrid ferries in service at the moment. The two largest units in the company's fleet, the 169.5m-long *Berlin* and *Copenhagen*, were each fitted with a Norsepower rotor sail in 2020 and 2022, respectively. ■

THE *PR24* WILL FEATURE A LECLANCHÉ 10MWH ADVANCED BATTERY SYSTEM. SOURCE: LECLANCHÉ

NORWAY

THE NORWEGIAN MARITIME CLUSTER SPREADS A WIDER NET

By **Charlie Bartlett**, correspondent

The GCE Blue Maritime cluster comprises more than 100 Norwegian ship designers, yards and OEMs. Recently, it has set out a new strategy of fully decarbonising, and becoming "the world's full scale net-zero maritime cluster", explains Daniel Garden, CEO of GCE Blue Maritime.

"Throughout the pandemic, we made up a new strategy called the new blue deal," he says. "The ambition is to have a standing internationally for having the latest innovations and technologies, and we believe the climate crisis is something we can throw at these companies and see what they come up with."

It has been a tough few years. During a period when oil prices soared to over US$100 per barrel and stayed there for four years, it seemed as though a new offshore support vessel, platform supply vessel or anchor handler was being delivered every other day. But then one day in June 2014, it suddenly cratered, and kept going, taking the Norwegian oil and gas sector with it.

"There were a lot of PSVs laid up because of the rates, and some were even decommissioned," says Garden.

Adjusting to the new reality, Norway's ship designers and yards began to diversify into new sectors. With an abundance of laid-up workboats, some decided to convert them to other uses, such as aquaculture vessels, and latterly, offshore wind farm support vessels, which would come to be known as commissioning, service and operation vessels (CSOVs.)

"Some of the findings from those rebuilds is that a PSV is much larger than an SOV, which means you have a lot of space to play with. So PSVs are quite good for rebuilding into smaller vessels, with space to put in new systems, battery packs and different types of deck machinery."

By the time 2018 came around, the Norwegian maritime cluster was busy inventing a new sector almost out of whole cloth: the expedition cruise sector, one which would require imaginatively luxurious vessels, but also technologically advanced, in the manner Norwegian shipbuilding had come to be famous for. It was not long, though, before Covid-19 brought a sharp end to single cruise itinerary in the world.

Emerging from sequential crises wiser and better diversified, Norway's maritime cluster ploughs ahead with the next thing – whatever that is. "At the moment there is about €6.1 billion in the [cluster] orderbook, combined," explains Garden. "Most of the equipment manufacturers have a significant export share of 70%."

GCE BLUE MARITIME IS CENTRED IN THE PICTURESQUE NORWEGIAN TOWN OF ÅLESUND. SOURCE: CHUNYIP WONG/PEXELS

Oil and gas remains the largest segment; but other segments are catching up. "If we combine cruise and ferries, it is about the same size. Aquaculture is also growing quite heavily," he adds.

In fact, aquaculture is only 2% behind the oil and gas segment, in terms of market share, showing that the sector has learned a lesson since 2014. Meanwhile, the cruise segment is making a slow return, necessitating some of those highly-advanced vessels built for challenging conditions. "There is a lag to get customers back to planning their holidays, but it looks like [expedition cruise] vessels are back in operation. Not all are fully booked... but the newbuild programme has started again."

With the Russo-Ukraine war driving up oil prices close to their 2014 levels, owners of oil and gas vessels who managed to stay extant are now reaping the benefits, and the conversions to CSOVs have ceased entirely. "Most of those [laid up PSVs] are now back in traffic," Garden says.

While the tendency may have weakened in recent years, with many Norwegian owners choosing "good enough" vessel constructions in Turkey or China over local content, Garden notes that, proportionally, shipowners within the cluster tend to build more of their vessels more locally, in proportion with other maritime clusters.

Another tendency, thanks to the close relationship between Norwegian shipbuilders and shipowners, is experimentation, with vessels often serving as a testbed for new technologies. "Studies by the Norwegian Technical University show that there is no single solution that will take us all the way to zero emissions. We can reduce emissions by looking at the shape of the hull, the waste heat recovery, cold ironing... so many things. So we as a cluster need to look into this," Garden concludes. ■

WHAT MAKES A VESSEL 'READY' FOR NEW FUEL TYPES?

By **Charlie Bartlett**, correspondent

VARD'S BRATTVAAG SHIPYARD IN ÅLESUND, SOURCE: RADU PARMAC

An uncomfortable fact about offshore wind farms is that they do, at present, have an operational carbon footprint thanks to the requirement for continuous monitoring and maintenance by commissioning service operation vessels (CSOVs). Accommodating as many as 70 wind farm staff with an onboard hotel block, CSOVs deliver turbine technicians to the base of wind turbines via gangway, in order that they can perform routine maintenance.

But travelling out to installations is a carbon-intensive process, as currently it is supported on most vessels by a four-stroke engine running on diesel, and the vessels are held steady on-station using dynamic positioning (DP) systems, which require diesel-electric generator power to operate.

CSOV operators note that this is bizarre, given that such vessels spend all day surrounded by forests of renewable electrical generators. The consensus among Norway's cadre of CSOV designers and builders, then, is that eventually these vessels will eventually operate on battery power, and plug into wind turbines. The mechanism for this is thought to be similar to that of shore power, by now a matter of routine in Norway, which benefits from an abundance of renewable hydropower.

But to do this, CSOVs will have to carry large battery packs with them, capable of sustaining the vessel's DP systems and hotel load while they are at the work site, with enough left over to return to port.

Operators of CSOVs do not necessarily want to invest in these battery systems right away, as there is an assumption that batteries, like Moore's Law in computing, will become better and more compact over time. In the meantime, there are some barriers to be overcome before the investment becomes worth the gamble. Svein Leon Aure, CEO of a new offshore wind operator, Norwind Offshore, explains to *The Naval Architect* that one potential hurdle is "a lot of politics".

"We will deliver the vessel with the battery and a charger," he says. However, "The energy the windmills are producing is very often sold already. So we cannot just tap from the production... even though it would be much more efficient from our point of view. So that is one challenge."

Bringing a charger

Roy Ove Standal, Norwind COO, adds: "With a 25MW battery package, we can operate on electricity about 15 hours per day."

Grappling with the statutes of the Jones Act, wherein vessels cannot freely operate out of US ports unless built in US shipyards and crewed by US seafarers, this is something the Americans, latecomers to the offshore wind boom, have already thought of, he indicates: "In the US, Equinor tells us... [new wind farm facilities] are obliged to offer a charging facility offshore."

At present, Norwind Offshore operates only one CSOV, a Vard-built former platform supply vessel (PSV), *Norwind Breeze*. The conversion involved the addition of an accommodation block amidships. Leon Aure tells *The Naval Architect* that the area under the deck – which would have been reserved for bulk and slop tanks when the vessel was still a PSV – will make an ideal space for the addition of a battery pack in due course.

Vard is now in the process of designing and building four purpose-built CSOVs to add to Norwind Offshore's fleet. The first of these, *Norwind Gale*, was delivered to Vard's Brattvaag facility in Norway, from Vard Braila shipyard, Romania, in October, and is due to be completed in May 2023. Like the other three sister vessels to be delivered thereafter, the vessel is of Vard's 4 19 design, with 70 cabins onboard,

with a heave-compensated gangway for transferring personnel to turbines.

Vard has applied some intriguing technology to the contouring of the vessels' hulls. Called 'parametric optimisation', it applies machine learning to the process of devising the best hull shape for the vessels; but instead of being optimised only for the best possible hydrodynamics, the iterative design program attempts to reconcile this need with the optimal geometry of accommodating battery banks inside the hull.

Vard has programmed computer software to identify the best possible geometry, taking into account factors like hull strength and ship speed, while maximising the space for battery capacity.

The parametric optimisation method leaves Vard's engineers free to think about other functions, explains Henrik Burvang, Vard design manager, Research and Innovation. "This enables us to do calculations overnight, on hundreds of different hull shapes and sizes – in order to find the lowest power consumption but also optimising the space inside," he says. "Are we able to fit large battery packages, or to fit all the special product tanks?

"We can vary wave resistance, changes in loading conditions, and we can simulate how the engine, energy systems, power management will respond."

Burvang claims that 87% of Vard's vessel orderbook will either be battery 'ready', or will have batteries fitted when they launch. For many, the term 'ready' has come to be regarded as misleading, referring to little more than empty spaces in the hull. In the case of Vard's vessels, there is a little more to it, he explains. "When we are designing ships that are 'ready' we have to investigate all aspects so that we know it will work."

The matter of putting batteries onboard a vessel is fraught with complications, given that if one cell is defective, it could start a chain reaction leading to fires which are nearly impossible to put out.

"Yes, to a large extent, ['ready'] boils down to providing the space," he says. "But you cannot provide that space anywhere. If you actually have the intention of installing these final systems, then you have to be confident that it is actually manageable, especially regarding safety, and the approval process.

"We look into all the components. How do they act, what do they need? How much ventilation do we need, and where, which kind of hazardous zones are created on the ship, and whether this is a problem for the ventilation system. If you're looking to a retrofit solution, that could be really challenging, to be able to properly integrate it, but the more you prepare in the design phase, the more studies we are able to do, the easier the retrofit will eventually be."

New-generation fuels

In the end, it may be that Norwind Offshore chooses to go down a different path for fuelling the vessels, contingent on whether wind farm operators can be prevailed upon to make charging available – and whether battery power proves to be economically viable. Aure says that his vessels may in due course be fitted with ammonia or methanol tanks, instead.

"There is no defined way as to how this will develop," he comments. "Certain areas are requiring that all additional energy produced should be converted to hydrogen, for example."

This would include wind farms far out to sea, where turbine arrays will float, rather than being fixed to the bottom. Locations for this include the US Pacific coast, where the continental shelf drops off sharply and makes fixed turbines impossible to install. Norway, which has an abundance of wind energy but hardly any turbines at present, is another candidate for floating turbine installations. Here, the economics of producing and refining hydrogen – or the energy carrying fuels of which it is a constituent part – are thought to be better than trailing long cable arrays into the deep sea.

If Norwind Offshore's CSOVs do go carbon-neutral in this context, then they will likely be retrofitted with e-fuel tanks and infrastructure, rather than batteries. Vard has also been looking into fuel cells, which can be used in place of an engine to eke out the best efficiencies from ammonia or methanol. Fuel cells have been able to improve on engine efficiency by three times, in some cases.

Despite the relatively low energy content of these fuels compared with conventional fossil hydrocarbons, it is anticipated that using the additional tank space for more fuel will still give the vessels more than enough power to meet with the requirements of their day-long operational window, as the energy content of these fuels is still higher than of which batteries are capable.

"If you want to have one kilowatt out of a fuel cell, that's good, it is steady state. But if you want to ramp that up to two, that takes significant time. So to make the system work well, we add a battery, which can give you instant power while you increase the power slowly with the fuel cell," says Burvang. ■

VARD HAS A CONTRACT TO DESIGN AND BUILD FOUR CSOVS FOR NORWIND OFFSHORE

LATE-BLOOMING ULSTEIN X-STERN FINDS A PLACE ON WIND FARM VESSELS

By **Charlie Bartlett**, correspondent

ULSTEIN'S SX222 TWIN X-STERN VESSEL DESIGN FOR OLYMPIC OFFSHORE

Ulstein's X-Stern design turns out to have been something of a sleeper hit, garnering little attention in naval architect and shipbuilder circles at first. With commissioning service offshore vessels (CSOVs), however, it appears to have found its niche. The designer and shipyard was contracted in July this year to provide four CSOVs for Olympic Offshore, and each features a 'Twin X-Stern' the name given to vessels with 'X' bows and sterns.

"We launched [X-Stern] in 2015, but it is only really this year that we have commercialised it," says Runar Muren, COO Design & Solutions.

Functioning akin to a large contiguous bulbous bow, the X-Bow has long been considered one of the best hull geometries for tackling heavy waves at speed and reducing the sensation of slamming on the bridge. But a quirk of the way CSOVs operate makes them a good candidate for operating with an X-Stern.

Sitting on station for long periods, a vessel might have to change direction based on the wind and waves; but having a bow and stern the same shape effectively reduces the need for this by around half. Taken to its logical extreme, it is the same principle which once yielded the cylindrical shape of some FPSOs, which have the advantage of presenting a similar profile whatever the direction of the wind and waves, greatly improving stability.

For a vessel with a prime mover and single propeller, the Twin-X-Stern would be impractical. But for Olympic Offshore's vessels, which feature two azimuth pods at the bow and two at the stern, it makes almost no difference which direction the vessel is pointing. In fact, the hull geometry would theoretically allow a vessel to proceed backward, with the bridge situated aft like a deepsea vessel. This function was tested on the CSOV *Windea Leibniz* in 2017, an Ulstein SX 175 design, which turned out to be a knot slower sailing backward. Still, though it might look absurd, doing so could improve crew comfort by reducing further the sensations of heaving and slamming; after all, there is a reason container ships and tankers position their superstructures and accommodation blocks toward the aft of the vessel.

The belated success of the Twin X-Stern now serves as a shorthand for Ulstein's company ethos, an attitude of self-justifying innovation.

Cathrine Kristiseter Marti took over from Gunvor Ulstein as CEO of the shipyard in November 2020. In conversation with *The Naval Architect*, she was asked whether she thought the maritime industry was ready for Ulstein's *Thor* – a civilian nuclear-powered vessel which would act as a bunkering ship for electricity – and in response, revisited the synecdoche of the Twin X-Stern. (*Thor*, of course, has one.)

"With the Twin X-Stern, we launched it in 2015, and we got no attention whatsoever," says Marti. "But then it was operated on the first windmill vessel, and they came back with the information they had, and had seen how it works. [CSOVs] are working in all directions, so it had the intended effect. And after that it was a big hit. This is why we come up with things sometimes, it does not land at first, so we say, keep trying."

"I think it shows what kind of resources we have here, where we have people who are interested, curious, and want to come up with new ideas," adds Muren.

It is this permission to be weird that gives Marti confidence in the future not only of her yard, but also of Norwegian ship designers in general. Earlier this year, Ulstein sold its first two CSOVs in China, to Shanghai Electric. "Very important. Chinese owner, Chinese class – we hope this is a step into a new market in China," says Muren.

The move was a compromise, giving Ulstein access to China's massive, and growing, offshore wind industry, at the cost of some intellectual property.

But challenged on this, Kristiseter Marti indicates she was not worried about giving away Ulstein's secrets. "This is why we always need to stay in the forefront," she says. "So that when they copy us, we have something new!" ■

RO-ROS

SEA TRANSPORT AND FIRE SAFETY OF ELECTRIC VEHICLES

By **Yeontae Kim**, EVP of Technical Division, Korean Register

The supply of electric vehicles continues to grow as emission reduction regulations and initiatives to encourage eco-friendly vehicles make their effects felt around the world. According to S&P Global Platts Analytics, global light duty electric vehicle sales reached a record high of 6.3 million units in 2021, with this number expected to rise to 26.8 million units in 2030. This rise has been reflected in a corresponding rise in the volume of electric vehicles transported by PCTC (Pure Car & Truck Carrier). However, high profile cases such as the intense fire aboard MOL's *Felicity Ace* in February 2022, which was carrying 4,000 vehicles, including electric vehicles powered by lithium-ion batteries, have focused attention on the difficulties of containing battery fires.

FIG 1: YEONTAE KIM, KR

In general, fire in an electric vehicle refers to the fire in the battery of the electric vehicle for propulsion. Lithium-ion batteries are mainly used in these vehicles. When a fire occurs, thermal runaway (a phenomenon in which the heat generated during a fire speeds up the exothermic reaction of the battery, further accelerating the generation of heat) occurs, making it very difficult to extinguish the fire. This phenomenon cannot be seen in conventional internal combustion vehicles and makes electric vehicles recognised as having a very high risk of fire. Particularly, the battery state of charge (SoC) is related to the occurrence of the thermal runaway phenomenon. The higher the charging rate, the higher the possibility of the thermal runaway phenomenon, which may make fire suppression more difficult (see Fig. 2).

However, since electric vehicles are an emerging technology, they tend to receive more attention when a fire occurs. In fact, the fire rate of electric vehicles is known to be only about half that of internal combustion vehicles, despite some differences between statistics.

SOLAS fire provisions

PCTCs are used to transport automobiles, and electric vehicles are also transported on these vessels. Fire safety equipment for ships is installed in accordance with SOLAS (International Convention for the Safety of Life at Sea). Portable fire extinguishers and fire hydrants should be equipped in places where vehicles are loaded, and fixed fire extinguishing system should also be provided.

According to SOLAS regulations, fixed fire extinguishing systems must be either a CO_2, foam or water fire extinguishing system. However, it is difficult to determine which type of fixed fire extinguishing system actually performs better on electric vehicle fires.

Firstly, for the fixed water fire extinguishing system, there is a practical difficulty for installation. The water spray nozzles should be installed at the ceiling of each deck, but, the liftable decks which move up and down make it difficult to install the water spray piping system. Unlike passenger ships, it is rare to find a water fire extinguishing system installed as a fixed type in PCTC ro-ro space. In general, CO_2 or foam fire extinguishing systems are used.

As for systems using CO_2, the possibility of reignition is high, and the foam system may be decomposed at a high temperature of 1,000°C or more. In addition, because there is typically a limited amount of extinguishing agent onboard the ship, it may be difficult to respond properly if the fire occurs again.

IMO is planning to discuss the revision of the fire safety regulations for ships with reference to the loading of electric vehicles. If preventative measures are not taken in time, the fire is likely to spread throughout all the vehicles aboard since they are loaded closely together, and it is difficult to extinguish the fire once it starts. Therefore, it is critical to detect a fire at an early stage and stop it from spreading. As improved fire detection systems are still in development, it is necessary to revise the relevant regulations, taking into consideration the latest technology. Additionally, the initial extinguishing method and measures for preventing fire spread should also be considered. However, is expected that it will take at least five years for the results of the IMO's discussion regarding the fire safety of electric vehicles to be applied to actual ships.

FIG 2: SAFE TRANSPORTATION IS INTRINSICALLY LINKED TO THE LITHIUM-ION BATTERY'S STATE OF CHARGE

New notation

To meet today's challenges and take the lead in responding to this issue, the Korean Register (KR) has developed a class notation called 'AFP-C(EV)' which covers the loading of electric vehicles. As well as the requirements set out by the existing fire safety regulations, AFP-C(EV) calls for the installation of additional equipment for detecting and extinguishing fire. This equipment includes a combined smoke and heat detector, a portable thermal camera, and a fire blanket. These measures will help improve fire safety in the ro-ro space.

Currently a smaller number of electric vehicles are transported by sea than those with internal combustion engines. It should also be noted that most electrical vehicles transported are new. But when more electric vehicles are transported than their traditional counterparts, including used electric vehicles which may have unstable batteries, new risks arise.

However, it should be noted that the main causes of electric vehicle fires are external impacts, overcharging or defects in the battery. When electric vehicles are transported by ship, there is no movement of the vehicle while it is being transported, and therefore no possibility of external impact. The vehicle is not charged during the voyage since the charging rate is managed and loaded by the vehicle manufacturer. When the vehicle is loaded, charging is not possible due to the narrow space, and therefore electric vehicle chargers are not installed on the ship. It means that the probability of a fire occurring while transporting electric vehicles on a ship may actually be lower than in a general onshore environment.

The advanced technology for safer battery manufacturing will also continually reduce defects in batteries. Unlike the commonly used electrolyte-type battery, the all-solid-state battery can fundamentally eliminate the cause of fire. While research is underway toward commercialisation of the all-solid-state battery, it will be possible to significantly reduce the risk of fire.

Along with the development of technology to manufacture safer batteries, the charging rate of electric vehicle batteries loaded on ships during sea transportation should be minimised. The early detection and extinguishing of a fire before spreading, safer sea transportation of electric vehicles will be possible. ■

FIG 3: FIREFIGHTING DRILL WITH FIRE BLANKET

LNG CARRIERS

THE LAST MILE FOR LNG BUNKERS

A fast and agile LNG bunker vessel designed to fulfil current and future requirements of ship-to-ship fuel transfer

By **Johan Lillieskold**, gas solutions specialist, LNG Competence Centre at Schulte Group, and **Fridtjof Rohde**, sales and project management, Technolog

Schulte Group in partnership with naval architect company Technolog has brought to market a new next-generation design for an LNG bunkering and gas-freeing vessel (LBV) intended to reduce CAPEX and OPEX. Designed to support the new spate of LNG-powered vessels scheduled to be operational by 2025-26, the new design will significantly reduce 'last-mile' costs for operators that have opted for emission-reduction and long-term cost savings by use of LNG, LBG (Liquified Bio Gas) or e-methane as fuel.

Current arrangements to receive LNG bunkers in port can be excessively time consuming and costly. Heavy inflatable fenders and space pontoons, and sometimes barges, are typically deployed alongside the LNG bunker vessel to protect the client (or LNG bunkers-receiving) vessel during operations. This is a cumbersome and manual process that each time can take a substantial deck crew hours to complete.

Further, Schulte Group and Technolog have identified a significant gap in the market for the service of gas tank warm-up, inerting and gas freeing (aeration) operations required before an LNG-powered vessel can safely enter a drydock or repair yard. At present, LNG-fuelled vessels and currently available LBVs are dependent on external service providers, such as LNG terminals or ports with required equipment deployed, to make a cold, gassed-up LNG tank, a warm, aerated, gas-freed tank.

The new vessel concept addresses all of these challenges. And whilst Schulte Group analysis suggests that shoreside truck-delivered bunkers will play a part in the unfolding LNG bunkers landscape, vessel-to-vessel operations will dominate and support the burgeoning number of merchant LNG-fuelled vessels that will make up the emerging low-emissions fleet within the next five years.

Further, all safety and environmental requirements associated with LNG and bunkers operations have been addressed in the design specifications.

One size fits all

Favourably affecting the OPEX of a client vessel's operations is the innovative outrigger system that can accommodate any vessel type.

In comparison to the time consuming process involved in manually rigging necessary fenders, the new LBV can deploy a size-appropriate outrigger arrangement in five minutes with the single push of a button.

(LEFT) JOHAN LILLIESKOLD, GAS SOLUTIONS SPECIALIST, LNG COMPETENCE CENTRE, SCHULTE GROUP. CREDIT: SCHULTE GROUP
(RIGHT) FRIDTJOF ROHDE, SALES AND PROJECT MANAGEMENT, TECHNOLOG. CREDIT: TECHNOLOG

The vessel type has been designed to maximise compatibility with existing and known future LNG-fuelled tonnage, including:

- Cruise liners, which often have structures protruding from the hull, such as lifeboats, deck structures and balconies (see Fig. 1). The outrigger and fendering system on the new LBV, which is safe and fast to deploy, accommodates all shape requirements.
- Vessels with short usable parallel bodies, for example, large, high-speed, slender container vessels with bunker ports located forward or aft. For this type of vessel, the new LBV's forward manifold will provide reach into or up to bunker stations.
- Vessels with a high freeboard, for example, VLCCs, large bulkers, large container vessels, large heavy lift vessels, such as semi-submersible crane vessels. The new LBV's long-reaching telescopic crane extends over 40m over the water, making it compatible with all known and soon-to-come LNG-fuelled vessels.
- Vessels with bunker stations located low down, for example, some cruise liners, ro-pax and some container vessels. Such vessels can have bunker ports situated as low as 3m above the water line. Current LBVs are usually equipped with a large crane with a fixed reach. Such cranes can be compatible, but often slow down operations when the LNG transfer system (hoses, release couplings, quick

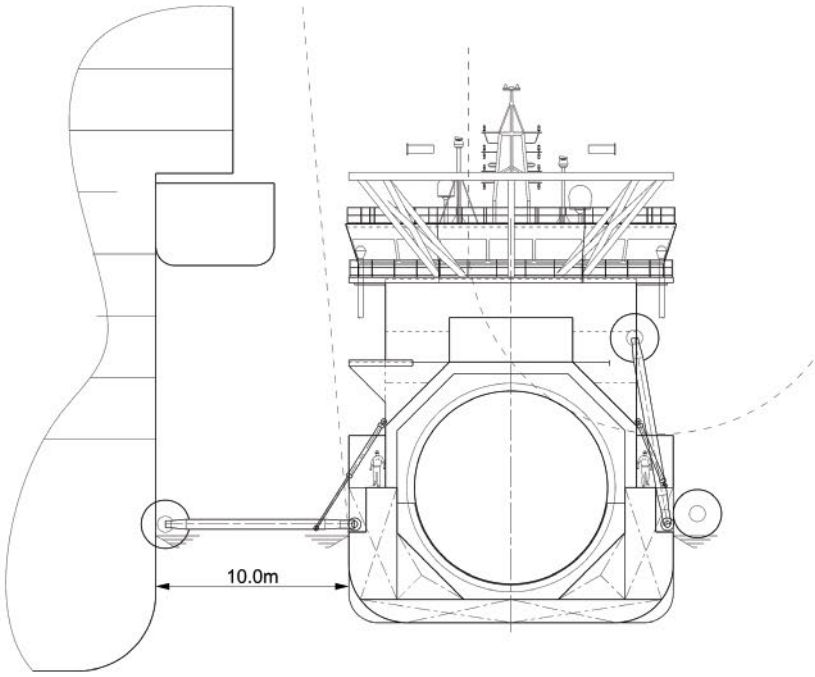


FIG 1: THE LBV ALONGSIDE A CRUISE SHIP, LOOKING TOWARDS THE HULL, WITH LIFEBOAT PROTRUDING. THE DEPLOYED OUTRIGGER SYSTEM KEEPS THE LBV A SAFE DISTANCE FROM THE SHIP WITHOUT THE NEED FOR PONTOONS. THE DASHED U-SHAPED LINE TO THE RIGHT REPRESENTS THE SAFETY BOUNDARIES AROUND THE VALES/GAS MAST, WITH PORT SIDE MAST IN USE. CREDIT: TECHNOLOG

connectors and release system) are being passed to a client vessel.

With the new LBV design, the telescopic crane can be adjusted to any required reach. Consequently, the manoeuvring of the LNG transfer system can be undertaken faster and in a more accurate and safe manner.

- Vessels with bunker manifolds located extreme forward or aft of the ship's length. The LBV's forward manifold will ensure compatibility with this type of vessel and still maintain a safe mooring pattern.
- Large-scale LNG terminals with loading arms typically located 14-16m above water. The new LBV can be equipped with a high manifold making the vessel compatible with large-scale loading arms. This can be advantageous in areas where an operator is a 'first mover', where no other means of loading an LBV is available.

Further, if the LBV is ordered without the high manifold, the vessel will be delivered with the necessary scantling, stability, routing of piping, penetrations, for example, all incorporated to allow for easy retrofit (see box/side bar).

To optimise efficiencies, the vessel design allows for tank sizes of between 3,000-4,500m³ LNG bunkers capacity, which is more than sufficient for most vessels' bunkering needs. Whilst it is smaller than Babcock Schulte Energy's LBV, *Kairos*, which has a cargo carrying capacity of 7,500m³, the new vessel design – at 4,000m³ and 89m-long – enables it to be fast and agile. Further, only the midship section is affected by the required tank dimensions – all other aspects of the design remain the same – resulting in a large cargo-carrying capacity in a compact design.

Drydock ready?

As more LNG-fuelled vessels enter the market in the coming years, so too will the additional infrastructure be required to prepare these vessels for routine drydocking and repair work.

Depending on the LNG-fuelled vessel's type of fuel gas tanks and/or required repairs, the fuel gas tanks will normally need to be liquid free and, at least inerted, if not aerated (gas free), prior to entering a repair site or dockyard. Certainly always when tanks are to be entered.

There will further be occasions where LNG-fuelled vessels are required to undergo unplanned repairs, often on a commercially urgent basis to avoid or reduce off-hire. Typical examples are after a hard steel frame indent from a tugboat, or a berthing incident requiring small to semi-major hot work. Current arrangements to prepare LNG-fuelled vessels in this way require the appointment of a third party, resulting in significant costs.

It is unacceptable, and will become increasingly so, to vent CH_4 (methane) to the atmosphere, other than in emergency situations. LNG-fuelled vessels are almost

SCALABLE DESIGN

Schulte Group and Technolog have designed the LNG bunker vessel with a series of selectable options, so that it can be tailored to requirements. Operators can choose from the following:

- Outrigger versus normal Yokohama type fendering system
- Sub-cooler versus no sub-cooler
- High manifold versus no high manifold (vessel will be delivered with necessary infrastructure in situ to enable easy retrofit at a later date)
- Forward manifold versus no forward manifold
- Battery hybrid versus no battery hybrid
- Cargo Tanks 304L (ammonia ready) versus 9% nickel steel (LNG only)

THE NEW LBV: KEY FEATURES

- Outrigger system that enables bunker operation with any type of LNG-fuelled vessel, including cruise ships. The unique patented design does away with spacer pontoons and inflatable fenders. The outrigger system can be launched in around five minutes by the push of a button.
- Flexible design options so that they can be tailored to requirements to ensure minimal CAPEX.
- Smaller crew required whilst still maintaining high safety levels made possible through an intuitive human/machine interface and rationalised deck, based on best practice operations for safe and easy mooring operations.
- Gas freeing and aeration equipment to prepare any LNG-fuelled client vessels for drydock.

never equipped with onboard gear to handle CH_4 and burn the same during a gas freeing operation. Nor are they equipped with large capacity inert gas plants to handle inerting of own fuel tanks or aeration fans for dry air aeration (final gas freeing).

It is against this background that we identified the considerable commercial and predictability advantages of incorporating an LNG tank conditioning system into the new LBV design, with the following key characteristics:

- High warming-up capacity through the circulation of hot CH_4 from LBV to the LNG-fuelled vessel - the cold vapour return from the LNG-fuelled vessel will be re-heated and sent back to the vessel's tanks. As and when the tanks warm up and gas expands, it is environmentally friendly combusted in the LBV's high capacity GCU (gas combustion unit).
- When tanks are warmed-up, the LBV produces and sends dry N_2 (nitrogen) inert gas to the LNG-fuelled vessels' tanks and returns increasingly N_2-rich vapour. This vapour return is efficiently and sustainably combusted in the LBV's GCU, regardless of its N_2 content.
- When the tanks are fully inerted, aeration of the same is undertaken by the LBV by supplying warm, clean dry air to the tanks.

The entire cargo system, including capacities and operation flows, are designed to timely (fast) reach above-ambient temperatures, to allow the LNG-fuelled vessel being gas free certified and approved to enter a repair site, or only enter the tank(s). This regardless if the client LNG-fuelled vessel is fitted with C-tanks or of membrane type.

The best calculations for a LNG-fuelled vessel with 6,700m³ membrane tank demonstrate that the new LBV can carry out this full operation – from cold tanks with CH_4 to warm and gas-freed, ready to enter tanks, or in commercial terms – obtain a gas free certificate allow entering a repair site, within five to eight days. This is comparison with the 20-25 days that is expected with currently available arrangements.

As a result, our conditioning system reduces LNG-fuelled vessels' off-hire periods and does away with the time and cost of sourcing gas freeing equipment, project management and finding a suitable LNG terminal or berth where such operation is allowed by local and national authorities.

Safe moorings all tied up

LBV vessels are expected to undertake numerous mooring operations each day. We have, therefore,

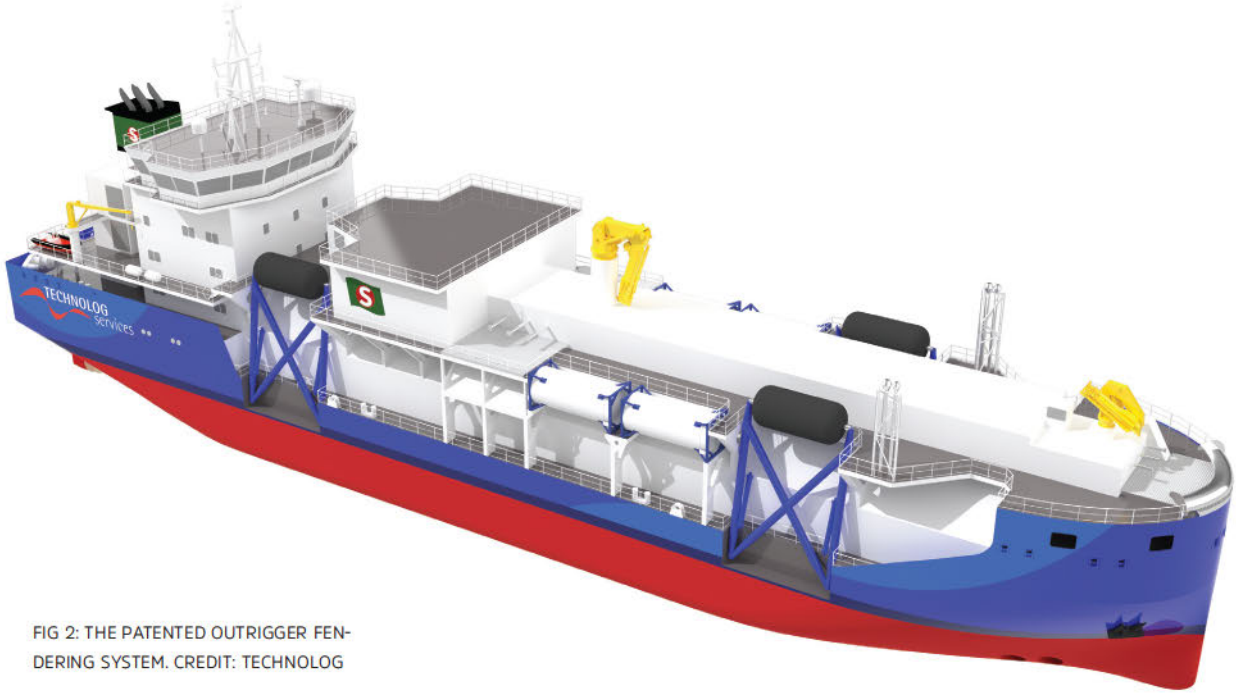


FIG 2: THE PATENTED OUTRIGGER FENDERING SYSTEM. CREDIT: TECHNOLOG

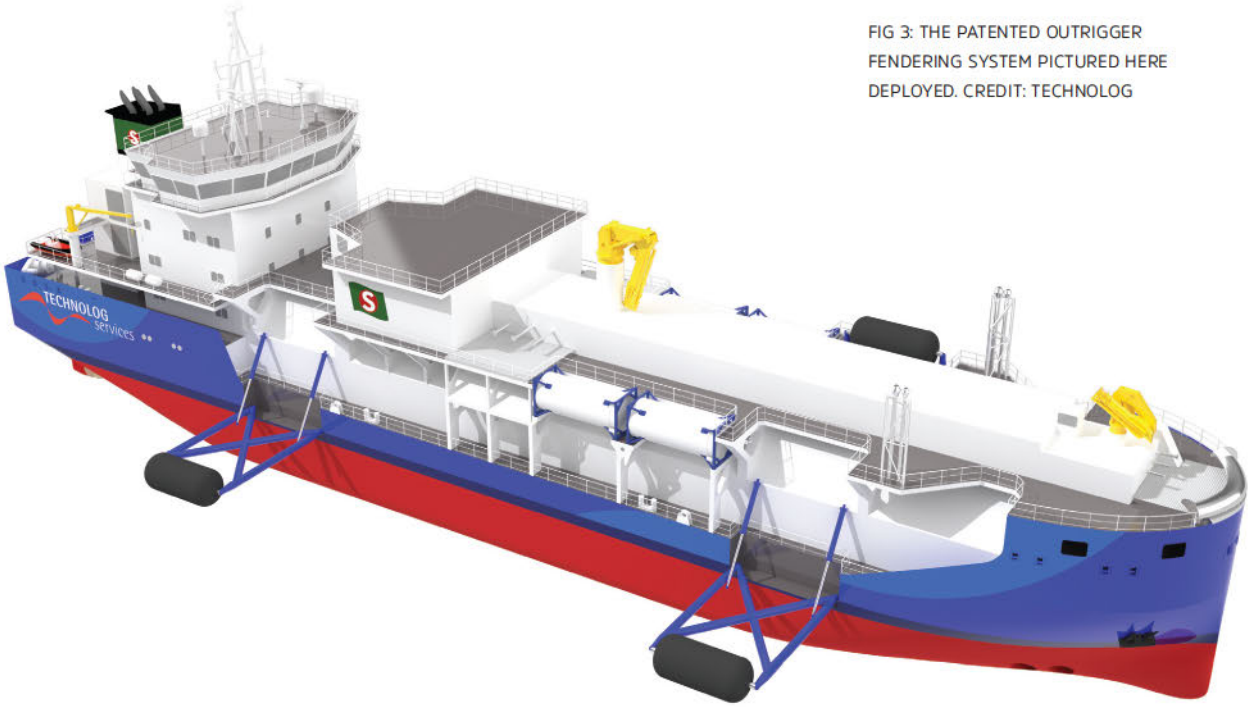


FIG 3: THE PATENTED OUTRIGGER FENDERING SYSTEM PICTURED HERE DEPLOYED. CREDIT: TECHNOLOG

invested particularly in designing effective and safe mooring stations, and incorporated experience and know-how from over 100 mooring analysis studies into the mooring station design of our vessel.

This new LBV is therefore equipped with a sufficient number of mooring stations and mooring drums, all of which are clear of other deck gear and equipment that could interfere with safe and efficient operations.

The forward mooring station is semi enclosed – with windlasses located on a different deck – hence nicely protected from weather, clean and roomy. Logical features, such as free sight of mooring ropes during operations, have also been designed into the mooring stations.

Further, as a result of using outriggers, the increased distance between the vessels is beneficial when moored alongside higher-freeboard vessels. This, as the increased distance results in mooring ropes with less-steep angles, resulting in safer mooring.

This makes operations safe and at same time reduces manning to the minimum, without being unsafe. These accumulated factors enable the LBV to be compatible with any LNG-fuelled vessel, to facilitate fast, safe and efficient mooring operations, meaning more bunkers can be delivered overall per day.

Environmentally sound

The better prepared the vessel is to tackle any de-carbonisation requirements, the more likely it's residual value will be maintained.

Measures built into the design and available as option or for future upgrade include:

- The battery hybrid solution which saves energy and reduces carbon emissions delivering an initial good EEDI and CII rating.
- The battery hybrid solution allowing normal LNG fuelling operations (bunkering) to be undertaken using battery power only with zero carbon emissions. Moreover, it reduces noise-pollution – important where noise can impact bunker permit applications.
- The hull has been designed to increase tonnage mile efficiency. Even if an LBV is normally not required for extensive sea voyages, the vessel has been built with a slender and efficient hull for good EEDI and CII ratings.
- The vessel has capabilities to be connected to shore power. In combination with the battery hybrid solution and 'green' shore power, depending on the operation profile, the vessel could operate largely carbon-emissions free.
- The basic design has even taken in consideration future retrofit for hydrogen power. Operation range will be limited if all operations are undertaken using hydrogen, but two to three days' operation is feasible between H_2 bunkering.

This next generation LBV brings safety, compatibility, eco sustainability, easy inerting and warm up for repair and maintenance, low CAPEX and OPEX, and a scalable and future-proofed vessel design that will meet the needs of the burgeoning LNG-fuelled vessel fleet. The unique design accommodates only the infrastructure required to carry out specific tasks, namely delivering LNG bunkers and de-gassing LNG fuel tanks, resulting in a small and agile work vessel.

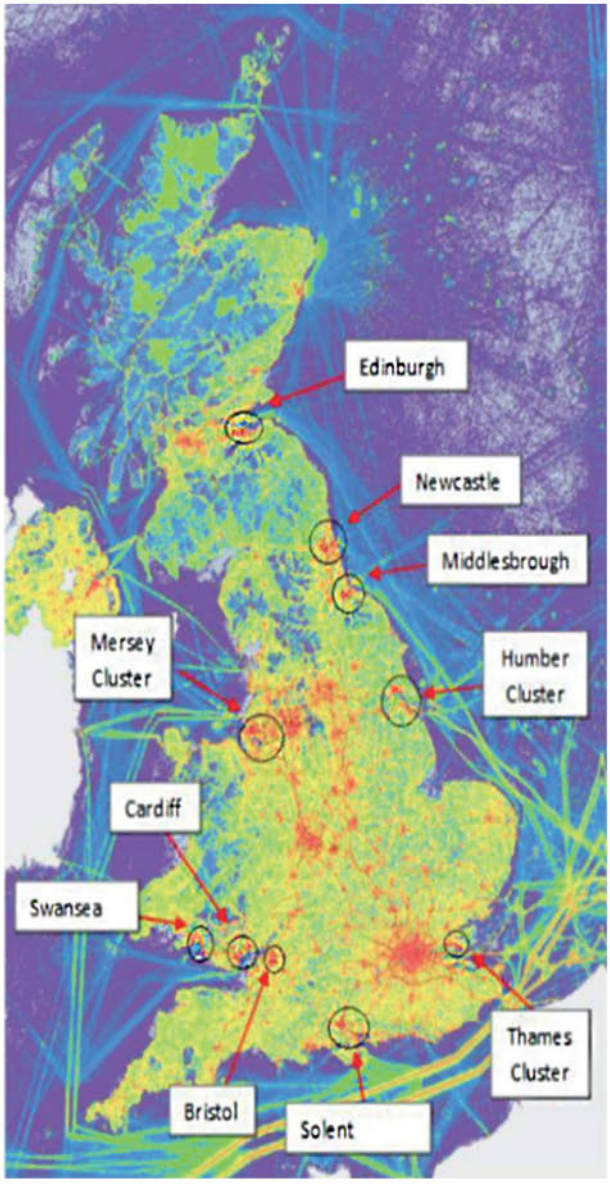
Schulte Group has combined its proven experience as an LNG bunker vessel owner and operator with Technolog's extensive applied knowledge of naval architecture, to develop a new innovative LBV design that is easy-to-use, fulfils present and known future requirements for at-sea LNG bunker deliveries and reduces last-mile costs. ■

LCO_2 CARRIERS

SOUTHAMPTON STUDENT TEAM DESIGNS A NET-ZERO LIQUID CO_2 GAS CARRIER FOR FUTURE UK CCUS PROJECTS

By **S T Tudora, T L Gard, N Hemrich** and **A Shafizam**, University of Southampton

Carbon capture and underground storage (CCUS) in disused undersea gas deposits has long been studied and is becoming a reality through projects such as Norway's Northern Lights. They are particularly applicable to industries that cannot or will be slow to transition to renewable energies by 2050. Until the amendments to the London Protocol, currently banning the export of CO_2 for undersea storage, come into effect, each state will have to individually satisfy its CCUS needs.



In the United Kingdom, two similar projects exist at the planning stage: the East Coast Cluster around the Humber industrial area and the Merseyside HyNet scheme. Both aim to use pipelines to pump the CO_2 into depleted offshore gas reservoirs, either in the North Sea or Liverpool Bay. However, many significant emitters of CO_2 in the UK are located far away from either pumping site (Fig. 1), such as the Solent's Fawley oil refinery (330nm) or the Port Talbot steelworks (311nm). At Fawley up to 5Mt CO_2/year are projected to be emitted in the future.

Seaborne transport of CO_2 has been shown to break even compared to pipelines at 250nm and is more flexible. Existing CCUS projects deal with much smaller volumes of waste (Northern Lights: 1.5Mt CO_2/year), and there is a gap in the knowledge of what a large LCO_2 gas carrier operating in coastal waters might look like.

Southampton rises up to the challenge

This is precisely the problem that a team of student interns (S T Tudora, T L Gard, N Hemrich and A Shafizam) at the University of Southampton's Marine and Maritime Institute have aimed to solve over the course of the summer. The work was supervised by Prof Dominic Hudson and Ms Georgina Keane and is to be presented at a major energy company.

The design is tailored for the Solent-Humber voyage, but operability along the Port Talbot-Mersey route has also been accounted for. The required yearly cargo volumes and handling equipment were informed by another of the Institute's projects, Ports of the Future. Instead, the focus was on the naval architecture related issues. Furthermore, it was decided that the design should be net-zero itself and follow the standards set in Lloyd's Register Rules and Regulations and IMO's IGC code.

The low-pressure future

Early on it was decided to transport the liquid CO_2 at 7bars gauge pressure and -50°C. Though existing schemes such as Northern Lights opt for a medium-pressure (15bar, -27°C), it is predicted that lower pressure will become more popular in the future. The higher pressures require a greater number of smaller, costlier and sturdier tanks, making it impractical for large capacities. Furthermore, low-pressure transport can be around 15% cheaper, as due to its higher density of CO_2 in this state, a greater economy of scale can be achieved. Broadly speaking, the

FIG. 1: MAP OF THE UK'S GREATEST CO_2 EMITTERS

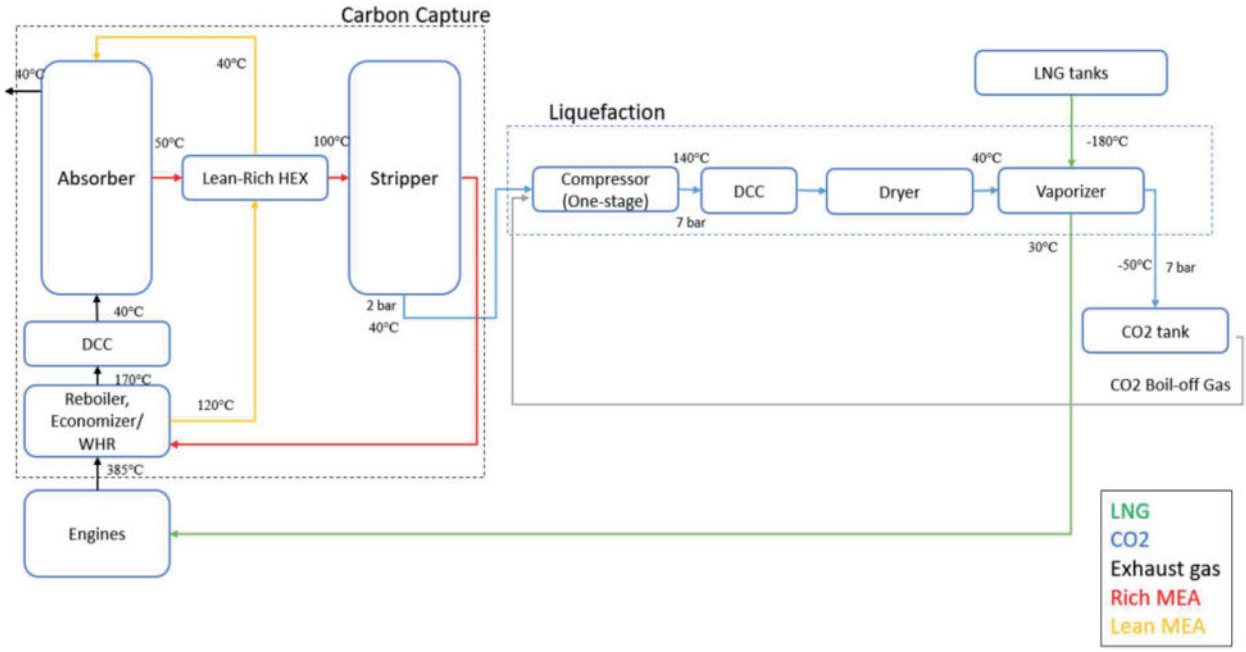


FIG. 2: DIAGRAM OF THE VESSEL'S CARBON-CAPTURE AND RE-LIQUEFICATION SYSTEMS

tanks are similar to Type C vessels found on pressurised LPG/product tankers.

This decision allowed for the preliminary sizing of the fleet and the individual vessels. Based on the Solent-Humber transport requirements, three or four ships sailing at 12knots with a capacity of 32,000m^3 was deemed optimal. Using similar vessel regression data and an inhouse concept design software, the first principal particulars and crewing requirements were established. As these would change along the iterative cycle, only the final technical particulars are presented. An increase in size and hence capacity would have superior economic performance but is not feasible due to the draught limitations in the Mersey. The hull form was designed based on a Very Large Crude Carrier (VLCC) due to similar L/B, B/T and CB.

Powering and onboard carbon-capture

The slow-going, high block-coefficient hull implicated difficulties in preliminary powering estimates, as most publicly available regressions were at the limit of their validity. A high Taylor wake fraction was noted (0.48-0.6), resulting in unrealistically high predicted hull efficiencies and a very lightly loaded and efficient propeller. Lacking the time for model testing, variation in the parameters was studied, and the final range of the necessary delivered power was not very wide, around 5MW. As vessels transition towards higher block coefficients and low Froude numbers to reduce emissions, public availability of regression powering data would be of great use.

Other powering challenges were the IMO minimum power line total installed MCR requirement of 8,127kW for this class of vessel and uncertainties in the auxiliary electrical loads for the various systems. The relatively low RPM and power requirement precluded the use of low-speed dual-fuel engines, as well as medium-speed ones. Therefore, it was decided to use a single-screw fixed-pitch propeller driven by an electric motor, powered by LNG dual-fuel generator sets, connected to a carbon-capture system capable of capturing 90% of CO_2 exhaust emissions. Space in the short machinery compartment (15.4m) became an issue, solved by placing the lighter high-speed gensets on a higher half-platform, and the medium-speed ones on a raised floor surrounding the motor.

Linking exhaust, boil-off and storage

The storage of LCO_2 at low temperature leads to inevitable generation of boil-off gas (BOG). It was crucial to calculate the amount of the BOG generated during the voyage to determine whether a re-liquefaction plant was needed. The high thermal conductivity of the steel structure of the tanks has to be counter-balanced by the thickness of the perlite insulation, implying a compromise between weight and boil-off management. Consequently, this rate was calculated to be 0.54%/day, or 23.34tonnes/day, requiring re-liquefication. This is done in the same facility as the ship-based carbon capture (SBCC), which results in a lower power consumption and a lesser area needed for the liquefaction process instead of liquefying the gases in separate facilities.

The ship-based carbon-capture (SBCC) system is designed using an amine solvent, a 30wt% aqueous solution of monoethanolamine (MEA). The process workflow is presented in Fig. 2 along with the operational temperatures and pressures. The engines and refrigerated LNG tanks are thermally integrated into the carbon-capture system, satisfying the heat duty of some main components, such as the stripper and absorber. Furthermore, the captured CO_2 is re-routed to a cargo tank at a reduced filling rate specifically for this purpose.

The extremely hot exhaust gas from the gensets is firstly cooled using the reboiler and direct contact cooler (DCC) to reduce its temperature for the SBCC system operation. An economiser or waste heat recovery system is installed alongside the reboiler to extract the heat load from the exhaust gas and is calculated to be sufficient for the heat

GROUP PHOTO OF THE TEAM

consumption of the SBCC with 30% heat recovered. The MEA solvent absorbs the CO_2, which is then drained at the bottom and passed through a heat exchanger and taken through the stripper to be liquefied. There the CO_2 is taken in its gaseous state, liquefied, and stored in the tanks, passing through a compressor, direct contact cooler, dryer and a vaporiser which uses the low temperature from the LNG tanks (-180°C) to increase efficiency.

Hydrogen fuel cells: future proofing

As this vessel aims to help reduce CO_2 emissions, preferably it would emit none at all itself. While this is not economically feasible in 2022, once hydrogen and its accompanying infrastructure becomes more available, the ship could be fitted with a hydrogen powertrain instead of one using LNG. This would replace the LNG gensets and eliminate the need for the carbon capture system. An alternative layout for the machinery was designed using PEM fuel cells and exchanging the LNG main deck tanks for hydrogen tanks.

Arrangement and tanks to carry LCO_2

Arrangement-wise, the vessel resembles a tanker/bulk carrier with a fully aft superstructure and machinery space. The bow and stern were modified to closer match the LCB to the LCG and accommodate the CO_2 tanks according to the International Gas Code (IGC), as shown in Fig. 3. The subdivision was also carried out in a manner to maximise cargo space whilst still allowing for inspection and maintenance of the CO_2 tanks, which were designed from first principles and industry information.

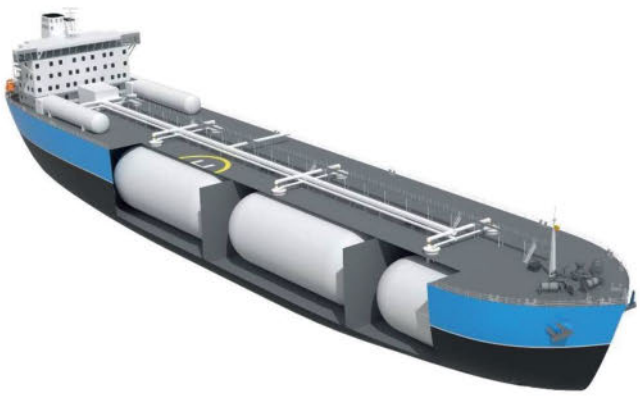


FIG. 3: SECTION VIEW OF THE TANK ARRANGEMENT

The tanks are cylindrical with hemispherical ends and are arranged in 4 sets of 2 longitudinally (2 x 3,000m³, 2 x 5,000m³, 2 x 5,000m³, 2 x 3,000m³). In mind was also the increased risk of dry ice formation due to the proximity to CO_2's triple point. Hence the tanks required thicker insulation, re-liquefication and suitable cargo handling and monitoring facilities. The tanks have a maximum filling rate of 95% to allow volume for boil-off gas. The high density of LCO_2 was found to result in a very small empty load draught – requiring ballast for return voyages. However, a ballast-free version would make for an interesting alternative design study.

Hydrostatics, seakeeping, structures

The hydrostatics analysis found that the ship meets the stability criteria defined by the IGC code. An investigation into the seakeeping of the vessel shows that the added resistance reaches 7% of the still water resistance for the most likely sea states in the full load condition and 56% in extreme cases. The ballast case values in the most encountered sea states reach an increase of 28% and 130% in extreme cases. Higher added resistance in the ballast case contradicts results published from a range of sources, therefore, a seakeeping experiment in various heading could be carried out to obtain more accurate results and a better understanding of the motion of the ship in waves.

The structure, efficiently designed according to Lloyd's Rules to withstand local and global loading, is to be built of sustainable steel from British manufacturers, incorporating recycled material. The midship section resembles that of a bulk carrier, with the tanks and their cradles occupying the holds. The main difficulty from the structural design came from the longitudinal loading, when attempting to align the LCB and LCG to achieve zero trim. The heavy LCO_2 brought the centre of gravity further

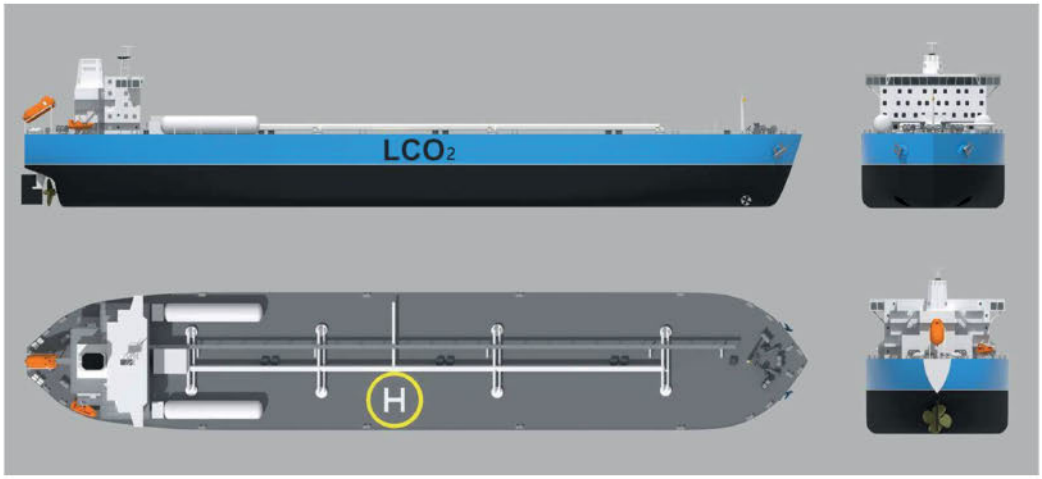


FIG.4: PROFILE, PLAN AND BODY VIEWS OF THE VESSEL'S 3D-RENDER MODEL

forward than the centre of buoyancy. There not being machinery and outfit weight aft to move the LCG further aft, a basis hull form with an LCB further forward could have resolved this issue more easily.

Costing reveals policy changes are needed

Based on the final design, a preliminary estimate of the capital and operational costs of the vessel was performed. This amounted to an initial build cost of £50 million and an annual operational cost of £38 million, implying a cost of 19.55 £/tonne CO_2 transported. The port charges are the most significant cost component (48.92%), with very large dock berthage charges per visit at Fawley and bulk liquid chemical dues at Immingham.

Removing the previously mentioned liquid chemical charge would reduce the cost per tonne to 12-13 £. This is in line with a previous report on the UK coastal transport of CO_2 published in 2018 and would make the seaborne transport component economically viable for investors. Therefore, it is clear that governmental authorities need to come to an agreement with port operators and CCUS leaders regarding a change in the policy of charging vessels engaging in the carbon-capture trade.

Summary

The project has highlighted the technical feasibility as well as certain challenges specific to LCO_2 carrier design. Specifically, the cargo transport conditions indicate the use of Type C tanks for the best economy of scale, at 7bars gauge pressure. Furthermore, the high density of the cargo implies that ballast would have to be carried on the empty return voyages – hence a ballast-free, optimised hull form might be an avenue for further research.

The size of the tanks led to the use of a larger, blockier hull – combined with the low operational speed, this placed the vessel at the limit of public power prediction methods. Predicting hull-propulsor interaction also was problematic, as inflow would be greatly reduced. Therefore, more powering data for ships with similar operational profiles would be useful.

The use of a SBCC system for the dual-fuel gensets paired perfectly with the cargo carried. Integrating the boil-off reliquefication, exhaust gas carbon capture and LNG tank refrigeration into one system, re-routing the boil-off and captured CO_2 back into the tanks, a greater efficiency was achieved. In the future up to 90% of CO_2 could be captured by SBCC systems – an alternative hydrogen-powered design could be implemented if this is deemed insufficient.

Another significant finding is the massive impact port dues have on the cost of transporting CO_2 – about 50% greater than if the liquid chemical charge at Immingham, say, were to be removed. Therefore, a shift in values away from the economical practicality of carbon-capture and towards the urgency of its implementation facing climate change appears more and more necessary.

The team would like to thank Prof Dominic Hudson, Ms Georgina Keane, Dr Tamara Topic, Prof Stephen Turnock, and in general the University of Southampton Marine and Maritime Institute for the support and guidance given throughout this project. ■

TECHNICAL PARTICULARS	
Length oa	181.75m
Length,bp	176.25m
Breadth, moulded	32.3m
Depth to main deck	17m
Draught, full load	9.94m
Gross tonnage	26,267
Net tonnage	8,724
Deadweight	48,238t
Vol. LCO2, 95%	30,400m^3
Complement	26
Main gen sets	2 x Wärtsilä 6L34DF + 2 x Wärtsilä 9L20DF
Output	2 x 2,770kW + 2 x 1,685kW
Motor type	The Switch PMM Frame 1500-23, max. power output at 100rpm 6,350kW
Service speed	12knots full load, 13knots ballast

CONFERENCES

ICCAS 2022 - INTERNATIONAL CONFERENCE ON COMPUTER APPLICATIONS IN SHIPBUILDING

By **Carsten Zerbst**, PROSTEP AG

THE HARBOUR CITY OF YOKOHAMA IS JAPAN'S KEY ENTRY POINT FOR INTERNATIONAL TRADE AND COMMUNICATIONS. SOURCE: CREATIVE COMMONS

The 20th International Conference on Computer Applications in Shipbuilding (ICCAS) was organised by RINA from 13-15 September 2022. Originally planned for last year, this was the first chance since the pandemic for users from shipyards and design offices as well as researchers and software vendors to come together in person and discuss the current status and future trends in the shipbuilding industry. The following text is based on the notes I took on the delivered speeches and presentations. As the event was run in up to three parallel tracks, I was unable to attend many interesting presentations. I therefore apologise to all the speakers that I missed.

This year's edition took place in Yokohama, Japan. Abe Akinori from the Japanese National Maritime Research Institute (NMRI) delivered a keynote speech which focused on the Japanese shipbuilding industry. Japan still plays a major role in international shipbuilding but has been overtaken by China and South Korea in respect to delivered vessels and gross tons. To prevent further decline, NMRI runs several research initiatives to help the domestic yard industry. Digitalisation is seen as a key driver to improve quality and reduce costs, with a focus on five digital twins spread over the ship's lifecycle, from hull structure through to ship construction and vessel operation. Mr Akinori stressed the importance on implementing the product lifecycle management (PLM) concept to not only improve the current running processes, but also as a means to preserve company knowledge as an asset to e.g. improve effort prediction.

As a part of the plenary session Prof Noriyuki Sasaki from the University of Strathclyde was given an award by RINA for his work on energy saving devices. His gated rudder concept has already been applied on four ships. It improves the hull efficiency by several percent and thus reduces the carbon footprint of a vessel.

The plenary session concluded with talk given by Akihiko Masutani from Sumitom Heavy Industry, a yard currently producing four VLCCs per year. He presented the yard's business concept as well as its improvement programme. This covered the usual suspects, such as improved tools in the design and construction phase, but also hull monitoring. Interestingly, the yard also works on sail-assisted vessels to help reduce fuel consumption.

Shipyard planning

Following a break for coffee, the conference presentations began. Kohei Matsuo (NMRI) gave further details on the work at NMRI. The shipyard planning system has many parallels to the research project run by Lürssen Yard, RWTH Aachen and PROSTEP in Germany, although differing in a much more elaborated visualisation capability.

Gordan Sikic (Lina *et al*) presented some results from a collaboration with the University of Zagreb. The aim of the collaboration was to implement a modular viewer as part of student's programme. He showed both the achieved results as well as the insights gained on how to run such a project with a part-time workforce.

Ludmila Seppälä (Cadmatic) gave a hands-on presentation on current industry needs and how this has been answered in Cadmatics' software. The presentation focused heavily on small improvements providing a real benefit in daily life; no fancy AR/VR/MR stuff, but really usable things applicable to any user, such as design automatisation.

Simon Crook (SSI) then presented his ideas on what the Japanese shipbuilding industry might need and how this is provided by SSI's Shipbuilding PLM solution. SSI's ARAS-based solution is currently implemented by a well-known yard, and I know at least two more of our customers who are thinking along the same lines. As PROSTEP is supporting this project, I'm not impartial on this and hope the yard can give an unbiased lessons-learned report at the next ICCAS.

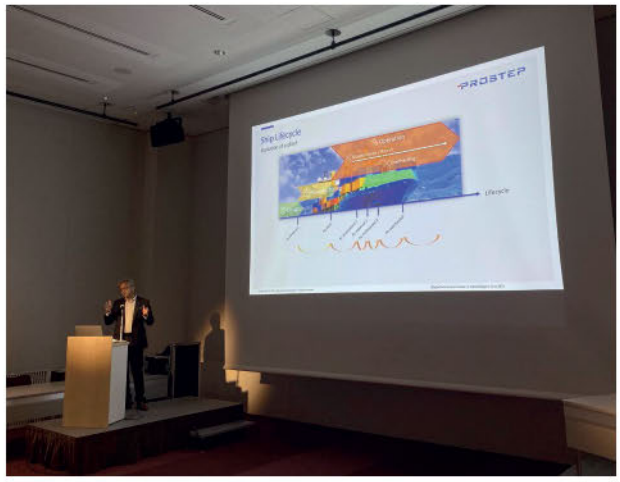
Oussama Chouche (Dassault Systèmes SE) focused on general production planning PLM processes and capabilities. The presented concepts for the 3D Experience Platform are in line with current industry trends.

Tokimasa Hiraki (Mitsubishi Shipbuilding) presented his insights on using an MS Hololens-based system for use on the shop floor. As part of the MATES software suite, a viewer has been developed for use by workers to provide detailed information on parts, augment a real view with 3D parts still to be installed, or measure distances. The system seems to pass the test pretty well but is facing the same hurdles as similar systems I know about. The most important one is the lack of ruggedised hardware, which might be worn on an eight-hour shift in combination with a hard hat.

Thinking ahead

The second day of the conference started with Jan Bitomsky from PROSTEP giving a talk on shipbuilding software integration. As with all kinds of software, it really pays off to think ahead on what one really needs. Mr Bitomsky presented a categorisation from a simple attribute level transfer (Level 0) to a full-blown native transfer of semantical information (Level 3) and some examples of when to best choose what level. All those business level thoughts were accompanied with implementation performed at yards.

Next up was Ahmed Elzalabany from my former alma mater, Technische Universität Hamburg, who presented



AUTHOR CARSTEN ZERBST GIVES A PRESENTATION AT ICCAS 2022

his work on a tool to plan and run commissioning tests. These tests are necessary to get a vessel approved, but planning 10k+ tests in the right order, getting the data back in a structured way, and even taking care about side conditions, is a task worth doing outside of MS Excel. This dedicated tool supports managing the tests, checking for resource allocation, collecting the results, and generating the necessary reports.

I then gave a presentation on the work of my colleagues Johannes Lützenberger, Josip Stjepandic and Matthias Grau in the DigiTwin project. In this project they implemented a solution to convert laser scan point clouds from plants or ship interiors into a native CAD model for the piping part. The talk illustrated the steps taken, some of the challenges faced, and the solutions found on the way.

In the afternoon session we heard from Min Chul Kong (Seoul National University). He is applying graphs (as in networks) to represent references to definitions. Typical shipbuilding regulations have hundreds of pages, and it is difficult as a reader to follow their highly cross-referenced content. By performing intelligent scanning process and hyperlinking the document, even down to equations and their contained symbols, he hopes to enhance the legibility of these complex documents.

Representatives of ClassNK, Nihon Shipyard and NAPA gave a presentation on a joint research project run by the three organisations. The project leverages the capabilities of NAPA Designer to run both the design at the yard as well as the checks on the classification side. It is accompanied by NAPA Viewer, a web-based 3D viewing application which allows visual checks without a NAPA installation. In this viewer NAPA implemented a nifty capability to put something like a classical 2D shipbuilding drawing on top of the 3D panel model, which was very much liked by the users. There was some concern that the solution is only applicable to yards using NAPA, but thanks to OCX support it should also be open for users of other software packages.

Jongoh Kim (Korean Register) presented work on a direct integration between NAPA Designer and the

classification societies rule approval tool. Using the integration, it is possible to provide a bidirectional integration allowing the user to check scantlings in the classification societies tool and get the result displayed directly in NAPA Designer's steel model.

The last NAPA Designer presentation was given by Yosuke Tanaka (Sumitomo Heavy Industrie) and Takayoshi Masui (NAPA) on a streamlined process to calculate dimensions on typical midship sections. The process was taken from several weeks down to one to two hours. It is based on a parametrised steel model with variables for double bottom height, side tank width or position and height of stiffeners, etc. Different configurations are checked, using initial scantlings provided by an SHI, and then run through an FEM calculation to check yield and buckling. The complete process is then automised using NAPA's Optimization MGR and runs unattended for an hour or two to find an optimal solution. All three presentation were impressive and a good showcase on what NAPA has to offer.

Low-cost location device

The third day of the conference started with a presentation from H. Kimura (Kyushu University) on using existing WLAN access points as a location device for indoor navigation. The method could be used as a low-cost solution to identify palette locations in a warehouse or shop floor and needs only a simple Raspberry PI with WLAN adapter as hardware. His proposal is based on a map with radio signal strength, requiring a simple lookup to estimate the position down to 1-3m. Unlike simpler triangulation-based methods, his map-based proposal has no problem with uneven radio distribution caused by obstacles like walls or machinery.

The next presentation was given by me on the ProProS research project run with Lürssen Yard and RWTH Aachen. In this project we developed a prototype to run a Deming (project management) cycle for shipbuilding production. In our case this includes all the steps to determine the necessary activities to assemble a section, estimate the duration (done by RWTH Aachen), schedule the activities considering restrictions on personnel, and finally get feedback from the shop floor and compare it with the original planning. This is currently a hot topic in the industry as well as in academia – we had several discussions about it in the coffee break.

Carlo Dentesano (Fincantieri) presented his work on using autonomous vehicles in the yard. Focusing on solutions that could be used with realistic effort, Fincantieri is currently concentrating on small-sized robots that can conduct time consuming task in the warehouse. Some success has already been achieved in performing inventory. The next step will be the transfer of actual items.

The conference's final session started with a presentation given by Richard Audoire (Dassault Systèmes) on the EU-funded NAVAIS research project to develop a ship design and construction approach that minimises the impact on the environment. The approach includes a specific attention to underwater noise, vibration noise, and propulsion reduction and the overall process relies on Model Based System Engineering (MBSE).

The last presentation was given by Miles Wheeler (Siemens) on the application of ML and AI to speed up ship design. The first part of the presentation was about using an ML surrogate model e.g. as a base for optimisation. The second part focused on reducing the number of parameters describing a hull by using a variational autoencoder. The benefit of this reduction is the ability to run less CFD simulation without reducing the investigated shapes themselves.

This year's ICCAS gave participant from yards, academia and software vendors a nice chance to meet again after Covid. The next meeting is scheduled for 2024 in Italy. ■

Carsten Zerbst leads a team at PROSTEP developing software for the shipbuilding industry. These are mostly integrations, to help yards run their daily business without the need for costly and error prone manual work when transferring data between ship design, production, ERP, or other IT systems.

MARITIME HISTORY

150 YEARS OF SHIP TANKS

By **Mark Barton & Chris Richardsen**

THE FIRST TOW TANK AT CHELSTON CROSS

2022 marked the 150th anniversary of William Froude opening the first ship tank in the world at his home at Chelston Cross near Torquay. It was Froude's analysis of the relationship between the hydrodynamic resistance of a ship at model and full scales that resulted in his verification of the 'Law of Comparison', which hydrodynamicists around the world still use to predict ship performance from model tests.

Froude was a protégé of Isambard Kingdom Brunel and while his career started with railways, in the 1850s his attention turned to ships. Froude had previously worked with H R Palmer who used a spring balance to measure the drag of barges on a canal and it is possible this gave Froude the idea. Initially Froude conducted experiments using models, often fabricated from tinplate, on lakes and rivers, especially the Dart, and acquired sufficient data to allow him to verify his famous law.

However, he recognised that exposure to wind, waves and currents was impacting on his results. As a consequence, Froude and his associate Henry Brunel obtained £2,000 from the Admiralty to build and operate an enclosed experimental facility with a steam powered carriage, or 'truck' as Froude called it, to tow models at steady speed whilst measuring their drag. This first tank, constructed on land adjacent to Froude's house, opened in 1872 and was 278 feet (85m) (long) x 36 feet (11m) (wide) x 10 feet (3m) (deep) with the first model tested being the sloop HMS *Greyhound*. William Froude contributed to significant improvements in warship hull and propeller design until his death in 1879 at the age of 68.

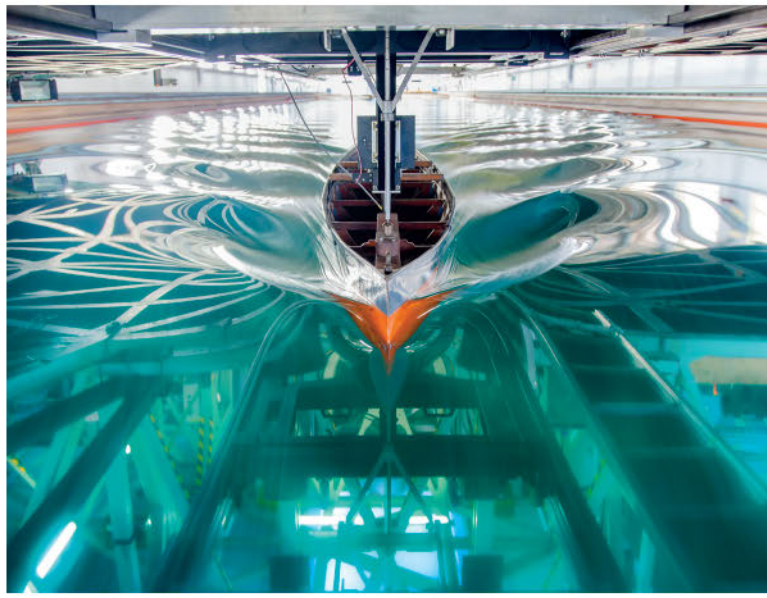
There are three notable elements that have continued to this day. The first is the British government's use of ship tanks. Robert Edmund (Eddie) Froude succeeded his father. Due to the design life of the first ship tank and lease cost he established a new facility on a redundant plot adjacent to the naval gunboat yard at Haslar. The last test at Torquay completed on 5 January 1886 and the new tank at the Admiralty Experiment Works, Haslar, opened a month later on 6 February.

Haslar's tank was larger at 400 feet (122m) (long) x 20 feet (6m) (wide) x 9 feet (2.7m) (deep) and the new facility was used intensively and tested models of all of the major classes of British warship that fought in World War One. The first submarine models were tested in early 1902, just a couple of months before HMS *Holland I* commenced its sea trials. Capacity limitations during the early inter-war years led to the Admiralty approving a second, larger tank built at right angles to the first. The new tank (known as No.2 Ship Tank with the original tank becoming No.1) was 890 feet (271m) (long) and had an adjustable false floor to allow experiments to be conducted regarding the impact of shallow water. This second tank remains in use today and has been operated by

QinetiQ since 2001. Whilst the tank remains the same there has been significant change in the sensors and measurement equipment.

The second element is the continuation of the water and the ceremony of the mixing. When Eddie Froude opened the tank at Haslar he took some water from Torquay with him and mixed it into the new tank. That tradition continued and water from that first tank at Haslar was mixed with the water of No.2 Ship Tank when it was completed in 1932 and a similar ceremony took place when the Ocean Basin opened. Drops of that water are still sent to the opening of any new ship tank to enable a mixing ceremony.

Thirdly is the ongoing importance of this experimental work. Despite all the work done by computer modelling these days, it has only served to demonstrate the continued need for more practical modelling. Computational methods depend on lots of data and as the computer models become more refined the limitations of the experimental data that we have and the need for more of it remains at the fore. Recent years have seen new shapes and purposes for sea vessels and enabling prediction of the performance of tidal turbines and wave energy devices has been part of the work undertaken in ship tanks. The challenge is not in getting a computer model but one that gives the right answers in prediction. Counterintuitively therefore computers have driven a need for more use of model testing to garner the underpinning data.



THE CURRENT SHIP TANK AT QINETIQ WITH IRIS THE CALIBRATION MODEL, HASLAR TODAY (© QINETIQ LTD 2013)

There is no doubt some time yet to go for ship tanks. ■

LETTERS TO THE EDITOR

IN SEARCH OF THE EFFICIENT SHIP: LESSONS LEARNED

NEW SHIP TYPES IN THE 1960S INCLUDED *METHANE PRINCESS*, THE FIRST PURPOSE-BUILT LNG CARRIER TO ENTER SERVICE. SOURCE: SHELL

Reading Jan van der Schans' letter in the October 2022 issue of *The Naval Architect* induced me to mutter Hear, Hear, especially as he made kindly reference to my own work. As a young naval architect, I had always felt that the usual explanation 'the shipowner tells us what he wants then we design and build that' totally inadequate by not exploring all the feasible alternatives. Especially so as the 1960s saw so many new developments on ship types: bulk carriers, OBOs, chemical carriers, liquefied gas carriers, ro-ros, container ships, to say nothing of the ever increasing size of tankers.

It was disheartening to learn the experience at P&O where every department seemed to operate in a 'silo' independent of all the others. My impression at that time was that BP and Shell Tankers were more enlightened, with big technical departments whose designs became the template for many independent tanker operators. BP developed the inert gas system which has contributed immeasurably to tanker safety; would any one tanker operator do the same today?

I used to tell my students at Newcastle University that the naval architect is the 'general practitioner' of the marine technology business, needing to know something about every aspect of ships in order to integrate everything into a balanced design, but like the medical doctor knowing when to call in the specialist, for example on noise and vibration.

All-embracing measure

Some 30 years ago, I was involved in the UK government sponsored study on The Efficient Ship. While this rightly looked at technical aspects such as resistance and propulsion, it soon became evident that there was no one overriding measure of merit such as fuel consumption per ton-mile. Aspects such as fuel consumption, freight rates and port delays all had incommensurate units. In searching for an all-embracing measure we concluded that the only way to bring all such to a common denominator was to adopt an economic or monetary one.

Of course at that time we could not 'price' in emissions, but surely we could do so today. While each aspect could be 'optimised' from the point of view of any one individual 'stakeholder', the time charterer paying for fuel costs for example, the optimum ship was the one that balanced all the stakeholders – shipowner (financial beneficiary), ship operator (day to day management), cargo owner or charterer, port authority, and sometimes the shipbuilder – with the flattest curve of measure of merit across all the likely variables, for example fuel price and resulting optimum speed on any one voyage.

Of course that varied with the type of system, from the 'open' system of a bulk carrier where the next voyage and cargo was influenced mainly by the then prevailing market conditions, to the 'semi-closed' system with a limited number of ports and cargoes (e.g. container ships or product distribution) and 'closed' systems with few variables (e.g route, traffic levels, port facilities such as long term contracts of affreightment or ferry services with little or no competition).

So are there any conclusions relevant to today? Yes: develop models of 'smart' ships both at the design and operating stage which incorporate all stakeholders that allow exploration of all the variables from payload source to destination, so that whatever measure of merit is used, whether at design or during each voyage, the optimum design is the one that performs best across a range of likely variables, which may vary with the importance of the individual stakeholder for the type of shipping system being considered – i.e. one size does not fit all. ■

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