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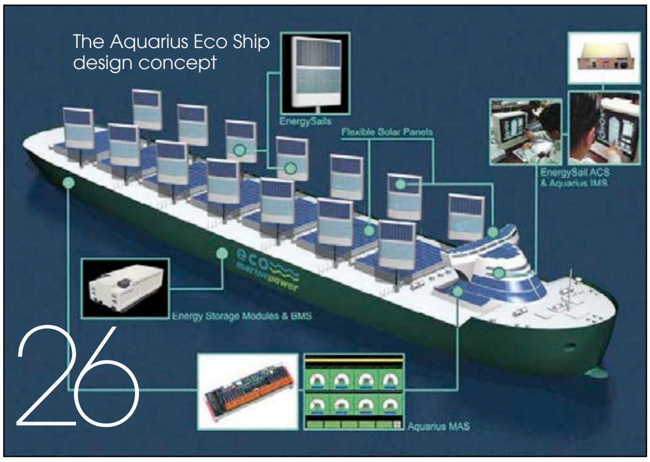

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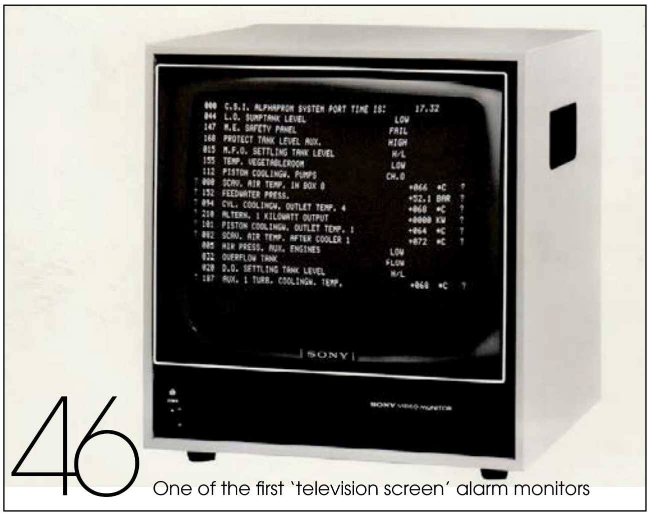

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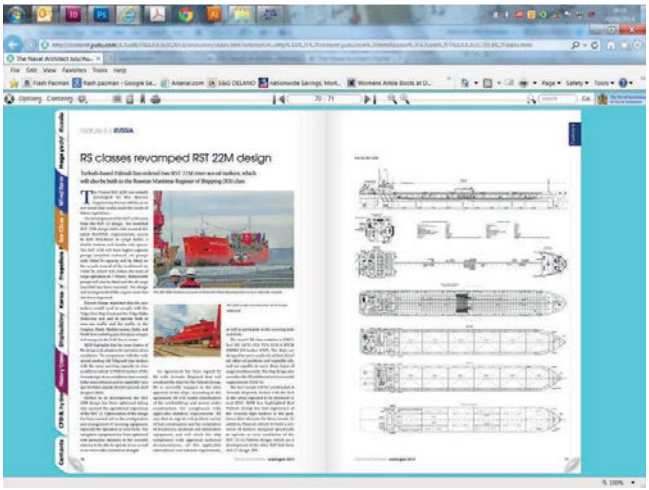


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Inclusion and engagement

Women remain marginalised in shipping and engineering

The role technology has played in changing gender relations is often understated and I'm reminded of a book a few years back by the South Korean economist, Ha-Joon Chang, who opined that the humble washing machine had a far more transformative impact on society than the internet, in that it helped to liberate women from household chores and led to decreased demand for domestic servants. This freedom allowed more women to pursue careers and as a result the possibility of greater independence.

While it's outside the remit of this magazine to debate the challenges this (coupled with technological progress) has posed to managing economic growth and expectations over the past century, the role of women in the maritime and engineering professions remains marginalised and that has to be a cause for concern. More than 2,000 RINA fellows, members and associates responded to the survey that we circulated earlier this year, but it was sobering to discover that less than 7% of those were women.

Moreover, as I discussed with RINA's chief executive, there is also a marked decline in women involved who return to the profession after taking time away from their careers to start families. Even those that do return often opt to take their careers down more managerial and administrative paths, rather than R&D, perhaps because these allow for a more flexible work/life balance.

Of course, the problem is by no means restricted to engineering and maritime, but it is particularly acute. There may be a certain chicken and egg paradox at work, whereby less young women are attracted to these industries because of implicit chauvinism, and lack of female role models, which then serves to perpetuate it. More holistically, there is also that school (no pun intended) of thought which points to wider failings in the teaching of the sciences within general education. But the fact remains that it's self-evidently detrimental not to be attracting, or retaining, the best possible talent.

Education and opportunities for younger professionals, such as internships, were one of the areas that respondents to our survey highlighted and I hope this is an area we might be able to give greater coverage in the future. I cannot overstate how valuable your views are in steering the editorial direction of *The Naval Architect* and other RINA publications. For a magazine editor there is nothing quite so demoralising as a silent audience.

Imagine trying to design a vessel based purely on intuition and guesswork. At best you can follow some general principles but without the data or empirical evidence it will never be optimised to its fullest potential. The same holds true for a magazine; we endeavour within these pages to provide an overview of the major developments affecting the commercial maritime industry and the implications for ship design and construction in a way that's of value for all interested parties. As one respondent succinctly put it: "[*TNA*] needs to be able to be picked up by a non-naval architect, be inspiring for them, invite questions and engender respect for the profession and what we do. The publication needs to have a good balance of technical papers, news for professionals, and articles that anyone can read."

Like any publication that aspires to quality, value-driven content, increasingly the question must be asked how much value there is in disseminating news and information readily available for free online? But if we dedicate more space to in-depth technical papers how many of you will actually have the time to read it? Are there certain topics we are giving insufficient attention to? And while we dedicate considerable space to innovations on the horizon, would you like to see more articles looking back at the evolution of ship design and technology (e.g. this month's Foundation feature on the early days of automation)?

I believe *TNA* should have an important role to play in ensuring the profession is perceived as an attractive, engaging and inclusive career path, while not alienating those of you who have been reading it for many years. Yet much as we aim to seek out the movers, shakers and innovators, we also look to you, the reader, to provide us with critical guidance and insight. Keep in touch. *NA*

Certification

DNV GL rolls out fleet-wide e-certificates

After years of testing and anticipation within the industry, DNV GL has begun the process of rolling out electronic class and statutory certificates across its entire fleet. Having worked with several shipowners and flag administrations on pilot projects to test and gain acceptance for the digitalisation of certificates, nearly 50 flag states have already granted DNV GL permission to issue the electronic certificates on their behalf, and many more are expected to follow.

Not only will the move significantly reduce the administrative workload for shipowners, charterers, regulators and crew members but it will also cut the processing time of certificates and any associated document handling costs.

Once an on-board survey has been completed, certificates will be immediately available to view on DNV GL's customer portal. Shipowners can then grant access to stakeholders by issuing them with temporary access codes and all certificates are secured with a digital signature and unique tracking number (UTN), to guarantee validity and authenticity.

Knut Ørbeck-Nilssen, CEO of DNV GL – Maritime, is excited by the change this development should bring about: "Over the last several years we have been leveraging digitalisation to improve the experience of our classification customers. The roll out of electronic certificates is a significant step forward in our pathway towards modernising classification. Electronic certificates will smooth our customer's interactions with class, allow stakeholders across the industry to capture value from digitalisation, and give us a platform for future improvements."

Renewable gas

Wärtsilä buys Puregas Solutions

Technology giant Wärtsilä has acquired Swedish company Puregas Solutions, in a deal valued at €29 million. A leading provider of turnkey biogas upgrading solutions, Puregas has subsidiary companies in Germany and Denmark, as well as the UK and US, and last year reported a turnover of €21 million.

Puregas uses a unique process known as CApure to separate CO_2 from biogas through chemical adsorption, in order to convert raw biogas to biomethane and renewable natural gas, making it suitable to use as fuel.

The move will provide Wärtsilä with added equipment and expertise in the upgrading of biogas and will expand the company's reach within the gas value chain. Puregas' solutions are in close alignment with Wärtsilä's gas-based technologies, so Wärtsilä hopes that the acquisition will complement its offerings: "We are acquiring a company with technical know-how, good references, and a strong market position. It provides us, therefore, with a good platform to expand our offering and support our customers with complementary biogas upgrading and liquefaction solutions," says Timo Koponen, vice president, Flow and Gas Solutions, Wärtsilä Marine Solutions.

An additional maximum payment of €7.3 million will be made, based on performance of the business, in the coming year.

Ballast water

Concern over lack of BWMS operational verification

September's BWMTech North America showcased the latest developments in ballast water management, but it was also where some shipowners raised concerns at the apparent lack of measures in place to verify a system's operational efficiency following Type Approval.

Carine Magdo, business development manager for Aqua-Tools, a France-based technology company specialising in water microbiological applications, attended the conference and spoke with several shipowners who were surprised to learn that there is currently no system in place to monitor whether a ballast water management system (BWMS) is working as it should.

Magdo, who has a number of years' experience working in land-based water treatment, was unsettled by the apparent lack of monitoring system: "It does appear that once certified by the USCG or IMO the ballast water treatment system is left to run and run without anyone really knowing if it's working or not.

"This is unheard of in land-based water treatment applications, where there are mechanisms to assess the biological and chemical make-up of the treated water. This should be a mandatory requirement," she continued.

With variables such as volume of water, flow rate and different types and sizes of marine organisms, ballast water treatment efficiency can vary dramatically depending on the working conditions and Magdo warned that "a Type Approval certificate alone cannot guarantee the efficiency of the system."

"Shipowners, independent laboratories, system manufacturers, Port State Control (PSC) inspectors – all parties involved in ensuring the BWM Convention is effective – need to think about testing the water, during commissioning, alongside and onboard," Magdo continued.


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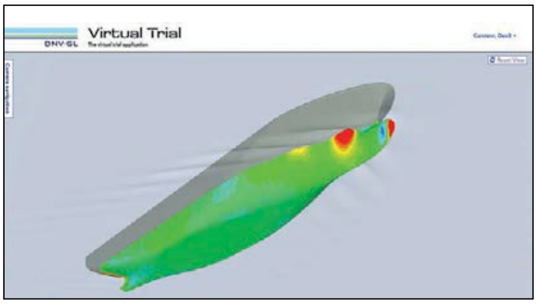
CFD

DNV GL launches CFD application

Classification society DNV GL has released a 'Virtual Trial' application that will make CFD simulation quick and simple for shipyards and owners without access to expert support.

The programme will allow users to analyse and compare the fuel efficiency of hull design variants at full-scale, without the need for CFD specific input or expert knowledge. What's more, CFD simulation is significantly quicker and cheaper than traditional model basin tests.



A 3D viewer allows users of Virtual Trial to investigate flow details (DNV GL)

The launch spells good news for shipyards and owners alike as it becomes easily achievable to conduct fully-automated, full-scale RANSE VoF CFD simulations on the propulsion and resistance of a vessel. Carsten Hahn, product manager at DNV GL – Maritime, highlights the programme's ease of use: "What we have done with Virtual Trial is to let our customers run CFD simulations, without having to invest in CFD expertise. Virtual trials can be launched in complete anonymity, from anywhere, at any time, by simply uploading the hull geometry file and defining the operation profile."

Users can upload individual hull forms, run simulations with pre-defined parameters and compare the results – which are available within a week and displayed in a web-based report – with the results of similar vessels in the application's database.

LNG

HMD receives LNG cargo system approval

Lloyd's Register has awarded Hyundai Mipo Dockyard (HMD) with an approval in principle (AIP) for its cargo handling system design for a 6,600m^3 LNG bunkering vessel.

The design was developed by HMD and Hyundai Heavy Industries (HHI) Corporate Research Centre to make use of both companies' knowledge and expertise in building gas carriers. The cargo handling system is primarily designed for LNG bunkering to an LNG-fuelled ship, however it will also be able to supply gas to a dual-fuel main engine and manage boil-off gas (BOG).

The proposed cargo pumps can bunker at a maximum rate of 1,100m^3/h to an LNG-fuelled ship. The design is also capable of supplying fuel gas to dual-fuel main engines through BOG compression or LNG vapouring. Any boil-off gas returned from the LNG-fuelled ship during bunkering can either be collected inside the Type C cargo tank or burned in the dual-fuel engine.

Singapore

CO_2 reduction efforts gain traction

More than 200 maritime leaders and professionals gathered at the Future-Ready Shipping conference in Singapore last month to identify priority areas for international action and exchange best practices in maritime technology transfer and capacity building.

Jointly organised by the Maritime and Port Authority of Singapore (MPA) and the International Maritime Organisation, representatives from shipping companies, classification societies, government organisations, universities and industry associations gathered to exchange views and to encourage cross-boundary collaboration.

Conference sessions included showcasing energy efficient technologies and case studies of efforts by ship owners and port authorities to adopt more sustainable practices. The conference included the news that Bureau Veritas and the Port of Rotterdam are the newest members of the IMO-Global Maritime Energy Efficiency Partnerships Project Global Industry Alliance. The alliance brings together 16 industry players to address barriers to the uptake and implementation of energy-efficient technologies and operational measures.

Newcastle University's Dr Alan Murphy used an invited keynote session to present an overview of current research. He explained: "Work we are currently undertaking with diesel power specialists, Royston, prompted a good deal of discussion. As an industry, we're very effective now at understanding the energy flows involved in shipping, and collecting data to show that. Our challenge now is to improve the speed at which data is processed, analysed and energy management plans updated."

There was also considerable interest in the work being undertaken to deploy sustainable technology in the marine sector of Low and Middle Income Countries (LMICs). *NA*

El Faro report could prompt class rule changes

It would have been no surprise if the official US investigation into the loss of the cargo ship *El Faro* in Hurricane Joaquin in October 2015 found blame lay with the master of the ship, but the 200-page report apportions blame to many other parties, writes Malcolm Latarche

As well as finding deficiencies in the management of the TOTE-owned vessel, its safety management system and even the USCG, the recommendations of the report look as though there will be repercussions for many more owners of US and foreign flagged vessels alike, and also likely to be some changes to SOLAS, class rules and to the working practices of the USCG.

The report states that *El Faro* had previously undergone major adaptations and that insufficient account was taken of its vulnerability to flooding as a consequence of the changes. Another issue was that the main engine lubrication level was supposed to ensure that the lubrication system would function satisfactorily when the vessel is permanently inclined to an angle of 15° athwartship and 5° fore and aft.

In fact, the level of oil in the system — while being within the parameters allowed by the classification documents — was in fact too low, and when the ship listed during the hurricane, power was intermittently lost. During the investigation, a former engineer on the ship said that it had previously been normal for additional lube oil to be added when heavy weather was expected but records indicated that this was not the case prior to putting to sea on the ship's final voyage.

Data recovered from the ship's voyage data recorder (VDR) showed that in the hurricane winds the ship heeled to starboard and began taking on water in Hold 3 through an open scuttle, and likely also through deteriorated internal structures and open cargo hold ventilation fire dampers, which compromised watertight integrity.

To correct the heeling, the master attempted to shift some ballast from starboard to port but the ship's construction and subsequent alterations had seen all but a small ballast water capacity replaced by solid ballast. These two small tanks with a 152tonnes capacity were used to make minor adjustments to the list of the vessel to facilitate the angle of the loading ramp during cargo operations while in port. Shifting all of the water ballast from one ramp to the other would only make a relatively minor change of less than 2degs in the vessel's heel.

It was not possible for the crew to ascertain the extent of flooding and this has lead the report's authors to recommend a regulatory initiative to require high water audio and visual alarms in cargo holds of dry cargo vessels. The recommendation extends to working with the IMO to amend the applicability of SOLAS Chapter II-1/25 to include all new and existing multi-hold cargo ships in place of the current requirement for only bulk carriers and single hold cargo ships.

The report also recommends revisions to ensure that all ventilators or other hull openings, which cannot be closed watertight or are required to remain normally open due to operational reasons, should be considered as down-flooding points for intact and damage stability purposes and should not be considered weathertight closures for the purpose of the applicable Load Line Convention. These changes should apply to new and existing vessels. Another recommendation is that there should be open/close indicators for all watertight closures on the ship on the bridge.

During the lead up to the loss of the vessel, the ro-ro cargo on board broke loose and was moving around. The report recommends that for US vessels there should be a regulatory initiative to require the installation of CCTV cameras to monitor unmanned spaces .

On a more general note, the report concludes that the shipowner did not identify heavy weather as a risk in the its Safety Management System (SMS) and the Coast Guard had not exercised its flag state authority to require identification of specific risks. There were other comments and recommendations around the company's SMS and it is almost certain that the USCG and Recognised Organisations entrusted with auditing such systems will be taking up matters with other shipowners and managers.

Weather monitoring and weather routeing services were also mentioned in the report. It would appear that the National Hurricane Center created and distributed tropical weather forecasts for Tropical Storm and Hurricane Joaquin, which in later analysis proved to be inaccurate. Applied Weather Technologies used these inaccurate forecasts to create the Bon Voyage System (BVS) weather packages which the master and navigating officers used when planning their passage.

There are many other points in the report that could see changes made to the SOLAS rules around performance standards of VDR systems and lifeboat drills. The potential impact should not be understated and it would be a prudent measure for all ship managers to obtain a copy with a view to examining its implications for their own safety. NA

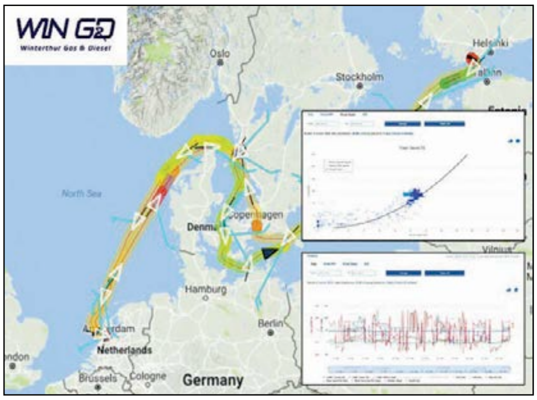
Data monitoring

WinGD and Enamor launch data platform

Winterthur Gas & Diesel (WinGD) has joined forces with marine automation, navigation and communication experts, Enamor Ltd., to develop and launch a data collection and monitoring (DCM) platform that is now ready for commercial use.

The companies have been working together for some time to develop a DCM platform for engines and associated systems on-board vessels, but signed an agreement earlier this year to formalise the partnership.

Vice president of research and development at WinGD, Dominik Schneiter, is excited by what the platform offers: "The DCM Platform will provide engine owners and operators with an advanced tool aboard ships that collects, stores, visualises and post-processes all engine data, as well as relevant ship information and other machinery data. This comprehensive fund of data will be the foundation of our digital solution portfolio, enabling value-adding analyses and remote support. It is the starting point of a game-changing product that will provide optimum customer value."



Data can be collected and monitored using WinGD and Enamor's new platform

WinGD and Enamor's collaboration will also make transmitting data from ship to shore reliable and safe via encryption. Once the information reaches dry land, it is analysed by shipowners and WinGD to improve engine and ship operation and will also be useful in the future development of products and services. The focus will be on storing data both on-board vessels and ashore: "The WinDG DCM platform is the gateway to engine, ship and ship machinery data, creating an Internet of Things network with most of the analytics done on the edge, i.e. on the vessel," Schneiter adds.

The DCM platform has been designed to work with WinGD's engine and ship-specific software, including an advanced Engine Diagnostic System (EDS) that the company is currently developing with Greece-based Propulsion Analytics. WinGD EDS has been designed to optimise fuel consumption, engine power, emissions and response. It's able to diagnose and predict any malfunctions or maintenance needed on-board, meaning unplanned downtime will be reduced.

www.wingd.com

Propulsion

Viking Line ferry first to use ABB Azipod propulsion

A new Viking Line ship will be the first cruise ferry to be fitted with ABB's Azipod propulsion system. The 63,000gt vessel will be built in China by Xiamen Shipbuilding Industry Co., Ltd (XSI) and is scheduled for delivery in 2020.

Once finished, the ship will operate between the Finnish port of Turku, the Åland Islands and Stockholm in Sweden, with the capacity to carry 2,800 passengers onboard its 13 decks. It will be fitted with twin XO 2100-type Azipod propulsion units designed and built in Helsinki, which feature intelligent control systems and advanced condition monitoring.

Azipod electrical propulsion systems are also gearless and steerable, with an electric drive motor that sits outside the hull of the ship in a submerged pod. The design improves vessel efficiency and manoeuvrability, making them them ideal for navigating the many small islands between Finland and Sweden.

Like the ship's predecessor, European-built *Viking Grace*, the new vessel will feature LNG engines and ABB may also be called upon to provide electrical power generation and distribution systems and bow thruster motors.

Jan Hanses, president and CEO of Viking Line, is excited about the first-of-its-kind project: "Our expectations for this vessel is that she will be the most efficient cruise ferry operating in the Baltic, if not the world, and our choice of ABB is based on our experience of them as a reliable, innovative supply partner with the knowledge and understanding to run major projects in Finland and locally with shipbuilders."

ABB has lots of experience providing Azipod propulsion systems for vessels operating in ice and the XO units have been designed to match the ship's ice class 1A Super notation given by DNV GL.

Viking Line's contract with Xiamen Shipbuilding Industry Co., Ltd does include an option to build a second cruise ferry at the yard.

www.abb.com

Automation

Ektank and Utkilen chemical tankers choose Høglund automation

Norway-based marine automation specialist, Høglund, has been selected to provide automation systems on eight chemical tankers being built in China for Ektank and Utkilen.

The systems will be installed on four 18,600dwt tankers for Ektank, and four 9,900dwt vessels for Utkilen, in order to better link systems including power management, cargo control and alarms. Not only will the ships benefit from improved access to data, which Høglund claims would otherwise be expensive and difficult to obtain, but they will also have access to Høglund's 24/7 engineer support service and customised automatic reporting systems that communicate directly from ship to shore. The company even claims that they are able to resolve 90% of all service requests remotely, reducing downtime and therefore avoiding delays to missions.

Børge Nogva, CEO of Høglund, explains the importance of investing in automation: "These developments point to a new level of awareness of the importance of integrated automation in the chemical tanker segment. Historically, automation systems have been a low-priority item, and as such, often including several different components from various manufacturers that are linked, but not integrated, even if they have the same logo.

"By prioritising integrated automation, Ektank and Utkilen will benefit from increased reliability, better visibility into the data within their systems, and a single point of contact for upgrades and service. Automation systems are the nervous systems of modern vessels – and as the fleet becomes smarter, it's becoming ever more costly to ignore them."

Fredrik Farsen, technical manager at Ektank, reveals that it's Høglund's ability to customise it's systems to suit specific vessels that made them a clear choice: "Høglund has a unique appreciation of the need to create a tailored system and support it from installation onwards. We see integrated automation as something that is becoming increasingly necessary for the long-term health of our fleet."

Høglund's systems have already been installed on the LNG bunkering vessel, *Cardissa*, and wind farm support vessel, *Windea La Cour*, this year.

www.hma.no

Wireless charging

Wireless charging first for hybrid ferry

Wärtsilä has successfully tested its wireless charging system on a hybrid powered coastal ferry, making the vessel the first commercial ferry in the world to be operating with high power wireless charging capabilities for its batteries.

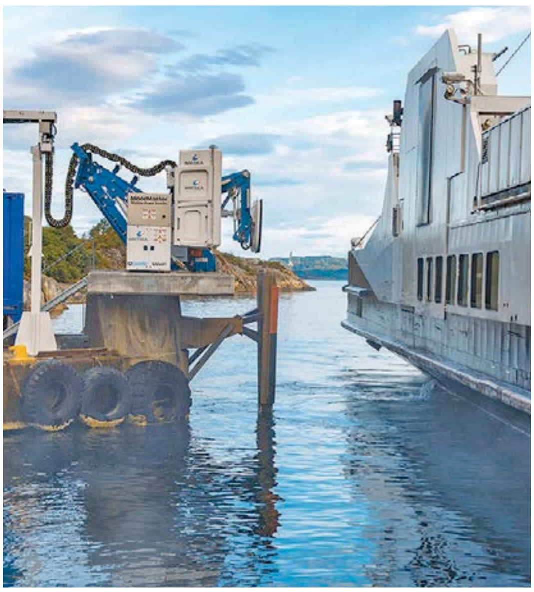
The 85m long vessel, *MF Folgefonn*, owned by major ferry operator Norled, tested out the wireless charging in Norwegian waters during August and September this year. The Wärtsilä system is able to maintain efficient power transfer at a distance of 50cm between two plates – one built into the side of the ship and one on the quay – making it the only system capable of transferring energy at this distance.

Based on inductive power transfer, Wärtsilä's system is able to transfer more than a megawatt of electrical energy. What's more, wireless charging not only makes for safer connections and disconnections due to the lack of cables, but it also reduces maintenance of the vessel since there is no wear and tear to connection lines.

Ingve Sørfonn, senior technical officer, Electrical & Automation, Wärtsilä Marine Solutions, says: "During recent years, wireless charging has been introduced for cars, buses and trains. We have now made this possible for marine vessels. The main benefits for customers are up to 20 percent more utilisation of the available charging time, increased operational safety, and greater system reliability. There is an ongoing trend to equip coastal ferries with battery powered and hybrid propulsion since they are particularly affected by environmental regulatory demands. Wireless charging will, therefore, create considerable value for operators of hybrid ferries."

www.wartsila.com

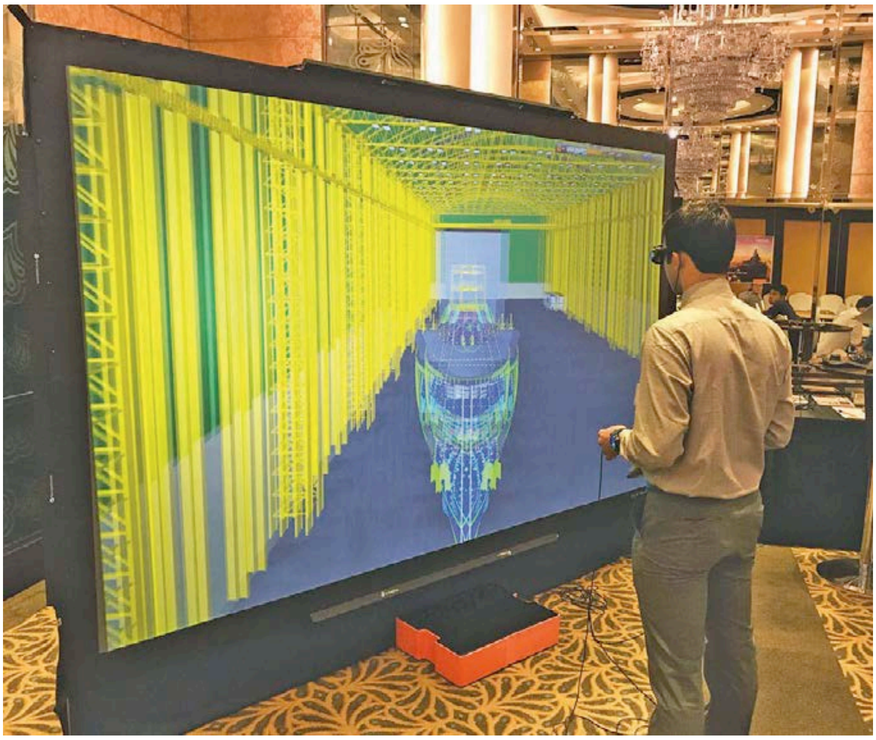
Wärtsilä's wireless charging system was tested on *MF Folgefonn*



Building a better future

The 18th International Conference on Computer Applications in Shipbuilding (ICCAS) took place in Singapore in September, offering a chance for industry experts to share developments, ideas and predictions for the use of computers in the digital age of ship building and design

With more than 70 papers presented, topics were varied and in some cases very specific, but there were some clear themes that emerged and prompted discussion over the course of the conference.



Virtalis' ActiveMove system in use at ICCAS 2017, Singapore

Digitalising information

In his keynote presentation, Mark Tipping, Offshore Technology manager, Marine and Offshore, Lloyd's Register, spoke of how data can and should be used to predict which parts of a vessel will need more or less maintenance in one, five or ten years to come, amongst other possible applications. Making reference to his grandfather's journal that he once used to log the state of his ship when he was at sea in the 1920s, Tipping reflected on the fact that not much has changed in terms of the types of challenges vessels might encounter or crews' ability to identify potential problems, but the way in which we capture, record and use that data has changed dramatically.

But however much ship design and building may have embraced the digitisation of information, Tipping suggested that the industry will be required to go further if it is to keep up: "We're starting to approach the buffers of our effectiveness, and this is where we are today, I think.[…]The pdf document, which I do believe revolutionised electronic documents, I think also summaries the mind-set that many of us have today – the fact that we've digitalised paper, not information, and that needs to transform as we move forward in the development of products."

Another keynote presentation came from Professor Dr.-Ing. Wolfgang Müller-Wittig of Nanyang Technological University (NTU), who spoke of the opportunities of augmented reality and smart interfaces, and how they are already being used in the automotive industry for the purposes of marketing products and to attract younger people to consider careers in the industry – a challenge that the maritime industry also faces.

Early stage design

There was a definite emphasis on improving the early stages of the design process, whether that be through introducing 3D models earlier on, or through companies joining forces to make their respective software or processes work more cohesively.

In fact, there were several presentations that claimed impressive reductions in man hours if 3D models were integrated into the design process at a much earlier stage. Namely, Hyundai Heavy Industries' (HHI) and NAPA's paper *Enabling a Paradigm Shift in Structural Design with a 3D Approach* [1], claimed that through using NAPA Steel in HHI's Basic Hull Design Department, the company was able to reduce its initial and basic structural design time by around 30%, while actually improving the quality of the design due to all information coming from a single source. Samsung Heavy Industries (SHI) and Intergraph PP&M (part of Hexagon), who have been working together for almost 20 years, also stated in their presentation, *A case study in optimising 3D early design for shipbuilding* [2] that by re-engineering SHI's early design process, they were able to shorten it from 11 months to just eight months.

3D to replace 2D in classification?

With a push for implementing 3D models earlier on in the design process comes the obvious question of why they shouldn't entirely replace 2D drawings that are currently submitted to classification societies. In some cases, companies are having to create 2D drawings only for this purpose, wasting time and resources that could be better spent working on 3D mock ups.

Delegates from Naval Group, Bureau Veritas and Dassault Systèmes presented their paper, simply entitled *3D Digital Classification* [3], and provided insight into what the use of 3D mock ups in the classification process would mean for ship designers, classification societies and software providers.

For all parties involved it seems that the current process is primarily time consuming – for designers it is of "negative value" to produce 2D drawings from a 3D model and for assessing things like structure or stability, classification society surveyors have to make an independent calculation by building a 3D model based on the supplied 2D drawings.

Another concern was the capacity for confusion that the current system has, both with inconsistencies that might arise from various revisions of drawings, to the way in which comments are communicated. And of course, the concerns for security of data and how stringently intellectual property could be protected were also high on the agenda.

A holistic approach

Some speakers championed the idea of holistic ship design, looking at the bigger picture and considering all aspects of the process from beginning to end, with Digitread AS's paper *Holistic ship design – how to utilise a Digital Twin concept design through basic and detailed design* [4] providing the most focussed presentation on the topic. Torben-H. Stachowski and Helge Kjeilen, Digitread AS, heralded the merits of a Digital Twin and the idea of a "single backbone" that connects all information, collected from different programmes, so that the model can mature through each stage of the process. This connectivity and the early introduction of a Digital Twin will in turn promote transparency that clients and colleagues alike will appreciate and eventually culminate in the production of a better vessel, giving companies "a competitive edge in a digital world."

Virtual reality

Virtual reality (VR) continues to prove itself as a viable option for ship designers and builders and although the equipment is currently a big investment for companies to make, the slow but steady uptake of the technology will see prices drop in coming years, speakers assured delegates.

VR specialist, Virtalis, brought along its stereo projection interactive ActiveMove system and ActiveMove CVR head-mounted display (HMD) equipment so that attendees could experience standing on the deck of a virtual vessel, with the ability to hover high above the ship and 'fly' into the engine room to make inspections or move components, all by using a hand-held controller to navigate their way around.

Alfonso Cebollero presented a paper he co-authored with SENER colleague Luis Sánchez, entitled *Virtual reality empowered design* [5] that was also published in the October issue of *The Naval Architect*. It outlined the logistics of incorporating a VR system into the design process, making the prospect of it becoming the norm for companies around the world all the more real.

A leap of faith

The general feeling at the three-day conference was that all of the technology is in place for the industry to truly embrace the digital age, but it's now up to companies to be brave enough to implement them and leave behind the comfort of practices that have served ship design and building well for decades.

Alexandre Tew Kaï's, of Dassault Systèmes, paper entitled *Driving transformation in the age of experience* [6] seemed to address these feelings. He proposed that as clients request more advanced and innovative designs, designers are required to use more sophisticated technology – technology that may be new to them, therefore possibly increasing the complexity and risk associated with the design. But, he argued, platforms such as Dassault Systèmes' 3DExperience help each stage of the supply chain to better communicate ideas and generally improve collaboration, in turn helping to decrease instances of duplication or error and save valuable time and resources.

If the industry is going to make the most of revolutionary technology such as VR, and take steps to transform ship design and production as we know it, it needs to jump in with both feet. It's not enough to digitalise 2D drawings through converting them to pdf format – 3D mock ups need to be created from the offset. Using classification as an example, transitioning from 2D drawings to 3D models will require all parties to completely rethink their approach to the process, but surely the result will be quicker, more reliable and more resource-efficient, which is ultimately what the industry is striving for and the reason for which computer-aided practices are being developed.

If the industry is able to get past the fear of the unknown, what lies ahead will be well worth the risk. *NA*

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Stolt refreshes the parcel tanker concept

Investment in more efficient newbuild plus the takeover of a competitor puts Stolt Tankers on a stronger footing for the long run. David Tinsley reports

New-generation parcel tanker: Stolt's C-38 class was led by *Stolt Pride*.(photo credit: MarineTraffic/Michael R.Thom)

Specialists in the parcel tanker disciplines and trades combine a distinct blend of operational and technical know-how with a financial and organisational resilience shaped by a long-term mindset rather than short-term opportunism, ever-alive to the exacting performance demands of global players in the chemical industry.

Market leader Stolt-Nielsen's latest generation of deepsea, stainless steel chemtankers endorses the group's reputation for quality tonnage offering the broadest cargo range and capability for multiple consignments, with the added benefit of increased energy efficiency.

Led by the 2016-commissioned *Stolt Pride*, the C-38 class embodies 43 fully-stainless tanks and a corresponding number of segregations by virtue of individual pumps and manifolds. The overall revenue-earning volume of 44,000m^3 encapsulates IMO I, II and III capabilities, conferring optimum flexibility including scope for the most difficult-to-handle cargoes.

The C-38 breed affords further testament to China's rising profile in the higher value-added spheres of mercantile vessel construction, with contracts for six 38,900dwt newbuilds having been awarded to Hudong-Zhonghua Shipbuilding of Shanghai. The initial deal for five vessels, to replace five tankers of the K-40 type dating from 1986, was signed in 2012. An option was subsequently taken up on a sixth C-38.

Finnish-headquartered Deltamarin, owned by China's AVIC Group, was retained by the shipowner to provide the concept and basic design, such that the hull form and propulsion arrangements have been developed from the company's proven B.Delta bulk carrier configuration. As with the Ch.Delta38, the chemtanker design is distinguished by a comparatively shallow draught in fully-laden condition and a significantly lower fuel consumption compared to existing parcel tankers of similar size. A new feature is the adoption of a device to close the bow thruster tunnel while at sea, obviating the extra resistance induced by such openings in the hull.

Besides the work undertaken for Stolt, Deltamarin's commission from the yard included 3D modelling of the cargo deck and engine room areas.

Each of the new parcel tankers is powered by a six-cylinder RT-flex50-D engine, produced in China under licence from Winterthur Gas & Diesel, and driving a Wärtsilä controllable pitch propeller. The nominal maximum continuous rating of this design of prime mover is 10,470kW, although a somewhat lower contractual output applies in the Stolt series. The fifth and sixth ships have been specified with scrubbers, enabling continuous operation of the main engine on heavy fuel oil (HFO) while ensuring compliance with the toughest sulphur emission limits, currently most apposite to trading into US waters.

Following the handover of *Stolt Pride* and second-of-class *Stolt Sincerity* in 2016, deliveries took place during the first half of 2017 of *Stolt Integrity*, *Stolt Tenacity* and a fifth ship, all assigned to Stolt Tankers in Rotterdam. The last of the sextet is to be placed under the commercial aegis of the deepsea parcel tanker joint enterprise, NYK Stolt Tankers.

TECHNICAL PARTICULARS

Stolt C-38 class: *Stolt Pride*

Length oa:	185.04m
Length bp:	181.75m
Breadth, moulded:	32.25m
Depth:	14.96m
Draught, scantling:	10.36m
Draught, design:	10.00m
Gross tonnage:	29,903t
Deadweight:	38,961t
Cargo capacity, @98%:	c.45,280m3
Stainless steel cargo tanks:	39 + 4 deck tanks
Cargo segregations:	43
Speed:	14kts
Class:	DNV GL
Class notations:	+1A1 Tankers for chemicals and oil products, BIS, BWM(T), COMF(V-3), CSR, E0, ESP, HL(1.5), NAUT(OC), Recyclable, TMON, VCS(2)
Flag:	Cayman Islands

Collaboration between the NYK Group of Japan and Stolt-Nielsen is also expressed in the regional operating company, Stolt NYK Asia Pacific Service (SNAPS), which has chartered four new 12,400dwt stainless tankers. The *Stolt Hagi* class employs an 18-tank, fully-stainless arrangement, and was built in Japan by Usuki Shipyard to the account of NYK Stolt Shipholding, one pair having been completed last year and the second pair in 2017.

Stolt's US$575 million takeover of JO Tankers' chemtanker business and assets was the largest-ever acquisition in the group's history. The transaction added 13 chemtankers to the fleet, and included a 50% stake in a joint venture with eight newbuilds. The programme, covering eight 33,000dwt all-stainless parcel tankers at New Times Shipbuilding in China, had been implemented by the Norwegian company, Hassel Shipping 4, in which Stolt now has a half-share through the takeover deal.

Two of the Hassel vessels had already been delivered when the purchase of JO Tankers was finally signed-off last November. Three more of the ships have followed in 2017 to date, with the seventh due before the end of the year and the eighth expected in early 2018.

Sectoral consolidation is often propounded as a way of combating overcapacity. In Stolt-Nielsen's case, though, the rationale for its takeover of JO Tankers was the advantage it offered, through the addition of the in-service ships plus the joint venture newbuilds, as a means of addressing the group's tonnage replacement needs over the coming several years, without having to add to the bloated world orderbook.

Another factor driving the acquisition was the complementary nature of JO Tankers' trading activities, offering Stolt the prospect not only of strengthening its presence in key areas but also of augmenting an already diversified trading structure, not least in adding a major new trade lane around Africa. The expansion of the service network was seen as allowing the group to better cater to the current and evolving requirements of its global customer base.

Together with the various deepsea, intra-regional and coastal fleet operations, Stolt-Nielsen's extensive interests in marine terminals and tank containers enables the group to provide integrated transportation and storage solutions covering the gamut of specialty and bulk liquid chemicals. *NA*

Revitalisation in coastal tanker fleets

Swedish members of the Gothia Tanker Alliance have implemented a major investment plan focused on IMO Type II chemical/product carriers for coastal and intra-regional distributive work

Fifteen newbuilds will be phased into the operating network overseen through the Gothenburg-headquartered Gothia Tanker Alliance, which holds shipment contracts with oil majors and traders, primarily across northwest Europe.

Ten of the vessels have been specified with dual-fuel propulsion machinery, the intention being to maximise use of LNG fuel so as to ensure compliance with the toughest emission controls and, as part of broader engineering strategies, to realise both owners' and customers' corporate environmental objectives.

Founded in 2013, Gothia Tanker Alliance now has seven partners from Sweden, Denmark and Germany, six of whom are well established tanker fleet owners with roots in the Baltic and north European coastal and shortsea traffic. The co-operative venture has 32 vessels at its disposal, spanning the 6,000-37,000dwt range, affording both the critical mass and the flexibility to meet the contract of affreightment and spot voyage requirements of clients, notably as regards ensuring year-round shipments throughout the ice-prone Baltic.

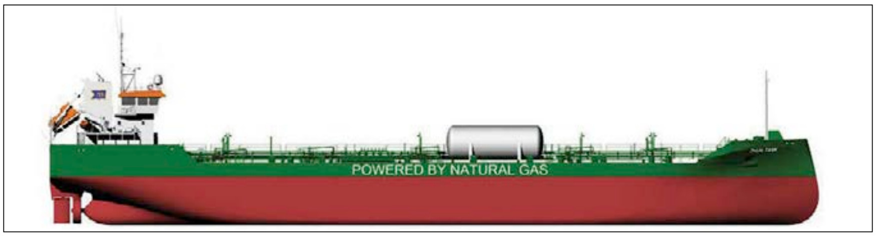
Three of the companies involved, Thun Tankers, Alvtank and Furetank, have ordered new tonnage for deployment within the commercial alliance. Thun is having four coastal tankers in the 8,000dwt category built by Ferus Smit of the north Netherlands, and has booked one 16,300dwt and five 17,500dwt intermediate traders from AVIC Dingheng Shipbuilding. Alvtank and Furetank have signed for two and three 16,300dwt newbuilds, respectively, from the Chinese yard.

Dutch shipbuilder Ferus Smit has constructed more than 30 vessels for the Erik Thun group over the years, and the latest deal with Thun Tankers for a quartet of 8,000dwt chemical/oil product carriers extends the business relationship into 2021. The contract represents the opening stage in a replacement programme for some of Thun's slightly smaller tankers delivered by the Dutch yard since the end of the 1990s.

The new series will provide a 9,540m^3 capacity in nine coated cargo tanks, offering the flexibility to transport chemicals and vegetable oil consignments as well as petroleum products. Given the importance of Baltic trade to both owner and the Alliance, the ships will be built to Ice Class 1A standard.

Measures to enhance hydrodynamic

Next generation 8,0000dwt tankers for Thun will have dual-fuel propulsion



efficiency include the fitting of the controllable pitch propeller in a nozzle ring, and the adoption of the builder's Eco bulbless, canoe-type bow, designed to reduce fuel consumption and enable speed to be maintained at different draughts and in adverse weather conditions.

The nominated primary power installation is a six-cylinder Wärtsilä 34DF dual-fuel medium-speed engine. Running in gas mode will meet both SOx and NOx limits in IMO Emission Control Area (ECA) waters and will also avoid penalisation where national or local NOx taxes apply. A significant feature of the Wärtsilä LNGPac fuel system is the weight- and power-saving, open type tank connection space (TCS), housing the process equipment for the gas supply to the engine. The vessels will also be equipped for 'cold ironing' in port, drawing electricity from the landside grid rather than having to bring generators on line.

Thun's newbuild project for a quintet of 17,500dwt IMO Type II tankers, assigned to AVIC Dingheng, underscores the company's bid to develop in the intermediate tanker category. The ships will be commercially managed by Furetank Chartering, which is responsible for the intermediate segment within the Alliance.

The six 16,300dwt product/chemical carriers ordered by Thun, Alvtank and Furetank at AVIC Dingheng will also be commercially husbanded by Furetank. The design has been developed by FKAB in conjunction with Furetank and displays an especially strong slant towards environmental protection, to the extent that it is claimed to offer a 49% reduction in CO_2 emissions relative to similar-sized vessels built between 2002 and 2012.

The ships will fulfil IMO Tier III criteria, using Wärtsilä dual-fuel propulsion machinery, LNG for inert gas production, 'floating frequency' power production and battery back-up for all vital functions so as to reduce auxiliary engine running time. Furthermore, the shaft alternator will feature a 'take-me-home' functionality, affording an auxiliary propulsion capability. *NA*

Vessels	Owner	DWT	Delivery
4 x coastal tankers*	Thun Tankers	7,999	2018-2021
1 x intermediate tanker*	Thun Tankers	16,300	2019
2 x intermediate tankers*	Alvtank	16,300	2018/2019
3 x intermediate tankers*	Furetank	16,300	2018-2019
5 x intermediate tankers	Thun Tankers	17,500	2019-2020

The newbuild programme includes15 product/chemical tankers

Series	7,999DWT	16,300DWT	17,500DWT
No. of ships	4	6	5
IMO type	Type II	Type II	Type II
Length oa	114.95m	149.9m	149.8m
Breadth	15.87m	22.8m	22.8m
Draught, summer	6.9m	8.8m	8.5m
Cargo capacity	9,540m^3	20,000m^3	21,000m^3
Tank coating	Epoxy	Epoxy	Epoxy
Ice class	1A	1A	1C
Main engine	3,000kW	4,500kW	
Deliveries	2018-2021	2018-2019	Apr 2019-Jan 2020

Gothia Tanker Alliance product/chemical tanker newbuilds

Odfjell focus on reinvestment in 'super-segregators'

With a cargo capacity of 54,600m^3, Odfjell's next-generation vessels on order in China will rank as the world's largest fully-stainless steel chemical tankers

The first of the four 49,000dwt newbuilds from state-owned Hudong-Zhonghua is expected to be delivered in June 2019, with the subsequent ships following at three-monthly intervals.

As the cargo handling system and configuration provides for separate products, grades and consignments in all 33 cargo tanks, the nascent class is also described by the Norwegian owner and integrated service operator as the largest in the "super-segregator" category.

Signed off last November, the US$240 million project denoted Odfjell's first reinvestment in its core chemtanker fleet for 10 years. Hudong-Zhonghua, which has a relatively recent track record in the sector, is regarded as having one of the very few construction facilities in China able to meet Odfjell's quality standards for such advanced parcel tankers.

The design has been developed to provide the highest level of cargo flexibility, with the capability to carry anything from high-end specialty chemical products, small parcels of chemicals and semi-gases, and large consignments of bulk industrial chemicals, up to full cargoes of clean petroleum products.

The new breed is claimed by the owner to offer the "best-in-class emissions per ton carried", with signal influences being the refined hull form and the nomination of Tier III-compatible propulsion machinery. Tier III technologies in the guise of high pressure selective catalytic reduction (SCR) and exhaust gas recovery (EGR) are integrated with the MAN main engine, a six-cylinder model of the G50ME-C9.5 type.

Besides its operational and environmental attributes, the series represents solid long-term value for the company's investors: "The ships were ordered on very favourable terms, giving Odfjell the most stainless steel cubic metre capacity per dollar on the market and unmatched efficiency," stated the owner.

In April this year, Odfjell extended its commitments at Hudong-Zhonghua by awarding the Shanghai yard a contract for two 38,000dwt parcel tankers incorporating 40 tanks, offering a cargo capacity of about 45,000m^3. Options on two further ships are appended to the deal, and 'future-proofing' of the design will include provision for switching to a dual-fuel engine solution.

Bow Neon, first of the 25,000dwt all-stainless newbuilds in China purchased by Odfjell from CTG.(photo credit: Odfjell/Ian Shaw).

Agreements securing four newbuild stainless steel tankers on long-term charter have also been entered into with Japanese owners. Two 35,500dwt vessels ordered by Nissen Kaiun at Shin Kurushima Dockyard are due to enter the Odfjell fleet on completion in the final quarter of 2018 and opening quarter of 2019, and will trade under charter for a minimum eight-year period. Incorporating 28 cargo tanks for an aggregate 37,500m^3 capacity, the ships' specification has been upgraded and tailored to Odfjell's requirements. Two other 28-tank, fully-stainless newbuilds, booked by Taihei from Fukuoka Shipbuilding and customised to Odfjell criteria, have been secured on a long-term bareboat basis. The Taihei ships will be of 39,200m^3 capacity.

The motivation for the extensive fleet renewal programme implemented over the course of the past 12 months is the age profile of the 'super-segregators' that are engaged in core areas of the company's business. In reference to its eight Poland-class and 14 Kvaerner-class tankers, Odfjell stated that: "The fleet is ageing and, due to restrictions set by many of our charterers, it is increasingly difficult to trade effectively in our core trades when the ship has turned 25 years old."

"This type of tonnage is not easily available in the secondhand or timecharter market. To secure adequate tonnage, we must build vessels, and our primary focus has been on securing replacements for our aging stainless steel super segregators." With shipbuilding prices for sophisticated tankers of this type at a low level in comparison to historic averages, Odfjell considers that the time is right to implement its strategy.

Odfjell's bid to strengthen capacity, extend market reach and achieve increasing revenue growth is expressed in the recent agreement with New York-based Chemical Transportation Group (CTG) pertaining to the purchase of five stainless newbuilds and creation of a pool for chemtankers in the 25,000dwt category.

During July this year, a deal was finalised for Odfjell's acquisition of the last five vessels in a series of 10 ordered by CTG from Chinese shipbuilder, AVIC Dingheng. Each is arranged with 24 cargo tanks made from Duplex 2205 stainless steel. Odfjell commissioned the first of its US$40 million purchases, the 25,000dwt *Bow Neon*, on July 14, and she was followed on August 30 by *Bow Palladium*. The remaining vessels are planned for handover in early January, end of March and May next year.

CTG will continue to own the first five tankers in the 10-ship series, which will be placed in the new Odfjell Chempool 25 under the commercial management of Odfjell Tankers. The 25k pool will also be joined by five 25,000dwt chemtankers that already formed part of the Odfjell fleet, and by the five newbuilds acquired from CTG, so that 15 compatible vessels should be available by mid 2018. *The Naval Architect* was advised that the main areas for the Odfjell Chempool 25 would be the Atlantic basin and South America, as well as Middle East/Far East trades.

Deepsea petrochemical shipping specialist CTG was launched in March 2014. At the time of the contract, the 10-ship project at AVIC Dingheng in Jiangsu ranked as the most extensive stainless steel chemtanker newbuild programme worldwide. The strategic relationship forged between CTG and Odfjell may be viewed as a move towards consolidation within the sector. *NA*

TECHNICAL PARTICULARS

Odfjell newbuilds

49k class

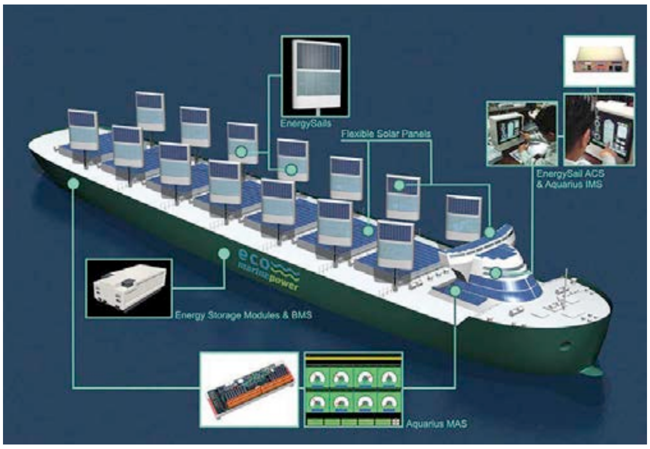
Length oa:	182.88m
Breadth, moulded:	32.20m
Draught, summer:	13.20m
Corresponding deadweight:	c.49,000tonnes
Cargo tanks:	33
Tank material:	Stainless steel
Cargo capacity, maximum:	c.54,600m^3

38k class

Length oa:	185.00m
Breadth, moulded:	32.26m
Draught, summer:	10.35m
Corresponding deadweight:	c.39,800tonnes
Cargo tanks:	40
Tank material:	Stainless steel
Cargo capacity, maximum:	c.42,400m^3

Is this the dawning of the age of Aquarius?

Combining wind and solar energy for ship propulsion has been mooted since the 1990s. Now, after several years of development, a new hybrid solution is set to be trialled onboard a bulk carrier



The Aquarius Eco Ship concept design with Aquarius MRE

Based in Fukuoka, Eco Marine Power (EMP) develops fuel and emissions reduction technologies for shipping. These include the Aquarius MRE [Marine Renewable Energy], a patented system which integrates rigid sails (made from marine grade steel or a carbon fibre composite) with solar panels, energy storage modules and marine computers to exploit wind and solar energy in unison. Aquarius MRE can either be retrofitted to vessels or incorporated into future designs such as EMP's own Aquarius Eco Ship concept.

Earlier this year, EMP took a huge step forward with the announcement of a strategic partnership with Japanese shipowners Hisafuku Kisen, which will see the installation of the Aquarius MRE system for sea trials. Already underway is a feasibility study involving three of Hisafuku Kisen's bulk carriers — *Belgrano*, *Nord Gemini* or *Bulk Chile* — to determine the sort of propulsive power that might be gained by deploying the system.

"On a large bulker or tanker our estimate is that annual fuel savings of around 10% are possible and thus emissions would also be reduced by this amount," explains Greg Atkinson, EMP's founder and chief technology officer.

A number of wind and sail-based marine energy solutions have grown in prominence in recent years. These range from the in-development B9 sail cargo ship concept, which utilises wind and bio-gas, to skysails (or kites) and Flettner rotors. But Atkinson says EMP's sails, known as EnergySail, differ as they build upon trusted technology: "Our concept is derived from a proven rigid sail design that was deployed on around 14 Japanese ships in the 1980s. No other wind propulsion solution for shipping I am aware of has been deployed and tested that extensively."

Production and design of EnergySail is being carried out by Teramoto Iron Works of Onomichi, Japan, which was one of the companies involved in the manufacture of JAMDA (developed by Japan Machinery Development Association) folding rigid sails. Earlier attempts to promote JAMDA sails coincided with high oil prices in the late 70s oil crisis and it was possible to achieve fuel reductions in the region of 10-30%. As fuel prices dropped, JAMDA sails were no longer deemed cost effective, yet the concept has been given fresh impetus by the drive to reduce harmful emissions and greenhouse gases.

Unlike wing sails, EnergySail uses square or rigid sails (SRS), which utilise winds from astern of the ship, meaning that listing is not a major issue. Atkinson explains: "For cross winds, listing can be minimised as required by simply reposting the sails to minimise side forces. Our EnergySail also has an inbuilt method for minimising wind load on the sail if required. The repositioning of the EnergySails is done automatically by the EnergySail ACS [Automated Control System].

Moreover, by taking the innovative step of fitting rigid sails with solar power, Atkinson believes EMP's solution offers distinct advantages over rival wind-based concepts. "Aquarius MRE incorporates a marine solar power system that has already been installed on a ship and evaluated over two years. By comparison with rotors, the major advantage is that our EnergySails can be lowered/stored when not in use and therefore will not interfere when the ship is loading/unloading cargo or be an obstacle if the ship needed to pass under a bridge, for example. Also, our system basically doesn't require any power when in use apart from when the EnergySails need to be re-positioned due to changes in the wind direction."

The EnergySail can be operated as a standalone unit or as part of an array, while the solar panels can be mounted on both the sails and decks. These will in turn charge batteries for power into the AC or DC distribution unit.

A computer system jointly developed by EMP and KEI System, Japan, called EnergySail Automated Control System (ACS) handles its positioning. The two companies also collaborated in developing the interface with the main engines and other equipment, known as the Aquarius Management and Automation System (MAS). EMP says the technologies developed as part of the Aquarius MRE solution are also suitable for application on offshore or land-based projects.

Work on the project originally commenced in 2010 with a pre-study on the use of rigid sail systems, including their economic viability. Two years later, EMP had developed a preliminary design and filed for patents (granted in 2016) for EnergySail and the overall system, Aquarius MRE. From here, it was possible to develop a prototype, including a basic computer control system, and begin feasibility testing.

Then in 2014, attention turned to the solar power system which was trialled onboard the Greek ro-pax, *Blue Star Delos*. This 145m vessel operates on a daily circuit from Piraeus to several islands in the Aegean Sea, where wind speeds can sometimes reach more than 50knots. *Blue Star Delos* was equipped with a marine-grade photovoltaic (PV) power generating system, consisting of 16 thin PV layers made using polycrystalline cells affixed to a flexible, lightweight backing material (2mm in thickness) and attached to aluminium trays mounted above the deck.

Energy storage was achieved with 12 valve-regulated lead-acid batteries configured into a 24V 5.4kW/h battery pack and installed in an equipment space directly below the panels. Both the batteries and data logging system had been approved and certified for use on ships by ClassNK. The trials determined that under operational conditions the system could provide a continuous stable supply of power to a DC load, with the possibility the power yield could be further improved, however a more detailed analysis over a longer period would be necessary. Furthermore, the impact of the marine environment, and how much maintenance the panels and frames would require, needs closer investigation.

Atkinson says that for the present Aquarius MRE is attracting greater interest for retrofits but he anticipates increased focus on newbuilds over the coming years. The Aquarius Eco Ship, a low emission and green shipping focused solution, has been designed to be highly flexible and configurable so that it can be applied to most ship sizes and types. Its novel design has already caught the eye of the mainstream media and it has received coverage from the BBC and Daily Mail.

EMP says it will be issuing regular updates on the progress of the bulker trials when they commence next year, as well as other Aquarius MRE tests. Many of the subsystems – such as the batteries and computer control systems – have already received class approval: "We are currently in discussions with two classification bodies about obtaining approval for the EnergySail and the other parts of the system as well. We are also building a complete system at the Onomichi Marine Tech Test Centre [based at the Teramoto Iron Works] and this will be used to move forward with the approval process." *NA*

Looking for a rebirth

Very few countries these days can claim a healthy orderbook and Russia is no different. However, there are several reasons why shipyards in the country are looking to stabilise and ultimately grow production, writes Malcolm Latarche

In the days of the USSR, the Soviet fleet was the largest in the world and shipbuilding was a major industry throughout Russia and its satellite states. Since then, things have not gone so well and today most of the new vessels operated by Russia-based countries are built in Asian yards. Many of them are sophisticated ships such as the ice-breaking LNG carrier *Christophe de Margerie,* delivered to Sovcomflot earlier this year.

Christophe de Margerie, pictured during sea trials, was delivered to Sovcomflot earlier this year

Russia's own production, as far as commercial ships are concerned, is generally of a lower order. Aside from the double acting shuttle tankers *Mikhail Ulyanov* and *Kirill Lavrov* delivered as long ago as 2010, Russian shipbuilding production comprises mainly river-sea vessels of various types, a handful of product tankers ranging from 13,000–45,000dwt, fishing vessels, tugs and patrol craft. Military ships feature strongly for both the Russian navy and foreign buyers but the details of these are mostly not made public. Another strength and unique ability is the construction of nuclear-powered icebreakers.

Shipbuilding in Russia is conducted at over 50 yards although many of them are small repair facilities and have built only one or two small vessels over the course of the 21st century. The yards are a mix of state-owned and private facilities and are spread throughout Russia, including many located well inland along Russia's extensive canal and river network.

Considering the number of yards, the output of non-naval vessels is remarkably small. Since 2000, the annual production figure has varied from 14 to 46 vessels and the annual deadweight from around 46,000dwt to 275,000dwt. The annual figures had been quite consistent until 2014 when there was a sharp dip that has extended until this year. In the period from January 2014 through to September 2017 just 60 vessels have been completed.

Some of the downturn appears to have been due to delays of deliveries as the final quarter of 2017 shows no less than 33 vessels for a deadweight of 166,438 due for delivery. The likelihood of all these vessels being completed is remote so many will be carried over to add to the 22 vessels on the orderbook for 2018 delivery. Beyond next year, the combined orderbook for non-naval vessels is just 16 vessels between 2019 to 2022.

By far the majority of ships produced in Russia are built by the state-owned United Shipbuilding Corporation (USC) which is also the main builder of naval vessels. The company has a workforce of over 80,000 and its facilities include about 40 domestic shipyards, design offices and shiprepair yards.

USC is also a major shareholder in Russia's newest shipbuilding facility, the Zvezda shipyard in Russia's Far East. Once a military facility, it is intended to be the jewel in the crown of new Russian shipbuilding when completed. Its development was initiated by Rosneft, the partially state-owned oil company, some four years ago to enable modern large tankers to be built in Russia.

The development of the yard has been a little behind schedule but when complete it will allow vessels of almost any size to be built in Russia. Target vessels include tankers up to 350,000dwt and Arctic class LNG carriers up to 250,000dwt to exploit Russia's Arctic oil and gas reserves. It is also likely that large naval vessels, including aircraft carriers, will be constructed there.

Earlier this year, Zvezda and Hyundai Samho established an engineering and project management joint venture, Zvezda-Hyundai, for technology transfer and ship construction management. In September, the joint venture announced a design and building contract for a series of 114,000dwt LNG-fuelled Aframax tankers to be built at Zvezda for Rosneft and operated by Sovcomflot. Delivery of the first vessel is scheduled for 2020.

Russia is supposedly in the process of modernising its navy, replacing some of the older vessels that date from the soviet era. Some of these replacements may have come from European yards, but after the annexation of Crimea in 2014 and France's cancellation of naval contracts for Mistral class assault ships, it is certain that Russia will build them domestically. At one time, the consensus among western defence analysts was that aircraft carriers and other large ships would be part of the programme, but recent comments by Russian officials would suggest that smaller vessels such as corvettes and frigates would be prioritised.

Earlier this year, Aleksey Rakhmanov, USC's president, highlighted the importance of naval vessels saying that the orderbooks of Russia's naval shipyards are full till the end of 2023, with defence orders accounting for about 80% of incomes of USC. "As far as naval shipbuilding is concerned, our orderbooks are full till 2021-2023. Most of our shipyards were not so busy even in the Soviet years," he said.

USC's commercial orders are, as are most of those for yards in the private sector, predominantly for shallow-draughted river-sea vessels of both general cargo and tanker types. River-sea vessels are not unique to Russia but the sheer size of the country, and the fact that major population centres are usually located on rivers or canals, means that this type of vessel is an essential element of inland transport. The vessels usually fall in the 4,000-8,000dwt size although when trading along rivers, the capacity may be limited towards the lower end of the range.

Such ships are currently being built at USC's Krasnoye Sormovo, Lotos and Nevskiy yards and at the private Okskaya Sudoverf. The latter has particularly targeted the river-sea vessel sector because it believes that it has great potential. The river-sea fleet, in terms of ship numbers, is on par or exceeds the ocean-going fleet and many of the ships operating are well past what would be considered a normal lifespan. Ships of 40 to 50 years old are not uncommon and are candidates for replacement, although funding newbuildings may be a problem. The latest designs of river-sea ships preserve some of the features of older versions but are generally slightly larger and deeper.

Of the 60 vessels delivered from the beginning of 2014 to date, just over half – 33 vessels – were river-sea types. Russia's total forward orderbook of non-naval vessels stands at 71 ships, and of these, 15 are river-sea ships. The largest vessels on the orderbook are the series of five 114,000dwt tankers at Zvezda.

The latest vessel to be added to the orderbook was contracted in early October when the Onego Shipyard won a contract from Rosmorport in Petrozavodsk to build a Damen designed Trailing Suction Hopper Dredger (TSHD) 2000. Last year Rosmorport took delivery of another Damen TSHD 2000 – *Severnaya Dvina*.

Damen has had close contact with Rosmorport to identify some additional design requirements to the new vessel. This includes a self-emptying system for bow discharge.

After delivery in 2019, the ship will be used for maintenance operations in the northern region of Russia. The new vessel will be the sixth Damen dredger in Rosmorport's fleet.

Russian expertise in icebreakers, especially nuclear-powered ships, is well known, but the last of these — *50 Let Pobedy*, launched in 2007 — had a sorry saga attached. It was more than 12 years late in completion due to a lack of funds for icebreakers following the end of the soviet era. Despite the delayed construction the ship has proved its worth in operation.

In anticipation of increased traffic on the Northern Sea Route, Russia has decided to increase its fleet of nuclear icebreakers and currently has three under construction along with a conventional icebreaker. It also has a non-nuclear icebreaker, *Ilya Muromets,* which began sea trials in early October.

Ilya Muromets has been described as the most advanced icebreaker built for the Russian Navy. It was built at the Admiralty Shipyard and will be able to perform the function of a hydrographic survey vessel along with the functions of an icebreaker, a patrol and a tug vessel.

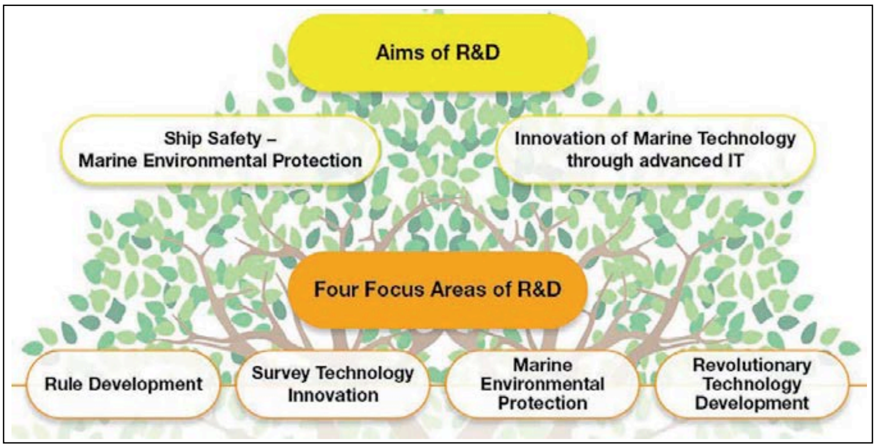
The three nuclear icebreakers, *Arktika, Sibir* and *Ural* are all scheduled for 2019 delivery and are being built for Rosatomflot at the Baltic Shipyard in Sant Petersburg. According to Rosatomflot director general, Vyacheslav Ruksha, quoted recently in the Russian press they will be the world's most powerful icebreakers and will be used primarily for the Arctic LNG-2 project. LNG-2 is Novatek's second LNG project after Yamal LNG. The launch is planned for 2022 to 2025.

The power for each of the ships comes from RITM-200 reactors which can produce 175MW each and are designed to deliver 60MW at the propellers via twin turbine-generators and three motors. The ships are 173.3m long and have a 34m beam. They will also be able to force ice up to 3m thick. *NA*

Hopes are high for the Zvezda shipyard

ClassNK plots its research route to 2022

In late September, the Japanese classification society published its R&D Roadmap, which sets out the goals and projects for the next five years



Pragmatic and focused: ClassNK's R&D Roadmap

The Roadmap details how research into core technologies will in turn influence how it develops its human resources going forward. Four focus areas have been identified: 'Rule Development', 'Survey Technology Innovation', 'Marine Environment Protection' and Revolutionary Technology Development'.

These, the publicity states, "will develop improved technical rules in terms of rationality and transparency, revolutionise survey processes with the development of robotics instruments of surveys…, investigate and research into developing new solutions for environmental regulations utilising its global network and develop maritime technology innovation through digitalisation". This 'foundational R&D', combined with the utilisation of damage information for the purposes of damage prevention, will dictate ClassNK's research philosophy.

Speaking to *The Naval Architect*, the class society explains that the review of survey and construction rules is more of refinement than an overhaul of its existing system, as amendments are regularly undertaken when necessary. However, it says:" we need to be able to comply with the rapid advancement of revolutionary technologies. With this review we are taking a close look at the system and structure of our current rules, as well as the technical content, and re-evaluating where necessary in order to adapt to future technologies."

"During this review, we will be working proactively with universities and research institutions, with the added goal of contributing to the human resource development through the sharing of knowledge."

Those emerging technologies include the use of drones and robots for surveys. Work is already well underway on this front and ClassNK aims to have "comprehensive procedures" for drones established by 2019, although some of this will be implemented from next year. Another ongoing project is what it describes as the 'rationalisation of surveys using digitalisation', which will allow for customised survey menus for individual vessels and the use of advanced technologies for diagnoses of ship conditions. The aim is a holistic improvement of survey methods such as items, contents, intervals and procedures for both classification and class maintenance surveys.

In recent years, ClassNK has been actively engaged in projects for analysing and assessing the performance of vessels in the real world. On an operational level, it partnered with the Finnish software house NAPA in creating the ClassNK-NAPA GREEN support system, a platform which provides suggestions for dynamic and adaptive trim optimisation and performance analysis. There is also a separate ongoing project, scheduled for completion around 2020, to develop evaluation and certification technology which the class society says will "develop a method a method to accurately evaluate vessel performance [in areas] such as speed, fuel consumption and so in actual seas."

Like all the major class societies ClassNK is making forays into Big Data with what it calls the 'Internet of Ships Open Platform', a project announced earlier this year which brings together a diverse range of players with their own particular expertise in shipping data utilisation. "Currently we are working on developing procedures and rules that will allow everyone to transfer data safely in confidence," it says. Given the ubiquity of data platforms *The Naval Architect* queried whether there had been any discussion with other IACS members with regard to a harmonised approach. ClassNK admits there have been no discussions yet but that "in order to realise a greater level of data transmission we plan to deliberate with our fellow class societies at every stage going forward."

While DNV GL and Lloyd's Register have been very publicly heralding remote and autonomous ship concepts, ClassNK has hitherto adopted a more cautious stance, but that could soon change. In May 2017, it was announced the it would be part of a consortium led for Mitsui OSK Lines (with other partners including Mitsui Engineering & Shipbuilding, the National Institute of Maritime, Port and Aviation Technology, Tokyo University of Marine Science and Technology) to develop an autonomous ocean transport system, providing input on rules and regulations. ClassNK says it anticipates many different design concepts for autonomous vessels emerging in the near future. "Considering this point, we plan to develop and publish guidelines on fundamental requirements for the safety aspect of autonomous vessels by mid 2018, so that we can grant Approval in Principle (AIP) to these designs." *NA*

Charting a course to 2050

Research by the Japan Ship Technology Research Association (JSTRA) has looked at the influence innovative technologies will have upon the evolution of the maritime industry. Kohei Matsuo, of the National Maritime Research Institute in Tokyo, explained more at September's HIPER conference

The study investigated the way in which new technologies have been adopted in other industries, as well as examples of advanced technology implementation in the maritime industry worldwide. Considering the applicability of these technologies to the maritime industry then became the basis for discussing future ship technologies 30 years from now.

For our project, we surveyed literature and interviewed relevant parties (universities, research institutions, manufacturers, etc.) to extract technologies that could be applied to ships in the future. We also analysed individual technologies from the viewpoint of feasibility/maturity and magnitude of impact. This led to a technology roadmap to organise short and medium-term R&D projects. We extracted noteworthy technologies (six fields, a total 116 cases) for future ships and analysed them.

General overview

Advanced R&D focuses increasingly on a few specific areas: technology on the environment and energy, nanotechnology, information technology, and life sciences. The Japanese government has also focussed its funding on those fields. The research results from the technology on environment and energy, nanotechnology and information technology can become directly applicable to the maritime industry. But even some life sciences (e.g. brain science) may lead to applications in future maritime technology.

Overall, the current fields of science and technology are likely to communicate and cross-fertilise. Therefore, the future lies not in developing single technologies in depth, but to combine and integrate from a variety of fields and other industries. Many interesting developments in maritime technologies can be found in the US. While developed for the US Navy, many technologies can be applied just as well in the civilian sector.

Likely 'game changing' technologies include innovations in shipbuilding, ship operation and logistics utilising information and communication technology (ICT). The following should be the material applied by nanotechnology.

Materials

R&D efforts have been made for higher strength and more flexible steels. These achievements are sequentially incorporated into the shipbuilding industry. Meanwhile, there is R&D on smarter or functional materials in other industries.

Future ship materials will increasingly involve composites of various materials, such as steel, carbon, and organic material. We see already the practical use of composite fibre reinforced plastics (CFRP) in the aerospace and automotive industries. The application of new nanocarbon materials, such as carbon nanotubes (CNT) and graphene, should be game changing for the maritime industry. Ship structures have moved from wood to steel, and carbon may bring the next revolution.

Nanocarbon material is not only a good structural material, but also a good functional material e.g. for built-in electronic circuitry, semiconductors or heat exchangers. Ship outfitting work may dramatically change (e.g. embedding electrical materials and printed circuit board directly into hull elements by printing). By realising ultra-light ships, we may also see different hull forms and structural designs for volume carriers such as cruiseships, megayachts, ferries and navy vessels. Concept on life cycle assessment (LCA), including ship recycling, would also be affected.

We may see increasingly high-performance materials with a variety of new features such as transparency, ability to reactively adjust shape or mechanical properties (biomimetic technology), self-healing and intelligence (with sensors embedded).

Simulation and design

Along with increasingly available High Performance Computing (HPC), our capabilities in simulation have progressed, for example, modelling directly complex turbulence or hydro-elastic fluid-structure interaction for ships. Simulation will proceed towards multi-scaled and/or multi-physics models, with high accuracy and high reliability. In the future, we will be able to analyse and determine the behaviour of ships or systems purely by simulation (simulation-based design or one-shot manufacturing). Tailored on-demand production will be taken for granted in the future society.

In addition, simulation will spread to include non-technical aspects, such as the human element in a system (behaviour model, human simulation, soft computing) or business models (Product-Service Systems, or PSS). The focus will spread from the product itself to its service, to maximise the product value. With respect to ship technology, various simulation technologies which are not only extensions of the classical applications (stability, hydrodynamics and structural behaviour) are expected to evolve and support design and operation.

Data science, or statistical science, is likely to become more important and widely used. The importance of 'data science' is recognised as the fourth science (fourth paradigm). For example, physics-based simulation will be enhanced and/or supplemented by data mining, Big Data analyses and employing artificial intelligence (AI) techniques such as machine learning.

In the design field, design errors are minimised by visualisation and advanced verification, using a wide range of techniques including 3D CAD and Virtual Reality/Augmented Reality (VR/AR) technology.

Manufacturing and construction

By introduction of the Internet of Things (IoT) in the production site, soon steel plates will be automatically conveyed by machines communicating with each other based on a predetermined construction plan, from the steel cutting stage to the various assembly stages.

Furthermore, it will be possible to record the complete building process through a spreading monitoring network of wearable devices all over the shipyard. These devices enable real-time traceability of the whole ship construction, also allowing quantification of a shipbuilding site's ability or work skill.

Current standard procedures may change by the introduction of ICT technology. Currently, the design department and the production site have different roles and are separated in the shipyard organisation. It is also believed to be more efficient to divide work processes as much as possible. With ICT technology, especially with the spread of wearable devices or AR technology, information is integrated between the design department and the production site. Digitisation of shipbuilding sites will not only lead to mutual understanding between design departments and production sites, but may also lead to new ideas of 'on-site design' or design incorporation to the production department, which ultimately draw or determine the specifications in the manufacturing site and not in the design room.

At present, 3D printing can only produce small parts and has limitations in the strength and type of materials used. However, these issues should be fundamentally resolved soon and 3D printing is expected to spread rapidly also in shipbuilding. This will in turn advance the use of composite materials in ships. The Office of Naval Research (ONR) of the US Navy published a report to explore the possibility of producing the whole ship using 3D printing. Already, it is possible to build houses based on 3D printing.

Automation and robotics are also important, increasing productivity and quality. In the aerospace industry, automation of production is progressing by expanding the use of robots in the production lines of large passenger aircraft. The same trend is likely for shipbuilding.

ICT technology

Computers are embedded everywhere around us, but we are often not aware of them (what is known as 'transparency of computer'). One of the R&D directions in ICT is on the fusion of humans, things (ship, yard) and computers. The fusion of the real world (physical system) and cyberspace (cyber system) will combine the wealth of information from penetrated sensor networks in the real world with the powerful computing capability of cyberspace.

Noteworthy in this movement is an effort to discover entirely new knowledge from the vast amount of information (Big Data). Management or policy initiatives are starting to be based on analysing correlations from Terabytes of data. We will be able to handle enormous amounts of data as never before, such as oceanographic data, marine data from ship operation, construction data from shipyards and personal data (e.g. health monitoring) from the crews and workers. This might lead to perspectives on ship design, construction and operation. We can make quantitative and rational decisions, going beyond traditional intuition and experience.

Research looks into new ways of interacting with computers. New computer architectures mimic the human brain (neuro-synaptic computing). Future connection of the human brain and the computer may expand human capabilities; it may be possible to transmit one's intention by downloading from the brain to a computer. Inversely, it may be possible to upload knowledge and skills. The craftsmanship of workers may be transmitted directly to the brain (such as neuro-feedback technique) rather than through instructing words or texts. Our notion of training through a tedious process of nurturing may become history. When this comes to pass, it will have a major impact on our society, especially to education and training schemes.

In any case, ICT technology plays a key role for innovations in various fields. Advanced ICT skills will be required by our maritime workforce and this has implications also on education.

Transport and logistics

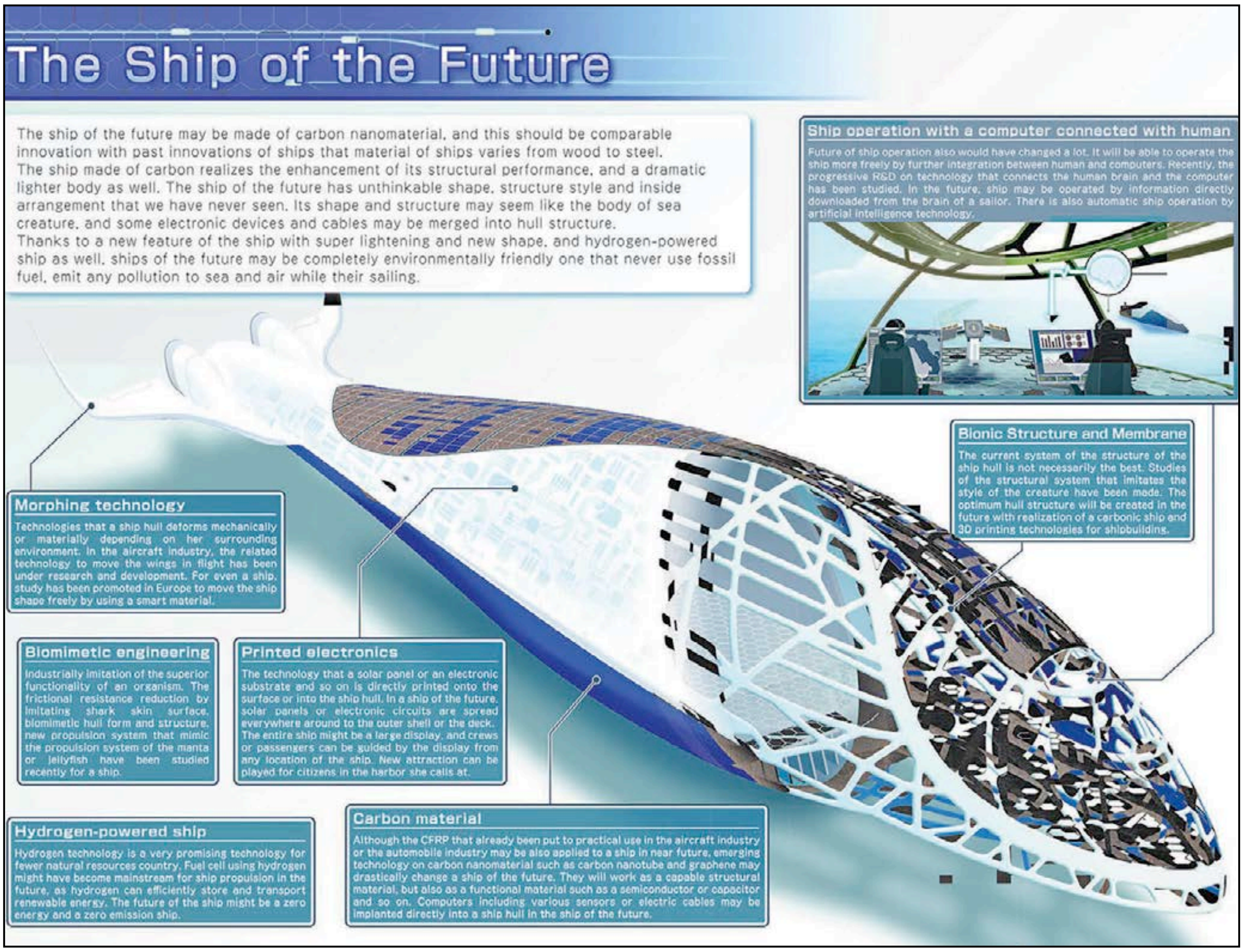
A variety of players in the retail and logistics industries are competing to build new infrastructure and business models. We see the emergence of large, highly-automated logistics facilities with the ultimate goal to deliver products at customers' specifications whenever and wherever they want it. It is inevitable that this trend will come to the field of shipping as well. Land-based and sea-based logistics will be tightly connected.

Various technologies are starting to emerge that will make shipping more competitive, such as the use of drones, unmanned operation of ships and ports, new ship concepts (such as cargo ships with changing hold arrangements for each voyage), or optimising operations and logistics based on Big Data analysis. In addition to optimised transportation, we may also see new business models such as adding value to the cargo while transporting it.

IoT technology and Big Data analyses are already used for condition based maintenance schemes and performance monitoring of ships. In the future, we will see increasingly unmanned operation of ships.

Environment and energy

As for cars and planes, we will see shipping move towards low, and eventually zero, CO_2 emission scenarios. The vision of a future zero emission ship (ZES) combines various energy-saving technologies and sources of renewable energy, such as wind and solar power, bio-fuels and tapping into wave and tidal energy. Hydrogen technology will play a key role, as hydrogen allows efficient storage of energy generated offshore, such as wave and wind energy, solar power or even artificial photosynthesis using offshore algae farming.



JSTRA's vision of the future

In general, sustainable shipping will play an increasing role. As we need to protect and preserve the habitat of our oceans, the management of biological resources and water in a sustainable way will result in the demand for a 'Non-negative Effect Ship' (NES). Design and operation of ships will then be aligned with this ultimate goal.

Survey on individual element technologies

116 promising future ship technologies were grouped in six technical fields:

- Materials
- Design and construction of ships
- Ship operation and maintenance
- Transportation and logistics
- Propulsion and engines
- New types of ships (other technologies)

For each element technology, time span of R&D and impact to maritime industry were estimated, leading to priority ratings for:

- CFRP material
- Self-healing material
- Virtual ship laboratory
- 3D printing (additive manufacturing)
- Laser technology (cutting, welding, bending, etc.)
- Autonomous or unmanned ship
- Robotics (manufacturing robot, drone, nano robots, etc.)
- Asset visibility
- Big Data analysis of logistics data
- Superconducting technology
- Hydrogen energy

Let us then outline possible future scenarios for the following five matters, when future technologies are introduced, as follows:

Carbon ship

Future ships may be made of nano-carbon material, which is a similar game changer as moving from wooden ships to steel ships was in the past. Carbon ships would be lightweight and high strength, resulting in a completely changed hull and arrangement designs. For example, hull form and a hull structure may mimic the shape of a sea creature. Outfitting may be embedded in the material (sensor, power lines, data lines) and parts of the structure may be directly 3D-printed. Bulkheads may become transparent or contain displays. In any case, composites will be on the rise, combining metals, carbon and organic material.

Construction and design

Through the IoT in the production site, soon steel plates will be conveyed automatically as machines communicate amongst each other. Robots will support at each stage, making ship assembly highly automatic. In the future, it may become commonplace to deliver the ship in just a few days from its order. ICT networks will spread to every place in the shipyard, allowing us to record the complete assembly process in real-time. This will ensure the quality of the vessel, but also help in quantifying the performance of the shipyard. By recording data such as welding quality and fitting accuracy of the ship for every place, we can objectively show the quality of our shipbuilding. Design optimisation will progress by numerical simulation, design automation and Virtual Reality. There will no longer be routine work in design — we will look for richer creativity and advanced engineering capabilities in the designer.

Ship operation

Future on-board systems will be operated with common operating systems such as Google's Android. This will allow the connecting of various types of equipment in the ship to one common system. The whole ship becomes a programmable entity. Ships may be operated after downloading and installing the optimum voyage plan from the web for each voyage. You can control the ship and your luggage by the smartphone app you use in everyday life. The data wealth from assorted ship systems is harvested in Big Data analytics, supporting, for example, real-time and true logistics. The real world is mirrored by Digital Twins in cyberspace. Vessels are connected ship-to-ship and ship-to-shore, e.g. to ports and hinterland logistics.

Transportation and logistics

The future of logistics goes toward bringing anything that people want, anywhere and at any time. There will be transparency and traceability of goods (raw materials, origin, processing method and distribution channels). Consumers and markets get closer together and ships will play their role in this system. Small-size containers equipped with IoT devices may be used in door-to-door transportation between manufacturer and consumer. Containerships carry things in large quantities, possibly becoming moving warehouses on the sea.

Zero emission ship

The standard procedure of using fossil fuels to move ships may change. Instead, ships may have zero carbon footprints, tapping into wind energy, solar energy, artificial photosynthesis, etc. Hydrogen will play a key role in this as widely used energy storage. Ships will run on hydrogen, but also transport it for land-based use in a future hydrogen society. *NA*

For more information, see the extensive paper in the 11th HIPER Symp., Zevenwacht, freely downloadable from www.hiper-conf.info.

Developing a clearer picture for composite materials

Composites have been used in ship construction for around 50 years, although their adoption has been impeded by the regulatory framework. A recent position paper by a multidisciplinary team at the University of Southampton makes the case for performance-based regulation

RNLI Severn class lifeboat (image courtesy of RNLI)

Advanced fibre reinforced polymer composite materials have huge potential to shape the modern world. The use of composites in aerospace, automobile and wind blade design is now widespread, but they have much broader potential for use in other sectors such as building and bridge construction, railway and rail infrastructure, as well as marine and offshore. The potential is greatest when there is a need to move towards lighter and more energy-efficient structures that also provide more sustainable design and facilitate rapid installation. Composites also offer additional benefits such as cost reduction, as they are corrosion resistant and have a better performance under fatigue loads, thereby offering significantly reduced maintenance compared with metallic materials.

In 2013, the global market for composite products was US$68 billion, which is predicted to grow to US$105 billion by 2030 (UK Composites Market Study). The UK's share of this market is currently around £2 billion (around 3%), which is estimated to grow to £12 billion or more by 2030 (2016 UK Composites Strategy). In the marine industry this equates to an increase from £220 million in 2015 to £370 million in 2030.

When considering incorporating composite materials in design to reduce financial risk, companies often seek public funding to develop demonstrators, which generally have targeted effort on production capability and assessing material and structural performance. Numerous studies have been undertaken that demonstrate the potential of composite materials but the question of regulations and certification has been largely overlooked, although it is widely recognised as one of the major inhibitors to the uptake of composites. This is because regulations, codes and standards are often inappropriate for composites, and particularly in the marine sector are explicitly and implicitly based on named materials, such as steel. The outcome is a 'prescriptive' or 'equivalence' based approach, which does not permit appropriate consideration of composite materials, despite their potential benefits. The regulations surrounding the use of composites was the subject of a University of Southampton study conducted by a multidisciplinary team that has resulted in a recently published position paper [1].

The paper presents a detailed review of the existing regulatory regimes in the aerospace, automotive, construction, defence, maritime, oil and gas, rail and renewables sectors. The review, the first comparative study of its kind, has highlighted the need for an alternative approach to the regulatory processes. Although each industrial sector has different demands on materials and their use in load-bearing structures, the review underlines the need for a more generic approach in regulatory regimes. At present, many government departments and agencies share responsibility for developing and implementing regulations. Hence, companies must deal with multiple authorities and testing protocols to get their new composite products to market, resulting in a significant barrier to adopting composite materials and the design freedom they offer.

The paper recommends that a performance-based regulatory framework, which currently provides the guiding principles for the certification of composites for aerostructures and wind blades, should be adapted to the needs of each sector. Another important recommendation of the paper is the call for one government department to have overall responsibility for the regulation of composite materials usage, with possible representation in other departments. In the present paper we discuss specifically the implications for the marine sector, summarise the current situation based on our research [1] and highlight specific cases which illustrate our concerns and demonstrate the need for a performance-based approach.

Composite materials in marine

The paper details how state regulations regarding ship construction, repair and maintenance are based on rules and regulations developed at the International Maritime Organisation (IMO) — for example, UK shipping laws are prescribed by the Secretary of State and administered by the Maritime and Coastguard Agency (MCA). Not all governmental entities, however, have sufficient expertise to regulate all maritime affairs alone. Thus, other entities, in particular classification societies, perform a crucial function in the practical application and evolution of IMO regulations.

Foremost among IMO's international regulations is the International Convention for the Safety of Life at Sea (SOLAS) [2], a binding international agreement that prescribes uniform maritime regulations and standards which seek to promote safety. Of the 12 detailed chapters that define the regulatory provisions of SOLAS, two are of particular relevance to the use of composite materials: Chapter I (General safety) and Chapter II (Construction and fire safety). Regulation 5 (equivalents) of Chapter I states that any fitting, material, appliance or apparatus should be at least as effective as that required by the SOLAS regulations. However, neither the exact tests or means required, nor the meaning of "as effective as" are detailed and left to the powers of the national authority.

Also significant is the requirement that equal effectiveness be established by trial, although the extent of the trials required is not prescribed and therefore could be as high a hurdle or as low as the national authority considers fit. Chapter II deals with the construction and structure of ships, which includes materials for environmentally acceptable recycling and the restricted use of combustible materials. Regulation 11.2 deals with the materials to be used for ships' hulls, superstructures, structural bulkheads, decks and deckhouses. In particular, it provides that these shall "be constructed of steel or other equivalent material." In this context, "equivalent material" is defined as "any non-combustible material which, by itself or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable exposure to the standard fire test (e.g. to aluminium alloy with appropriate insulation)", specified in the Fire Test Procedures (FTP) code [3]. The performance-based approach to material regulation, however, is restored in Part F of Chapter II (Alternative design and arrangements). The deviation from the prescribed safety and design arrangements is only permissible after engineering analysis, evaluation and approval of the proposed alternative design and arrangements and must be submitted to the relevant maritime administration in accordance with the relevant IMO guidance. This will practically be a matter of gathering technical evidence through experiments conducted by a classification society. Amendment to the SOLAS regime would arguably only be relevant and considered after the use of composites becomes well established and tested by national administrations.

The IMO sub-committee on ship design and construction considers the guidelines for use of fibre reinforced polymer (FRP) within ship structures, in particular the working group on fire protection. At its meeting in February 2017 [4], the group was tasked with finalising draft interim guidelines and agreed that four years was a suitable period to allow maritime administrations to gather experience in their use as a supplement to the guidelines for the approval of alternatives and equivalents in accordance with SOLAS regulation II-2/17. The interim guidelines were approved as such at the IMO MSC meeting in June 2017 and are intended to ensure that a consistent approach is taken with regards to standards of fire safety and the overall safety provisions of SOLAS are maintained. This IMO work was initiated in 2010 by two commercial Scandinavian projects; Stena's interest in a new build (RoPax) with a lightweight composite superstructure and the re-build of two existing vessels, adding cabins and using Glass Reinforced Polymer (GRP) in the design. The MCA considered the projects and turned to the IMO for guidelines on how to manage the regulatory aspects.

Other relevant codes are: (1) the MCA workboat code [5], for vessels less than 24m in load line length, which expressly permits the use of composite materials; (2) the large commercial yacht code [6], for yachts greater than 24m in load line length not carrying cargo or more than 12 passengers; the high speed craft (HSC) code [7], in addition to classification society rules from, for example, Lloyd's Register [8] and DNV GL [9].

Generally, the regulatory framework in the maritime sector is more prescriptive than its aerospace counterparts, for instance, in its various specific requirements for the use of steel. Furthermore, in the maritime sector, combustibility and fire protection are the key drivers of material suitability, through the maritime regulatory provisions requiring a ship to be able to withstand fire to an extent or for a period of time that is not replicated in the aerospace regulations, for example. This arguably presents a more general obstacle to increased use of composites in the maritime domain. However, maritime administrations must obviously be confident in the abilities of composite materials. In the aerospace sector there are highly detailed standards prescribed specifically to composite materials, which neatly map how such alternative materials may comply with airworthiness regulations. In the maritime sector, the relevant regulations pertaining to material application often lack the comprehensiveness and therefore, in many ways, the authoritativeness of their aerospace counterparts.

Consequently, there is a relative lack of progressive guidance authoritatively detailing what is expected of proposed alternative composite structures that maritime administrations may confidently use as a suitable benchmark, particularly outside of the field of insulation from fire. It means that even after considerable expenditure to develop the safety case for the use of a particular composite there is no guarantee of approval. Clearly this situation is undesirable, because it hinders the insertion of composite materials into designs, and must be resolved if a policy to make composites usage more attractive in the marine sector is to be developed.

Current usage

Notwithstanding the situation with the regulations, composite materials have been used successfully in the marine industry for more than five decades, by presenting specific cases to the regulators or in applications where the use of composites is not constrained by the regulations. A well-known example of the application of composites is that of the

UK Royal Navy Hunt class mine sweepers, which were the largest warships built from GRP (Glass Reinforced Polymer) upon their introduction in the 1980s. The mine sweepers were built to defence standards, as there was no obligation to follow civilian regulations. The first was *HMS Wilton*, a Ton class minesweeper re-hulled in a monolithic GRP laminate, as a prototype in 1973, with the purpose of making it non-magnetic and able to maintain a low magnetic signature. This then led to the design of the Hunt class mine sweepers, which at a length of 60m, were the largest composite structures in the world when built. 13 Hunt class mine sweepers were built and 12 remain in service. The eight still operated by the Royal Navy are currently being refitted to extend their life to 2035. There have been three fires involving RN mine sweepers, all on Hunt class vessels, that were contained and did not spread to surrounding compartments — one that occurred during build and two during service[10].

Scandinavia has a history of designing and operating composite naval craft, utilising GRP sandwich material dating back to at least the 1980s. The include the Swedish Navy's experimental ship, *HSwMS Smyge* (27m), to test stealth technology and the Norweigan Skjøld class patrol vessels (47.5m, maximum speed of 60knots). The Stockholm (50m) and Göteborg (57m) class vessels were the predecessors to the Visby class (72.7m) mine sweeper/hunter craft, made from foam cored sandwich composite material with carbon fibre reinforced polymer face sheets. In the development of these vessels the designers worked with DNV to make their own rules, again with no obligation to follow civilian regulations for naval operations. However, risks were mitigated by a safety case approach, and use of active firefighting/suppression systems. The advanced structural design of the Scandinavian vessels offer lightweight solutions through their use of composite sandwich materials and together with the UK experience of single skin composites have demonstrated long term use, over 40 years, of composite materials in the marine sector.

There is a separate category of rules and regulations for vessels that only operate in national waters, that are not subject to IMO rules as they do not operate internationally and therefore only need to satisfy their national regulators. From the commercial sector, a passenger vessel constructed from GRP sandwich material, *Walona* (30m), has operated in Swedish national waters since 1984. There are also many examples of fast ferries made from carbon fibre reinforced composites making short trips in Scandinavia, and Damen have made a fleet of composite ferries for a Turkish operator.

The Royal National Lifeboat Institution (RNLI) has operated a large fleet of composite vessels since the late 1980s, when the Mersey class of boat began to be made from fibre reinforced polymer (FRP) material rather than aluminium. Lifeboats, being rapid response craft, require high performance lightweight materials and hence sandwich structure has been chosen for their design. The hull, deck and wheelhouse of the latest Shannon class lifeboat are constructed of composite materials, predominantly an epoxy resin film infusion glass sandwich construction, with carbon fibre used as the reinforcement in areas with high load. RNLI acts as its own regulator, without any formal class approval, although it did refer to special service craft rules, with third party testing under the auspices of Lloyd's Register (LR) used to validate its designs. Loading profiles were developed from historical records [11], to generate global design loads that generally exceed class society requirements [12], with the RNLI working with the MCA in this period to develop the rescue boat code, using a performance-based approach. LR is a partner in current work to improve the design, operation and maintenance practice of the RNLI's Severn class lifeboat for the purpose of improving its special service craft rules [13].

More recently, composite materials have been considered for wider military application, such as watertight composite hatch doors that would be fully interchangeable with steel hatch doors [14], and offer a 64kg (70%) weight saving. These were of a sandwich panel construction comprising GRP face sheets, a foam core and internal box section spars. A prototype door had the required blast and shock performance. In addition to weight saving, the composite doors had a low radar signature and were corrosion resistant, meaning they did not require painting during their life at sea. During the fire performance tests, it was the steel frame of the door, and its differential expansion, that limited the fire performance of the door system, causing the seal between the frame and the door to be breached after 36 minutes exposure. This failed the A-class division fire tests requirements, where the integrity and load bearing capacity must be maintained for 60 minutes [3].

A Dutch manufacturer, VABO Composites [15], offers watertight composite ship doors and hatches, that include the locking system and frame for new build installation. This is for a B-class division (B-30), however, which only requires the integrity and load bearing capacity to be maintained for 30 minutes [3]. These products offer a 50% weight reduction over conventional steel doors, and won the JEC World Innovation Award in 2017. These doors and hatches are made from glass fibre/vinylester resin, produced using a resin transfer moulding process, and were certified by Bureau Veritas for installation on the innovative, new-build fishing vessel *MDV-1 Immanuel* in the Netherlands in 2015. The return on investment (ROI) for a busy cargo ship based on weight and fuel reduction for 12 composite doors and hatches is stated to be five years [15]. Maintenance costs are practically eliminated and vibration isolation, ballistic resistance and flame retardation can also be integrated into the design during manufacture. Installation is now being completed on two minesweepers in Italy, with plans for robotic automation during production predicted to enable cost parity with steel and ROI from day one.

CTruk builds multi-purpose composite marine craft for a variety of applications, including offshore wind farm support vessels that are 40% lighter than their aluminium counterparts. The vacuum infused composite structures are designed and engineered by Optima Projects and minimise weight and cost. Its range of 11-28m infused composite vessels include a Small Waterplane Area Twin Hull (SWATH) design, allowing smoother transit in seas of up to 2m significant height with motions approximately a quarter of those of a conventional catamaran due to more hydrodynamic hulls [16]. These vessels are certified to Bureau Veritas or DNV GL small craft rules.

In 2014, Japanese classification society, ClassNK, and Nakashima Propeller Co. Ltd. installed a 2.12m diameter carbon fibre composite propeller on the main propulsion system of the merchant vessel, *Taiko Maru* [17], a 499gt chemical tanker owned by Sowa Kaiun YK. *Taiko Maru* had already previously had Carbon Fibre Reinforced Polymer (CFRP) propellers installed in its side thrusters in September 2012. Based on their successful performance, Sowa Kaiun YK made the decision to extend use of the CFRP propeller technology to its main propulsion system, making the vessel a world first in this regard. During sea trials, the CFRP propeller required 9% less horsepower to operate, compared to a conventional aluminum-bronze propeller, and expansion of their use on merchant vessels is expected to contribute to improved fuel economy and greater efficiency in operations. ClassNK released the first Guidelines on Composite Propellers in August 2017 [18].

The examples above show the potential of composite materials to be used more widely in the marine sector. In some of the projects the relevant classification societies and regulators were part of the consortium, or had oversight of the work. Therefore, there is potential to inform new designs, if a way of sharing of the generic knowledge gained and lessons learned from these projects, many of which took years to complete, could be found. This is an element of the future projects presented below.

Future developments

A lightweight composite cabin was unveiled by a UK consortium in May 2016 from a project co-funded by Innovate UK (IUK) and Defence Science and Technology Laboratory (DSTL)[19]. The consortium, which covered the design, engineering, manufacturing and fitting out of the cabin, included Carnival UK, Gurit (UK) Limited, PE Composites Limited (PEC), the University of Southampton, Trimline Limited and Lloyd's Register. The prototype is approximately half the weight of a typical cabin and complies with the prescriptive requirements of the FTP code [3], through use of a lightweight homogenous non-combustible panel rated to B-15 classification in accordance with SOLAS/FTP for cabin interfaces. The main benefits from the reduction in topside weight saving is the ability to incorporate more cabins in a cruiseship, with a corresponding increase in revenue, in addition to improved stability and vessel efficiency. The prototype cabin was displayed at the SMM exhibition in Hamburg in 2016, and PEC has recently been awarded further funding from IUK to productionise and certify the cabin for installation on cruise and inland waterway vessels as well as superyachts, ferries and military vessels.

The changing use of materials in the marine industry, by incorporating lightweight composites in the design, is set to continue. A 17-partner, €11 million Horizon 2020 EU project, FibreShip, has recently been funded [20]. The main objective of the project is to create a new EU-market to build complete large-length ships in FRP by developing, identifying and qualifying FRP materials for long-term structural strength and fire resistance. There are three targeted vessels categories (containership, ferry and fishing research vessel) within the project, which will also cover the different phases of the life cycle from design, engineering, material production and shipbuilding to the final dismantling of the vessel in the business plan. The use of FRP materials in large-length ships will deliver a significant weight reduction (about 30%) and a relevant impact on fuel saving, ship stability, environmental impact, and increase of cargo capacity. The mid-term impact is estimated to be about 5% of the total shipbuilding market in Europe, which has a turnover of about €2 billion, and it is envisaged to have a long-term impact of up to 54,000 new direct jobs. Furthermore, it is estimated that European shipping companies could deduct up to €1 billion per year in costs with the adoption of the proposed FRP shipbuilding technology.

Another large project funded in the same call is Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships (RAMESSES). This is a 37-partner, €13.5 million Horizon 2020 EU project [21], to demonstrate the benefits of new materials in 13 industry-led and market-driven demonstrator cases through the entire maritime process chain, from components through to equipment and ship integration to repair. The technical performance, as well as life cycle cost efficiency and environmental impact, will be assessed and validated by specialist teams following common procedures and testing standards. The test program will be based on risk assessment and a widest possible use of existing results, and be supervised by rule making bodies, ensuring relevance for commercial approval beyond the project. Test data and best practice procedures on design, qualification and production of new material solutions, will be made available in a maritime test database and a central knowledge repository, thus allowing fast qualification and approval of similar maritime applications in future.

A project specifically looking at both the technological and regulatory barriers that exist in the use of adhesively bonded hybrid joints (combination of steels and composites) is QUALIFY (Enabling Qualification of Hybrid Structures for Lightweight and Safe Maritime Transport). This has a project budget of €3.7 million from Interreg 2 Seas, and is made up of 10 partners from academia, shipbuilding companies and classification societies [22], plus an observer partner network. Its objectives are three-fold — to evaluate the long term structural performance of adhesively-bonded hybrid joints, to develop reliable inspection and maintenance methodologies and to develop a procedure (guidelines) for the qualification of these joints in primary structures for marine applications.

These are exciting projects that offer significant potential to change the usage of material in the ship building industry. However, the regulatory aspects for the use of composite material also need detailed consideration to prevent them becoming a barrier for implementation. A more generic performance-based approach that adopts best practice, whilst considering the requirements of each industrial sector, could be a prerequisite to achieving a larger penetration of composites into load-carrying structures across sectors. *NA*

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How our ships got 'automated' machinery spaces

Between 1960 and 1980, the way in which engine rooms were run on-board vessels changed dramatically. Willem de Jong looks at the introduction of control engineering and how it altered the way ships are manned today

The *MV Andorra,* in 1964, was the first ship that went to sea with arrangements to allow it to sail with an unattended engine room. A few years earlier, in 1960, ships first sailed with manually-operated machinery and large engine room crews. Just some twenty years later, the operation of ships with unattended machinery spaces and reduced crews was well established and generally accepted in the industry.

Whilst the world seems certain to expect the introduction of autonomous vehicles on our roads sooner rather than later, and the marine industry has projects in hand which may lead to remotely-controlled or autonomous ships, it is interesting to look back and consider how ships were first 'automated' — in what form automation was first introduced, what problems it presented and how it affected manning requirements. In the late fifties and the early sixties the challenge of reducing ship operating personnel was much in the minds of shipowners. The golden years of shipping that followed the second world war were over, fleets had been renewed and enlarged, competition started to bite and some fleets feared a manning problem. Stimulated by developments in control engineering and automation taking place in the oil, chemical and other process industries, marine engineering systems started to change from fully-manual to partly-automatic and remotely-controlled systems.

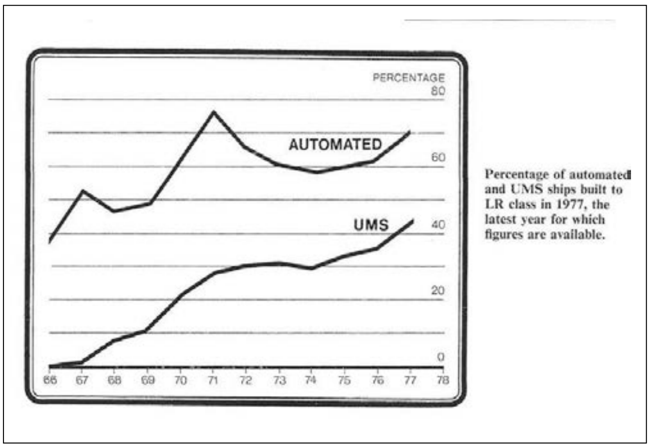

Figure 1: The percentage of automated and UMS ships built to LR class in the period 1966 to 1977 (LR Annual Report 1978)

Japanese owners and builders were first. Following a study of automation and rationalisation carried out by the Mitsui group of companies, *MV Kinkasan Maru* went to sea in 1960 with an enclosed, air-conditioned watchkeeping room in the engine room, provided with essential controls and instruments for the main engine and other essential systems. By 1963 there were already some 30 Japanese ships with control engineering systems, allowing engine room manning levels to drop from 25 to around 15 officers and ratings. By that time owners in other countries had also started to install control engineering equipment on their ships. The first British ship with the machinery designed for automation and operated from a control room was *MV Clan Macgillivray*, which went to sea in 1962 and was soon followed by two similar vessels, *Clan Macgregor* and *Clan Macgowan*. The arrangements in these ships had the simple aim of reducing the number of personnel in the machinery space down to just two people — one engineer officer for watchkeeping and one rating for routine cleaning. The control room was air-conditioned and partially sound-insulated, and from this position the officer could observe essential data, manoeuvre the Sulzer main engine, start and stop pumps and control and parallel the diesel generators. Automatic controls and alarms were provided for temperature, pressure and other systems. As mentioned above, in 1964 the next important milestone was reached when *MV Andorra*, owned by the East Asiatic Company, went to sea without a watch below. The owner's prime intention was not so much to reduce the crew numbers but to dispense with the unrewarding watchkeeping task and to redeploy staff during daylight hours on maintenance tasks that could be carried out at sea. The ship was propelled by a 12,000bhp diesel engine driving a controllable pitch propeller which could be controlled from the wheelhouse. A control room had been fitted in the engine room, containing switchboards, propulsion controls and the alarm and instruments panels.

By that time the 'automation virus' had seriously affected the marine industry. Engineers from yards, contractors, shipping companies, statutory bodies and classification societies were sent on courses to learn about pneumatic, electric and hydraulic control systems and components. Conferences and seminars were organised, just as they are now on the possible advent of unmanned ships. Shipowners and equipment manufacturers in particular showed great interest and were attracted by the potential for smaller crews and increased demand for control equipment respectively. Many shipowners started to convert the machinery installations of existing ships in order to operate the installations with fewer personnel down below. In general, these modifications were not intended to run these ships with unattended engine rooms but usually for operation with one watchkeeper at sea and unattended in port. On diesel-propelled ships these installations included bridge control for propulsion, automatic auxiliary boiler operation, automatic control of temperatures and pressures, an alarm and monitoring installation and a fire detection system.

Classification societies and statutory bodies became involved in these developments and in 1963 Lloyd's Register issued a guide to owners and builders entitled *Automation in Ships*. In 1966 Donald Gray, principal surveyor of Lloyd's Register (LR), published *Centralised and Automatic Controls in Ships*, the first book on marine control engineering.

Whilst installations in ships enabling them to operate without engine room watchkeepers had already been approved, in 1968 this was followed up by LR with the introduction of the official Unattended Machinery Spaces (UMS) notation. This notation could be obtained if the installations complied with the basic safety requirements which had been inserted in the classification regulations. Within one year some 205 diesel and 23 steam turbine ships qualified for the UMS notation. Other classification societies took similar action, introducing their own notations for such ships.

The essential safety features required for UMS operation at that time included:

- Bridge control for propulsion
- Alarm system for propulsion and other essential machinery
- Control station for machinery
- Fire detection alarm system
- Fire prevention arrangements
- Bilge level alarm system
- Facilities for local control in the case of remote or automatic controls being out of action

Ships	Mcgillivray	Macgregor	Macgowan
Total watches	290	192	101
Number of watches with one or more faults	40	34	25

Figure 2: Statistics on the Clan vessels' early 'unmanned' watches

The early years

It is understandable that in those early years of marine automation, problems were experienced with control and monitoring equipment. The difficulties encountered were usually associated with environmental conditions, lack of adequate testing and failure to appreciate the requirements. Many of the hardware items used in those years had been in industrial use for a sufficiently long time to have established their reliability in such applications, but they were not good enough for shipboard use. Attempts by manufacturers and contractors to 'marinise' the equipment often failed and complete re-design was necessary. Learned papers from the likes of Gray, Munton and McNaught list in great detail the multitude of failures which were experienced in those early years of marine automation. McNaught's paper includes the table above (see Figure 2) referring to the experience on the three Clan vessels referred to earlier.

These ships were not operated with the machinery space unattended but with an engineer officer in the control room and a rating down below for cleaning and routine maintenance. Not all of these faults concerned control equipment, some were due to failures of the conventional equipment. This questioned whether the machinery itself was sufficiently reliable to be automated. One leading marine engineer declared in 1964 that the "machinery in its present state of development cannot be left for long periods without human observation or action". Similarly, another senior marine engineer said that "limitations on automation are imposed more by doubts on reliability of conventional equipment than by availability of components for an automation scheme". No doubt such questions stimulated the efforts to make the conventional equipment and systems more reliable.

Particularly on existing ships being converted to reach a certain stage of automation, the early systems were rather primitive — simple pneumatic bridge control systems, alarm systems with rows of lamps controlled by electromechanical relays and sensing and measuring devices not very suitable for marine use. Sensors were often unreliable, difficult to adjust and with tiny terminal boxes unsuitable for marine cables. In order to improve the situation, in 1968 Lloyd's Register issued an Environmental Test Specification, to which equipment could be tested under standard conditions that simulate the marine environment, with particular attention paid to the effects of heat, humidity and vibration. On the basis of such tests to this or equivalent specifications, lists of type-approved instruments and control equipment were published. Items that initially worried designers, owners and authorities, more than anything else, concerned the layout, the choice of sensors and testing of fire detection installations — essential for safe UMS operation. In machinery spaces, detectors have to function under the most complex conditions of atmosphere at sea and in port with widely varying climatic conditions. The direction of air currents in such a space will vary greatly under these conditions, which makes it difficult to achieve the optimum siting of the detector heads. These detector heads could be tested by a test unit provided by the manufacturer or by a realistic test fire. With a test unit, one could not test whether the siting was correct and an open test fire in a machinery space is not an attractive idea. Just the use of smoke, delivered by a stage smoke generator, did not work either as the cold smoke from such a device does not have any updraught and is blown away by the engine room ventilation before reaching the sensors. Over time and with growing experience, practical solutions were found, both to select and locate the sensors and how to test them.

Effect on manning

The general cargo and multi-purpose ships, which in the late 1950s and early 1960s were used by the liner companies, had crews of some forty to fifty officers and ratings. Usually on such ships the engine room crew consisted of about eight to 10 officers and a corresponding number of ratings. These ships were completely manually operated — the automatic pilot system for navigation was on most ships the only automated function. At sea, two officers would be down in the engine room, plus a rating. Due to the advent of automation and control engineering, engine room crews were gradually reduced. By the end of the seventies, engine room crews amounted to some five officers and a few ratings. Through rationalisation and technical changes on board, not only in the engine room but also on deck and elsewhere, the total crews of ships were drastically reduced. For the liner companies the introduction of the relatively simple containership, replacing the liner general cargo vessels, plus not requiring crew to deal with cargo handling equipment, also played an important role.

As a result of the technical changes on board and the drive for rationalisation, some owners and maritime countries experimented with so-called ‘integrated crews’ and the use of maritime officers. These maritime officers were trained for both deck and engine room work. It is surprising perhaps that this development, which seems so logical taking into account the way ships can now be operated, did not become more popular.

Further developments in the run up to 1980

In the following years, new systems were introduced and marine control engineering became a more professional business. Sometimes, however, the ambition was too great. In the late sixties, a bulk carrier was equipped with a hard-wired data logger, collecting data from the machinery and other systems, which was subsequently sent to the owner’s office by Telex Over Radio (TOR). After some time, the office staff did not know what to do with the sheer amount of collected data. The story goes that the crew got fed up and were instructed to disconnect the three

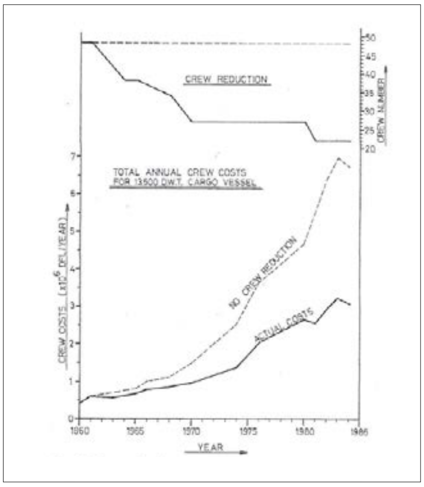

Figure 3: The crew reduction on a 13,500dwt general cargo vessel used in a liner service over the period 1960-1984. It also shows the financial effect of this change

large cubicles of the data logger and throw them over the side!

In 1969, *Sea Sovereign*, a 210,000dwt steam turbine tanker, was the first ship with an on-line computer. This was an 18-bit computer with 16-bit used for the programme, one bit for testing and one bit for programme protection. The brain of the system was the central unit with a core memory of 24k words. The main functions of the ship to which the computer was applied were: propulsion (bridge control, boiler control etc.), navigation (auto pilot, course prediction etc.) and cargo handling (loading and unloading). The cargo program used the whole of the core memory, as did the sea programme. Consequently, the sea programme had to be removed from the memory and stored on tape when cargo pumping was in progress. Standard control systems were available in case the computer system was out of order.

In the 1970s, integrated circuits, microprocessors and larger computers became available, enabling more advanced equipment. Such systems allowed the input of digital as well as analogue sensors, which was a great leap forward. The subsequent sysems were not only more advanced but were also much better suited for the marine environment.

Generally it could be said that by the year 1980 shipping had become used to these systems and that UMS operation was by then, for most types of ships, fully accepted.

As part of the research for this article, a number of senior marine engineers, deck officers and captains were consulted to establish how they experienced the introduction of initially simple, followed by more advanced, automation equipment and the advent of UMS operation. Some of those officers had commenced their career on fully-manned ships, without any form of automation, and were subsequently subjected to these systems and the new way of working. Others came on board once the first steps had already been taken.

The overall consensus was that it was sometimes difficult with unreliable equipment — not just the automation equipment but also the conventional equipment — but that they could manage and that they gradually put more trust in the systems. And once the systems really got working, they found that the engine rooms became safer and better places. Continuous supervision of machinery with good monitoring and alarm systems was found to be better than the old system of regular but manual watchkeeping, which required good housekeeping and completion of a decent checklist before leaving the engine room unattended. Without this, watchkeepers were punished by alarms during their night of rest. Plus, it was reassuring to know that in the case of automation systems failing, they would be able to operate manually. But of course, engineers had to get used to the idea that somebody on the bridge was in control of ‘their’ engine and many captains were initially nervous when operating direct bridge control systems, instead of an engine telegraph and leaving the actual engine control to the engineer down below. Looking back, one may conclude that the engine room crews deserve praise for the

One of the first ‘television screen’ alarm monitors way they adjusted to the new way of working. Few serious casualties were ever reported due to unattended machinery operation.

Are there lessons to be learned?

Looking to the future and expecting ships with smaller and smaller crews, finally perhaps leading to unmanned ships, the question arises whether in that process one may learn from the experience described above.

Preparing for a crewless ship, the following points may be worth remembering:

- Go carefully — build up experience step by step
- Use properly tested sensors and sensor systems — do not make the same mistake we made some 40 or 50 years ago
- Do away with equipment relying on regular onboard maintenance, such as fuel oil treatment systems, auxiliary boilers and oily water separators.

Plus, will equipment like ballast water management systems (BWMS) and exhaust gas scrubbers ever be suitable for unmanned operation for days or weeks? After all, there will be no maintenance staff on-board working in the engine room during the day to keep the equipment going. It may be doubtful even whether main and auxiliary diesel engines will be reliable enough to operate long periods without human intervention. Redundancy arrangements will not solve all these issues.

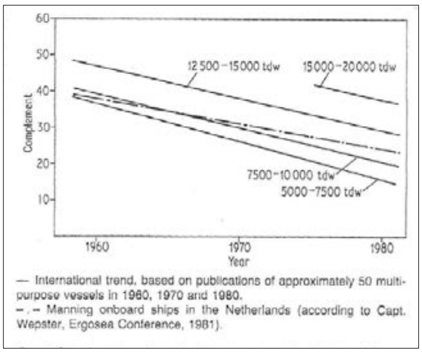

Figure 4: The crew reduction for a few ship types over the same period (1960-1984)

The reports we have seen until now concerning the introduction of unmanned and autonomous ships mainly concentrate on the 'Big Data' systems required for remote and autonomous operation. It may well turn out that these systems will become available without too many problems. It is more likely that the real problems will lie in the area of machinery and sensor systems, both for propulsion and navigation. These problems may be easy to solve with battery-operated ferries on short routes but the situation may well prove to be very different for worldwide trading cargo ships. *NA*

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